Pesticides reduce biodiversity

Pesticides are a major factor affecting biological diversity globally, along with habitat loss and climate change. They can be directly toxic to organisms, or cause changes in their habitat and the food chain. ***Richard Isenring*** *reviews the science for PAN Europe.*

Charles Darwin and Alfred Wallace were among the first to recognise the importance of biodiversity for ecosystems. They suggested that a diverse mixture of crop plants would be more productive than a monoculture, and though there are exceptions, recent studies confirm this idea[1].

Biodiversity loss

But the earth's biodiversity is currently being lost at an alarming rate. Changes in habitat and biodiversity are being caused by the changing climate and people's increasing use of plant and animal resources.

This alarming trend is not in doubt and is widely documented by myriad studies. For example, the doubling of EU cereal yield resulted in the loss of half the plant species and one-third of carabid beetles and farmland bird species[2]. In farmland habitats in the UK, population declines have occurred in about half of plants, a third of insects and four-fifths of bird species[3]. In the EU, up to 80% of protected habitat types and 50% of species of conservation interest now have an unfavourable conservation status. A 'business-as-usual' scenario would mean that the current decline of biodiversity will continue and even accelerate, and by 2050 a further 11% of natural areas which existed in 2000 will be lost, while 40% of land currently under low-impact agriculture could be converted to intensive agricultural use[4]. In industrialised countries, farming practices have fundamentally changed. In the UK and many other places, mixed agriculture has been lost and farms have become increasingly specialised. Traditional crop rotation has been abandoned and in the British lowlands, field sizes have increased while field margins and hedgerows have shrunk. Over the same period populations of many species living on farmland have declined[5]. This loss of biodiversity is not just of sentimental concern. Human well-being depends on services delivered by intact ecosystems. People's livelihoods ultimately depend on the biological resources provided by ecosystems.

Increased use of pesticides

Of all the components of agricultural intensification, the use of pesticides, especially insecticides and fungicides, has had the most consistently negative effects on species diversity. The use of pesticides (particularly herbicides) and synthetic fertilisers has increased dramatically over the past 60 years. Between 1990 and 2006, the total area treated with pesticides increased by 30% in the UK, and the herbicide-treated area increased by 38%[6]. Additionally, the use of insecticides has reduced the potential for biological pest control[7].

Impact on wildlife

Many pesticides are toxic to beneficial insects, birds, mammals, amphibians, or fish. Insecticides, rodenticides, fungicides (for seed treatment) and the more toxic herbicides threaten exposed wildlife through their toxicity. Over the past 40 years, the use of highly toxic carbamates and organophosphates has increased dramatically. In the South, organochlorines such as endosulfan, which are highly persistent, are still used on a large scale. Pesticide poisoning can cause population declines which may threaten rare species. Pesticides accumulating in the food chain, particularly those which cause endocrine disruption, pose a long-term risk to mammals, birds, amphibians, and fish.

But pesticides can also have indirect effects by reducing the abundance of weeds and insects which are important food sources for many species. Herbicides can change habitats by altering vegetation structure, ultimately leading to population decline. Fungicide use has also allowed farmers to stop growing 'break crops' like grass or roots. This has led to the decline of some arable weeds[8]. In Canada, losses among 62 imperilled species were closely related to rates of pesticide use. Species loss was highest in areas with intensive agriculture (aerial spraying)[9].

Pesticides threaten bird species

While average populations of all common and forest birds declined by about 10% in Europe between 1980 and 2006, populations of farmland birds have fallen by 48%[10]. Large declines in bird species are also found in the United States. A recent US survey found that one in three bird species is endangered, threatened, or of conservation concern[11]. In North America between 1980 and 1999, populations of grassland species declined more than species living in shrubland. In 78% of species there was an association between population trend and change in agricultural land-use[12].

In Europe, the population decline among farmland birds was far greater in countries with more intensive agriculture[13]. It has been predicted that introducing EU agricultural policy into EU accession countries will cause a major decline in key bird populations as occurred in the German state of Saxony-Anhalt[14].

Important Bird Areas (IBAs) include agricultural areas with important bird populations. But IBAs have no official protected status and agricultural expansion and intensification threaten half of IBAs in Africa and one-third in Europe. It is estimated that worldwide bird populations have declined by 20% to 25% since pre-agricultural times. Altogether, 1,211 bird species (12% of the total) are considered globally threatened, and 86% of these are threatened by habitat destruction or degradation. For 187 globally threatened bird species, the primary pressure is chemical pollution, including fertilisers, pesticides and heavy metals entering surface water and the terrestrial environment[15].

Direct poisonings

In the UK, the volume of seeds eaten by many bird species poses a potential risk if they are treated with toxic fungicides[16]. Organophosphate insecticides, including disulfoton, fenthion, and parathion are highly toxic to birds and have frequently poisoned raptors foraging in fields[17]. Field studies have led to the conclusion that 'direct mortality of exposed birds is both inevitable and relatively frequent with a large number of insecticides currently registered'[18]. In the US, some 50 pesticides have killed songbirds, gamebirds, raptors, seabirds and shorebirds[19]. In a small area of the Argentine pampas, monocrotophos, an organophosphate, killed 6,000 Swainson's hawks. Worldwide, over 100,000 bird deaths caused by this chemical have been documented[20].

Besides lethal poisonings sublethal quantities of pesticides can affect the nervous system causing changes in behaviour. In an orchard, parent birds made fewer feeding trips after azinphos-methyl, an organophosphate, had been sprayed[21].

Reduction in food sources

Herbicides and avermectin residues (used to worm livestock) affect birds indirectly by reducing food abundance[22]. Lower availability of key invertebrates and seeds for farmland birds in northern Europe has been linked to insecticides and herbicides, intensification and specialisation of farmland, loss of field margins, and ploughing[23]. Spraying insecticides within 20 days of hatching led to smaller broods of yellowhammer chicks, lower mean weight of skylark chicks, and lower survival of corn bunting chicks[24,25]. More frequent spraying of insecticides, herbicides, or fungicides was linked to fewer food invertebrates. This resulted in lower breeding success of corn buntings and may have contributed to their decline[26]. In Sussex, herbicides were a major cause of the decline of grey partridge populations by removing weeds which are important insect hosts[27]. Increasing pesticide use has been linked to periods of rapid bird decline[28]. Those species at risk from indirect effects in the UK include grey partridge, corn bunting, yellowhammer, red-backed shrike, skylark, tree sparrow, and yellow wagtail[29].

Risk to mammals

Pesticides and other chemicals have caused declines in populations of Britain's wild mammals, particularly the bats and rodents[30]. Certain pesticides can gradually accumulate in the food chain, a particular concern to top predators such as mammals or raptors. Anticoagulant rodenticides are highly toxic and some can bioaccumulate. Non-target predatory mammals (such as dogs and foxes) and raptors frequently suffer 'secondary poisoning' by eating rats or mice poisoned by rodenticides. In France, foxes were poisoned by residues of bromadiolone in prey tissue[31]. In the UK, following rat control with rodenticides, local wood mice, bank vole, and field vole populations declined significantly[32]. At least 25-35% of small mammal predators (polecats, stoats, and weasels) sampled had been exposed to rodenticides[33].

Herbicide use can affect mammals such as the common shrew, wood mouse and badger by removing plant food sources and changing the microclimate[34]. Hares prefer a more diverse habitat and likely prefer increased fallow land[35]. On organic farms, foraging activity by bats was significantly higher than on conventional farms, possibly due to a larger abundance of prey insects[36].

Impacts on insects

Broad-spectrum insecticides (such as carbamates, organophosphates and pyrethroids) can cause population declines of beneficial insects such as bees, spiders, or beetles. Many of these species play an important role in the food web or as natural enemies of pest insects. Since 1970, insect numbers in cereal fields in Sussex have dropped by half[37]. Numbers of bugs, spiders and beetles were considerably higher in untreated fields[38]. On British organic farms, numbers and species richness of butterflies was greater than on conventional farms[39,40]. The number of carabid beetles and spiders was usually higher on organic farms. Conventional management practice appeared to affect natural enemies far more than other insects or target pests[41].

Bees perform essential pollination functions. Honey bees are under pressure from parasitic mites, viral diseases, habitat loss and pesticides. Intensified agriculture, habitat loss, and agrochemicals are considered to be among the chief environmental threats to Europe's honey and wild bees. On organic farms in the US, close to natural habitat, diverse native wild bee communities provided full pollination services, while diversity and numbers of native bees were greatly reduced on other farms[42]. The carbamate bendiocarb, and the three pyrethroids cypermethrin, deltamethrin and permethrin which are used in the UK, all poison bee colonies[43]. Synergistic effects between pyrethroids and EBI fungicides (imidazole or triazole fungicides) can increase the risk to honeybees[44].

Clothianidin, and to a lesser extent, imidacloprid are highly toxic to bumble bees and other wild bees[45]. These two neonicotinoid insecticides are used to treat corn and sunflower seeds. In 2008, clothianidin caused many bee poisonings and colony deaths in southern Germany[46]. The product has since been withdrawn. When imidacloprid-treated seed is grown, the pesticide can enter the environment to poison bees[47]. Residues of imidacloprid in maize pollen grown from treated seed can be a high risk to bees[48]. Even at low doses of imidacloprid, bee foraging behaviour was negatively affected[49] and long-term exposure led to reduced learning capacity among bees[50]. In alfalfa, imidacloprid affected the number and species diversity of arthropods (natural enemies such as spiders) more strongly than among target pest insects[51]. Untreated field margins had a positive effect on the number of moths and butterflies, bugs, and staphylinid beetles at the edges of arable fields[52]. In organic plots, average numbers of spiders and carabid or staphylinid beetles were almost twice as high as those in conventional plots[53].

Effects on amphibians and aquatic species

One-third of 6,000 amphibian species worldwide are threatened. Besides habitat loss, overexploitation or introduced species, amphibians are affected by the pollution of surface waters with fertilisers and pesticides[54]. In the US, hexazinone, a triazine herbicide, is thought to endanger the red-legged California frog and its habitat[55]. Atrazine is moderately toxic to some fish species and can indirectly affect aquatic ecosystems by damaging aquatic plants. Atrazine has been shown to affect the immune system of some amphibians[56,57]. In Europe, the authorisation for atrazine has been withdrawn due to health and environmental risks[58].

Urea herbicides such as isoproturon and diuron often contaminate rivers, lakes, and groundwater. Most breakdown products of diuron are more toxic to microorganisms than diuron itself[59]. Fungicides based on copper are highly toxic to aquatic organisms[60]. A major study investigating amphibian communities in the US found that, among other factors, agricultural fields near surface water and pesticides will harm amphibian species richness[61].

Chlorpyrifos and endosulfan have the potential to cause serious damage to amphibians at concentrations occurring in the environment under normal conditions of use[62]. In laboratory tests, the survival of juvenile Great Plains toads and New Mexico spadefoot toads was reduced after exposure to certain formulations of the herbicides glufosinate and glyphosate[63].

In a study of the risks of 261 pesticides to aquatic ecosystems in field ditches, about 95% of the predicted risk was caused by only seven pesticides[64]. More selective pesticides would clearly be preferred. Surface water is frequently contaminated with insecticides through normal use at levels above those known to affect fish and aquatic invertebrates.

Effects on plant communities

In recent decades, the global use of herbicides has dramatically increased. Today, some non-crop plants (or 'weeds') are threatened with extinction in Britain[65]. Although the total volume of herbicides applied in the UK decreased slightly between 1990 and 2006, the herbicide-treated area increased by 38%[66]. Diversity of wild plants in agricultural fields and field margins is declining, especially in infertile grassland and hedge bottoms. A slight increase in plant diversity in arable fields in 1998 may have been due to the introduction of set-aside[67]. Field margins created within agri-environment schemes supported a higher number of plant species than crop areas, but plant cover and species richness are still relatively low when compared to other habitats (such as horticultural land) and set-aside[68]. By providing an unsprayed field margin at least three metres wide, the diversity and number of arable plants and insects hosted by them increased substantially[69].

In lowland areas in England, species diversity and abundance of plants, birds, bats, invertebrates, and plants were typically higher on organic farms than conventional ones. Positive effects were strongest for plants. It was estimated that organic fields had up to twice as many plant species and, on average, a weed cover twice as large[70]. Some herbicides are highly toxic to plants at very low doses, such as sulfonylureas, sulfonamides and imidazolinones[71,72]. Sulfonylureas have replaced other herbicides which are more toxic to animals. Experts have warned that the wide-spread use of sulfonylureas 'could have a devastating impact on the productivity of non-target crops and the make-up of natural plant communities and wildlife food chains'[73].

Hexazinone is a persistent triazine herbicide which leaches easily out of the soil[74]. In the US, at all application rates the EPA's levels of concern for aquatic and terrestrial non-target plants were exceeded. Aquatic ecosystems within or next to hexazinone-treated areas could be altered by the effects on aquatic plants[75]. Other triazines affect aquatic plants similarly, such as terbuthylazine and atrazine. In field tests, the herbicide glyphosate altered the composition of freshwater microbial communities[76].

Impacts on soil fertility

Soil fertility is vital to promote growth of plants. In South Africa, the feeding activity of soil organisms was higher in soil from organic vineyards than from conventionally treated sites[77]. The number of earthworms was up to three times higher in organic compared to conventional plots, and growth of symbiotic mycorrhizae was 40% higher in organic compared to conventional systems[78]. Composition and activity of bacterial communities can be significantly changed or reduced by pesticides.

Conserving biodiversity

In the EU, national policies set targets for biodiversity conservation[79]. The United Nations Convention on Biological Diversity provides national strategies and action plans for conserving species at national level.

The UK's Biodiversity Action Plan (BAP) currently lists 1,150 species and 65 habitats with a priority for conservation. In 2002, of 78 farmland priority species, 39% were declining, 21% had unknown or unclear status, 18% were stable, 15% on the increase, and 7% had been lost. From the total one million hectares of nationally-important wildlife sites ('Sites of Special Scientific Interest') in the UK in 2003, about 380,000 hectares, or 38%, were in an unfavourable condition mainly due to agriculture. Only 47% of important wildlife sites on farmland were in a favourable condition[80]. One of the BAP's targets is to reverse the decline in farmland birds in Britain by 2020. In winter, farmland bird density is much higher on stubble (rotational set-aside) than on cereal fields. However, EU policy recently changed and set-aside is no longer compulsory which could have negative impacts on farmland biodiversity across the EU[81].

Maintaining an appropriate population of weed species to support farmland wildlife is a challenge. It may be achieved by providing conservation headlands, by developing more selective herbicides, and through their selective use[82]. In England between 1978 and 1990, plant diversity on arable land declined. Between 1998 and 2007, plant diversity in main plots increased by 36% due to increased set-aside or fallow land, driven by agri-environment schemes[83]. On plots with reduced herbicide input, farmland birds used winter cereal stubble more often than on conventional plots[84]. Using more selective herbicides in winter cereals could benefit farmland bird species which feed their chicks weed seeds such as linnets or finches[85]. In the EU on arable or mixed farms which use integrated management practices, on average the use of herbicides was reduced by 43%, use of insecticides or molluscicides by 55%, and fungicide use was 50% lower when compared to conventional farms. On farms using IPM, the number of arthropods (such as beetles, spiders, springtails or sawflies), plants and earthworms increased significantly. Similar positive effects were observed for soil organisms, birds, and mammals such as wood mice[86].

The EU's Sixth Environment Action Programme identified biodiversity conservation as a high priority[87]. Areas protected under the Birds and Habitats Directives are connected in the 'Natura 2000' network. The proposed strategy on sustainable pesticide use in the EU aims to minimise risks to health and the environment from pesticides. Member states must eliminate or reduce the use of pesticides as far as possible in Natura 2000 sites, and promote farming with low pesticide input, particularly integrated pest management (IPM), and establish the necessary conditions for implementing IPM techniques[88].

Agri-environment schemes in the EU pay farmers for taking measures to preserve the environment and countryside. But spending on these measures is marginal to date. Farmers who practise less intensive farming and who conserve nature need to be rewarded[89]. The number and quality of conservation targets varies considerably between countries[90]. Organic farms, together with agri-environment schemes, have positive effects on the diversity of plants and beetles in the EU, while bird species were not significantly more diverse. This may be due to widespread chemical pollution. So a shift towards farming with minimal pesticide use over large areas is urgently needed[91]. Corn, sugar cane and palm oil are increasingly being used to produce biofuels. These crop plants are linked to a high input of pesticide and fertiliser and their use is threatening biodiversity.

The need for a rescue plan

A new quantitative rescue plan for biodiversity in Europe is needed for 2020, setting clear quantitative and qualitative targets, timetables and monitoring requirements. The success of a biodiversity rescue plan will also to a large extent depend on the EU's implementation of the new 'Regulation on the Placing of Plant Protection Products on the Market', as well as on how seriously member states implement the new framework directive on the sustainable use of pesticides. Member States should use this new opportunity to set dependency/use pesticide reduction targets and clear timetables.

A biodiversity rescue plan also needs to be accompanied by further reform of the EU's Common Agricultural Policy (CAP), departing from the current model where farmers receive income support for up-keep of their land to a model where farmers receive funding to provide public benefits. This would see farmers paid to use sustainable agricultural practices that provide environmental and health services.

In the International Year of Biodiversity 2010, we should fight together for reform of the CAP starting by encouraging more mixed agriculture, crop rotation, pastoral grassland and lower field size. We should encourage practices such as bigger field margins and the re-establishment of hedgerows. We should put prevention first, in a dynamic system, encouraging front-runners who are willing to make environmental improvements, and incorporate a policy of making agricultural production truly integrated. Such an approach would help reverse the decline of birds, bees, bats, arthropods and earthworms, which thrive best in association with organic farming. It is also the best way to re-establish communities of different animal and plant species which perform vital functions within ecosystems, bringing higher diversity which tends to be more stable, and as a result will also help ensure greater long-term food security.

A longer version is available on PAN Europe's website at http://www.pan-europe.info/Campaigns/biodiversity.html

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