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Insect decline, an emerging global environmental risk

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The Earth's entomofauna seems in an ongoing state of collapse. Insect decline could pose a global risk to key insect-mediated ecosystem functions and services such as soil and freshwater functions (nutrient cycling, soil formation, decomposition, and water purification), biological pest control, pollination services and food web support that all are critical to ecosystem functioning, human health and human survival. At present the attention for insect decline is low in all domains, ranging from scientific research to policy-making to nature conservation. Scientists made urgent calls to prioritise insect conservation. An international treaty for global pollinator stewardship and pollinator ecosystem restoration is urgently needed to counteract the current crisis. A review of insect pollinator conservation policies found that despite scientific calls and public outcry to develop polices that addresses declines, governments have not delivered such legislation, nor have they met basic monitoring needs recommended by experts.

Over the past decades, evidence has mounted that the Earth's entomofauna is in an ongoing state of collapse. Globally, insects make up three quarters of animal and plant species [1]. But these little things that run the world [2] seem to have been widely overlooked in science, nature conservation and environmental policy-making and law-making. Insect abundance in protected nature areas in Germany have fallen by 75% over the last 27 years [3]. Strong declines were also found in Netherlands [4]. Guardian columnist George Monbiot [5] coined the term 'insectageddon' to warn that the impacts of global insect collapse are more catastrophic than climate breakdown. Although this term has been criticised as being overly alarmist and unsubstantiated by data [6], entomologists warn that insects are indeed disappearing before we even have data [7]. Of the approximately 5.5 million insect species, about 90% has not even been named, nor have their roles in ecosystems been mapped. No global scientific monitoring of insect abundance in the past and present exists and there are no plans for systematic global monitoring in the near future.

Insects decline is a major concern for human health because essential micronutrients in our diet come from insect-pollinator mediated crops [8,9•] and because phytopharmaceuticals and nutritional supplements depend on pollinators [9•]. A modelling analysis found that complete removal of pollinators could increase global deaths yearly from non-communicable and malnutrition-related diseases by about 1.4 million (1.38–1.48) and disability-adjusted life-years (DALYs) by about 27 million (25.8–29.1), an increase of 2.7% for deaths and 1.1% for DALYs [10].

The Global Assessment Report on Biodiversity and Ecosystem Services by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) [11] concluded that the proportion of insect species threatened with extinction is a key uncertainty. Available evidence supports a tentative estimate of 10%

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(established but incomplete). Of an estimated eight million animal and plant species (75% of which are insects), around one million are threatened with extinction. Local declines of insect populations such as wild bees and butterflies have often been reported, and insect abundance has declined very rapidly in some places even without large-scale land-use change, but the global extent of decline is not known. A later systematic review estimates that worldwide over 40% of insect species is threatened with extinction [12••].

Insect decline could pose a global risk to key insect-mediated ecosystem functions and services such as soil and freshwater functions (nutrient cycling, soil formation, decomposition, and water purification), biological pest control, pollination services and food web support that all are critical to ecosystem functioning and human survival. Insect declines are expected to cascade onto ecosystem functioning and human well-being [2]. It could have far reaching impacts also outside of the insect realms, including loss of biodiversity higher-up in the food-web (e.g. insectivorous birds) and impairment of ecosystem resilience.

A review of the risks of pollinator decline for global food security [9•] showed that globally at least 87 of major food crops critically depend on insect pollination. Together these account for 35% of the world food production volume. Essential micronutrients in the human diet (e.g. vitamins A and C, antioxidants, lycopene, β-tocopherol and folic acid) come for 90–100% from pollinator-mediated crops. In total, pollinator mediated crops account for about 40% of global nutrient supply for humans [13]. Many crops for fibre, fodder, biofuels, timber, phytopharmaceuticals, dietary supplements, as well as ornamental plants also critically depend on pollinators [9•]. The loss of insect pollinators threatens global food security, can worsen hidden hunger (micronutrient deficiencies), can deprive society from a range of non-food plant based resources, erodes ecosystem resilience, and can destabilise ecosystems. Possible impacts of global impairment of other key insect-mediated ecosystem processes and services, especially those provided by aquatic and soil insects, are poorly known.

Pesticides are a key driver of insect decline, especially the so-called neonicotinoids (in short: neonics) [14–17]. Approved in more than 120 countries, neonics have become the world's most widely used insecticides, making up about 40% of the global insecticide market. In response to evidence of collateral damage to bees, in 2018 Europe partially banned 3 of 6 authorised neonics for outdoor use in crops, but large scale use in greenhouses and use as biocide continued and regrettable substitution by other neonics such as sulfoxaflor occurred [18].

Given that neonics are persistent and water soluble, its large scale prophylactic use has led to large scale pollution of water and soils. The current scale of use of neonics also has dramatic impacts on aquatic invertebrate life [19]. Hallmann *et al.* [20•] found that declines in insectivorous birds are associated with high neonic concentrations in Dutch surface water, hinting at cascading effects in the food web. An analysis of multi-year nation-wide data on breeding birds and pesticide use in the US confirmed cascading effects for insectivorous birds [21••].

In 2015 the IUCN Task Force on Systemic Pesticides published its World Wide Integrated Assessment (WIA) of the impacts of systemic pesticides [22–26,27••,28,29]. An update of the WIA was published between 2017 and 2020 [30,31••,32,33]. The findings show that at the present scale of world-wide use, the impacts of neonics on insect pollinators and on terrestrial and aquatic insects, cascade into impacts on population level and communities levels and put key ecosystem services such as pollination, soil formation, soil nutrient cycling, water purification and food web support at risk [31••].

At present the attention for insect decline is low in all domains, ranging from scientific research to policy-making to nature conservation. The UN Convention on Biodiversity covers all ecosystems, species and genetic resources. However, the Convention's Strategic Plan 2011–2020 [34] does not specifically refer to insects or pollinators but it emphasises restoration of ecosystem services and habitats in general. A post-2020 global biodiversity framework is scheduled to be adopted at CBD's COP15 in 2021. Another important step at the international level has been the IPBES thematic assessment on pollinators, pollination and food production [35]. The priority that IPBES gave to initiating a thematic assessment on pollinators is a sign of the emerging realisation of the global importance of pollinator decline.

An international treaty for global pollinator stewardship and pollinator ecosystem restoration is urgently needed to counteract the current crisis [9•]. Scientists made urgent calls to prioritise insect conservation [36,37]. In 2018, the EU Pollinators Initiative [38] started, but the European Court of Auditors found that the Commission approach to the protection of wild pollinators is inconsistent, policies are flawed, and the Pollinators Initiative does not have the tools and mechanisms to address those gaps [39•]. A review of insect pollinator conservation policies in the US found that despite scientific calls and public outcry to develop policy that addresses declines, multi-state agreements have not delivered such legislation nor met basic monitoring needs recommended by experts [40••].

Conflict of interest statement

Nothing declared.

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- • of special interest
- •• of outstanding interest

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Topical review of the present pollinator crisis and how it threatens global and local food security. An integrated approach that simultaneously addresses the key drivers is needed. This includes creation and restoration of floral and nesting resources, a global phase out of prophylactic use of neonicotinoids and fipronil, improvement of test protocols in authorisation of agrochemicals, and restoration and maintenance of independence in regulatory science. The authors argue that an international treaty for global pollinator stewardship and pollinator ecosystem restoration should be initiated in order to systemically counteract the current crisis.

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Declines in insectivorous birds are spatially and temporally strongly associated with high levels of neonicotinoid pollution in the Netherlands. This was the first study hinting at cascading effects of insecticides in the food web.

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Analysis of a rich dataset on breeding birds and pesticide use in the US confirms cascading effects of neonicotinoids-driven insect decline in the foodweb. The increase in neonicotinoid use in the US led to statistically significant reductions in bird biodiversity between 2008 and 2014 relative to a counterfactual without neonicotinoid use, particularly for grassland and insectivorous birds, with average annual rates of reduction of 4% and 3%, respectively.

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Where earlier studies mainly showed the negative impacts of neonicotinoids on pollination, this study documents broader evidence of the effects on ecosystem functions regulating soil and water quality, pest control, ecosystem resilience and community diversity. In particular, microbes, invertebrates, and fish are at risk while they play critical roles as decomposers, pollinators, consumers, and predators, which collectively maintain healthy communities and ecosystem integrity.

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This synthesis has an excellent infographic documenting the state of knowledge on impacts of neonic insecticides on biodiversity and ecosystem services. The high toxicity of these systemic insecticides to invertebrates has been confirmed and expanded to include more species and compounds. Most of the recent research has focused on bees and the sublethal and ecological impacts these insecticides have on pollinators. Toxic effects on other invertebrate taxa also covered predatory and parasitoid natural enemies, aquatic arthropods and soil organisms. The impact on marine and coastal ecosystems is still largely uncharted. Sublethal effects on fish, reptiles, frogs, birds, and mammals are also reported, showing a better understanding of the mechanisms of toxicity of these insecticides in vertebrates and their deleterious impacts on growth, reproduction and neurobehavioral of most of the species tested.

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This audit examined whether the Commission has taken a consistent approach to the protection of wild pollinators in the EU. It assessed the extent to which the Commission's framework for wild pollinators helped to stop the decline in their number and diversity, and whether the Commission used biodiversity conservation measures, and measures available in the common agricultural policy and the pesticide legislation to address the need to protect wild pollinators. The audit concludes that overall the Commission has not taken a consistent approach to the protection of wild pollinators in the EU. Major gaps in key EU policies addressing the main threats to wild pollinators were identified. The Pollinators Initiative does not have the tools and mechanisms to address those gaps. The Commission needs to better integrate actions to protect wild pollinators in EU policy instruments addressing biodiversity conservation and agriculture and improve the protection of wild pollinators in the pesticides risk assessment process.

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This paper provides a content analysis of 110 subnational insect pollinator policies in the US and characterises policy trends and document the spectrum of policy innovations. With a few exceptions, policies are nascent and anemic steps for addressing a crisis. This empirical account anticipates viable international policy and informs its design.

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