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Perspective

How should conservationists respond to pesticides as a driver of biodiversity loss in agroecosystems?

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ABSTRACT

Conservation biologists should seek to work with those involved in sustainable agriculture and rural development in expanded integrated approaches to reduce pesticide harm to humans, biodiversity and environmental services. Despite new evidence, conservation organisations have tended not to fully recognize the impacts of pesticides on biodiversity, and current conservation strategies pay little heed to addressing this threat. A comprehensive suite of strategies are required to reduce and rationalize pesticide use and mitigate risks to species conservation. This paper proposes six steps for conservationists to address pesticide problems: (1) revisit the *land sparing* versus *land sharing* debate and include the external impacts of agriculture as vital components in systematic conservation planning; (2) redefine narratives on *intensive* agriculture and support emerging forms of sustainable intensification; (3) focus and inform on improved delivery mechanisms and monitoring legal use to achieve better pesticide targeting and a major reduction in volumes used; (4) support efforts to reduce wastage and inefficiency in the food system by promoting technical changes and informed consumer choice; (5) design and encourage resilient temperate and tropical landscapes that minimise pesticide contamination on farms and at landscape scale; and (6) develop comprehensive policy responses to promote both better alternatives to synthetic pesticides and limit the use of the most harmful pesticides.

1. Introduction: re-emergence of an under-estimated driver of biodiversity loss

The last two decades have seen growing concern that many pesticides, particularly the insecticides known as neonicotinoids, are harming pollinators such as domesticated and wild bees (Goulson et al., 2015). Evidence has emerged that ecological damage may extend far beyond bees. In 2015 the IUCN report *Worldwide Integrated Assessment of the Impacts of Systemic Pesticides on Biodiversity and Ecosystems* (van Lexmond et al., 2015), authored by 29 independent scientists, synthesised over a thousand peer reviewed studies and concluded that systemic pesticides have serious negative impacts on pollinators and other terrestrial and aquatic invertebrates, amphibians and birds, and on ecosystem functioning and services (Chagnon et al., 2015). Soon afterwards, the European Academies Environmental Science Council published another comprehensive review reaching broadly similar conclusions (EASAC, 2015).

In 2016, the Intergovernmental Science-Policy Platform on Biodiversity (IPBES) published the results of a two-year study on pollinators. IPBES estimated the annual value of crops directly affected by pollinators as US$235–577 billion, and that over 40% of invertebrate pollinators were facing extinction, with neonicotinoid pesticides among the important factors threatening pollinators worldwide (IPBES, 2016).

These findings highlight wider concerns that the adverse environmental impacts of pesticides (which include insecticides, molluscicides, herbicides and fungicides) have tended to be under-estimated, particularly in the tropics, (Costantini, 2015), as have the substantial external economic costs of pesticides worldwide to both human health and ecosystem services (Pretty and Bharucha, 2015). Evidence has been

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building of serious biodiversity declines (Mason et al., 2013) caused by a range of insecticides (Luzardo et al., 2014) and herbicides (Chiron et al., 2014) often acting in combination with other stressors (Goulson et al., 2015). Pesticides with long half lives, the occurrence of spray drift or a combination of both can also adversely impact biodiversity in protected areas (Martín-López et al., 2011).

The joint work of IUCN, EASAC and IPBES help to explain why biodiversity continues to decline in modern farmed landscapes, even in Europe where habitat loss and poaching pressure have largely been halted, and where there is considerable investment in agri-environment schemes intended to increase biodiversity (Donald et al., 2006). Negative impacts of pesticides on non-target organisms have important economic considerations, for example, by contributing to the global decline of pollinators (Goulson et al., 2015). In parts of China, farmers are now pollinating plants by hand in order to provide a surrogate for the loss of pollination ecosystem services (Partap and Ya, 2012).

Until recently there has been a tendency for many conservation practitioners to assume that the most serious pesticide problems have been addressed with the banning of most organochloride and organophosphate insecticides. For example, while pesticides were a constant feature of resolutions at IUCN's World Conservation Congress until 1990, they virtually disappeared for 20 years until the formation of the task force on systemic pesticides in 2012 (www.tfsp.info), which advises the IUCN Commissions on Ecosystem Management (CEM) and Species Survival (SSC). Annual horizon scans of conservation biology priorities have not mentioned pesticides for over ten years (e.g. Sutherland et al., 2015), nor did a survey of 100 pressing questions for conservation biologists (Sutherland et al., 2009) and work on pesticides by agricultural scientists does not generally focus on impacts on wild biodiversity (Pretty and Bharucha, 2015). Historic impacts of organochlorine and organophosphate pesticides are acknowledged, but impacted species mostly recovered following the ban on pesticide compounds such as DDT (e.g., Ambrose et al., 2016). Continued biodiversity loss has been linked more generally to resource-intensive models of development and consumption, invasive species, nitrogen pollution, and climate change (Butchart et al., 2010); where agriculture is highlighted the focus tends to be on land use change and general intensification (Maxwell et al., 2016). While recognizing the critical importance of all these factors, we argue that the role of pesticides in driving biodiversity loss also deserves renewed emphasis, quantification and amelioration.

One common response to scientific evidence of serious ecological impacts from a pesticide is to consider a ban. However, there are considerable challenges to achieving this; the agrochemical industry is influential and well-organised to argue for the role of pesticides to protect crops against pests, diseases and weeds. The European Union's initial two year restrictions on using some systemic pesticides on plants that bees are likely to visit reached a stalemate in the European Parliament, resulting in the European Commission exercising its right, and imposing a restriction. Pesticide manufacturers challenged the decision in court and some governments remain openly critical of the Commission's decision (McGrath, 2014).Many farmers perceive themselves to be reliant to varying extents on currently available pesticides and restrictions need to be aligned with effective and practicable alternatives. Moreover, agroecological alternatives such as Integrated Pest Management are knowledge-intensive, and need effective extension and support services to mobilize new techniques, train farmers and provide ongoing support (Pretty and Bharucha, 2015).

Many compounds have been used for years after serious health and environmental problems were identified, particularly in developing countries (e.g. Sherwood and Paredes, 2014). Continued efforts to ban certain active ingredients, strengthen regulatory frameworks and improve the application of existing laws are important. But while withdrawal of compounds that pose the highest risk is one solution, efforts to address all pesticide externalities need to be situated within a wider strategic framework for biodiversity conservation, not least to avoid this scenario being re-enacted into the future with new generations of pesticides. We suggest six strategies that conservationists should consider to address biodiversity loss from pesticides. None of these steps are new. However, some have been largely ignored by the conservation community, while others have been subject to intense debate, which is influenced by a renewed focus on pesticide risks.

2. Revisit the *sharing* versus *sparing* debate

New evidence of pesticide impacts puts a fresh slant on a continuing debate. Rising human populations and changing consumption patterns mean that natural ecosystems will likely continue to be converted to agriculture (Harvey and Pilgrim, 2010). Conservation biologists disagree about the best way to respond. Some argue for *land sparing*, where agriculture is intensified and concentrated into as small an area as possible, leaving maximum space for conservation, while others argue for *land sharing*, de-intensifying agriculture, or intensifying production through more environmentally benign approaches (Bommarco et al., 2013), to increase biodiversity on farmland and reduce impacts on non-farmed areas (Fischer et al., 2008). A variety of shades of opinion exist between; most land sparing advocates stress the need to minimise detrimental off-farm impacts and there are many efforts to find an optimal mix between sharing and sparing (e.g., Kremen, 2015).

The land sparing argument assumes that land not used for agriculture is generally unaffected by agriculture and that intensification reduces the need for more land to be converted to agriculture. But the offsite impacts of agriculture, as evidenced by data on systemic pesticides, have now been recognized as greater than often assumed, and the impacts of pesticides on non-target species shown to be influenced by landscape context (Park et al., 2015). Research also suggests that intensification does not necessarily reduce the area under agriculture, or even slow the rate of agricultural expansion, particularly if there are strong market drivers (Byerlee et al., 2014). While new understanding of pesticide impacts does not provide a decisive answer to the sharing or sparing debate, future discussions need to recognize that agricultural impacts extend beyond land clearing (Matson and Vitousek, 2006); failure to do so has contributed to the current crisis. Greater efforts are needed to mitigate offsite impacts as factors in systematic conservation planning, developing new tools to help if necessary.

3. Redefine what *intensive* means in agriculture and support and fund emerging forms of sustainable agriculture

Pretty and Bharucha (2015) calculate that 50% of all pesticides are not necessary for agricultural benefit (drawing on data from 85 projects in 24 countries). The sharing or sparing debate focuses on distinguishing “intensive” from “extensive”, whereas the real issues should be about types of intensification (Tscharntke et al., 2012). A variety of agroecologically-based intensification strategies allow for ‘wildlife friendly’ farming, particularly for smallholders in developing countries who experience declines in biodiversity and food security (Pretty and Bharucha, 2014).

The concept of “sustainable intensification” is gaining traction (Pretty and Bharucha, 2014), including application of Integrated Pest Management (IPM) approaches on many millions of farms. In 2009 the European Parliament introduced a directive (2009/128/EC) for achieving sustainable pesticide use, which provides a comprehensive framework for reducing pesticide use and obliges Member States to encourage farmers to adopt IPM or organic methods, including through provision of capacity building material (http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32009L0128). Evidence on IPM shows that higher yields can be achieved with reductions in pesticide use (Pretty and Bharucha, 2015), intra-specific crop diversity can be used to manage pests (e.g., Bommarco et al., 2013; Ssekandi et al., 2016), and efficient agriculture does not require the adoption of large-scale monocultures (Mulumba et al., 2012). Resource-conserving agriculture can be highly efficient, as can small-scale, labour-intensive, lower