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Policy analysis

Wipe out highly hazardous pesticides to deter wildlife poisoning: The case of carbofuran and aldicarb

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ABSTRACT

Deliberate wildlife poisoning with pesticides is widely reported worldwide, regardless of whether the toxic compound is authorized, of restricted use, or banned. Due to their high toxicity, Highly Hazardous Pesticides (HHPs) are of special concern in this regard, with international calls claiming for concerted action to effectively address their severe impacts on the environment and public health. Continuous wildlife poisoning episodes with carbofuran and aldicarb across the globe illustrate how partial regulations are insufficient to address the adverse environmental impacts of HHPs. Carbofuran and aldicarb are restricted in 83 and 125 countries, respectively, including total bans in EU, where they are still responsible for wildlife poisoning. Remaining stocks in countries where banned may contribute to their short-medium term use, but the absence of a global ban leaves room for manufacturing, allowing in turn a continuous illegal trade and use over time. Following FAO's proposal to eliminate HHPs by 2030, and considering the decreasing presence in ecosystems of the few pesticides already banned or severely restricted at global scale, a total ban must be implemented to effectively deter the use of carbofuran, aldicarb and other HHPs in wildlife poisoning on the medium-long term.

1. Deliberate wildlife poisoning with pesticides

Pesticides are widely used in modern agriculture. They are inherently harmful for living organims and, due to excessive use and misuse, these toxic compounds may be present in the environment at concentrations hazardous for public health and the environment (Kohler and Triebskorn, 2013). Pesticides threaten species across terrestrial and aquatic ecosystems worldwide (Kohler and Triebskorn, 2013). However, besides their unintentional pernicious effects for biodiversity, pesticides are also often intentionally used to illegally kill wildlife (e.g., Ogada, 2014; Fig. 1).

Illegal activities, such as illegal logging or poaching, boost habitat degradation and species overexploitation, the two major drivers of biodiversity loss (WWF, 2020). Thousands of animals are poached globally either for trade of entire specimens or body parts (e.g., poaching of elephants for ivory or vultures for body parts used in traditional medicine; Mateo-Tomás and López-Bao, 2020), or in retaliation to real or perceived negative impacts of wildlife on human interests, such as predation on livestock, damage to crops, competition for game or attacks on humans (e.g., poaching of lions Panthera leo after livestock attacks; Carter et al., 2017).

Poisoning is one of the main methods used for poaching wildlife, together with illegal shooting and snares (e.g., the snaring crisis in Southeast Asia; Gray et al., 2018). Poisoning, however, can lead to massive mortality events of wildlife, and affect not only the individuals of the species targeted by poachers, but also many other animals, domestic pets, and even humans (including secondary poisoning; i.e., when an animal feeds upon another poisoned animal; Brakes and Smith, 2005). Poisoning threatens the populations of at least 2904 vertebrate species (i.e., ~5.1 % of the 57,155 vertebrates listed in the IUCN Red List), including ~12.1 % of the vertebrates included in the different IUCN threatened categories (Table 1). For example, the 30.1 % of the species of raptors and mammalian carnivores listed by the IUCN are threatened by poisoning ($n = 260$, both intentional and unintentional combined), including the 52.4 % of these species within the "Critically Endangered", "Endangered" and "Vulnerable" IUCN categories (Table 1). When toxic compounds are deliberately used for wildlife persecution, they can have devastating effects; as illustrated, for example, by the elimination of large predators in several areas of Africa, North America and Europe in late 19th and 20th centuries (Ogada, 2014;

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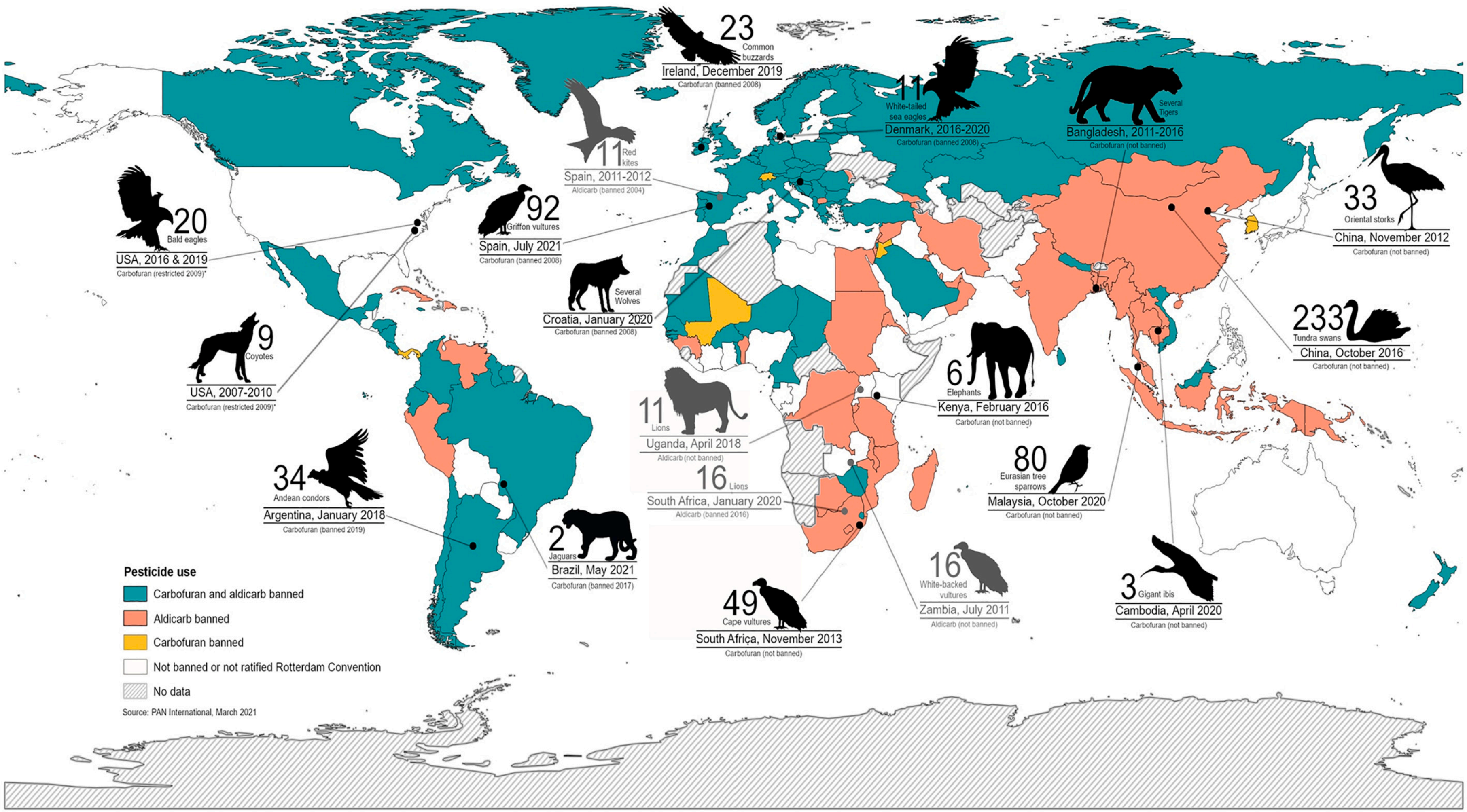

Fig. 1. Wildlife poisoning events with the Highly Hazardous Pesticides (HHPs) carbofuran (black) and aldicarb (gray) have been reported in countries all over the world since 2010, irrespective of whether the use of these HHPs was banned or allowed. Only a selection of cases is shown to illustrate the widespread use of aldicarb and carbofuran across species (rare and common) and world regions. Information on the HHPs banned per country was retrieved from the Pesticide Action Network (PAN) International List of Highly Hazardous Pesticides (PAN International, 2021) and contrasted with data from the Rotterdam Convention (2021). *Carbofuran use in USA was severely restricted in 2009 but some uses are still authorized in agriculture.

Table 1
We searched the UICN Red List for vertebrate species threatened by poisoning at global scale, according to the IUCN criteria for the inclusion of threats. We considered a species threatened by poisoning when threat categories "5.1.2. Unintentional effects (species is not the target)", "5.1.3. Persecution/control" or "9.3.3. Herbicides and pesticides" were recorded in the UICN assessment of the species (IUCN Threats Classification Scheme. Version 3.2. Available at https://www.iucnredlist.org/resources/threat-classification-scheme). We restricted our search to only global species assessments. We also considered these figures for raptors and carnivores, as predators either frequently prosecuted through illegal poisoning or affected by secondary poisoning (e.g., consuming poisoned preys such as rodents). The percentages represented by these species from the total and total threatened vertebrates (i.e., those listed as "Vulnerable", "Endangered", and "Critically Endangered") within each considered group are also shown.

IUCN category	Number of species threatened by poisoning	
	Vertebrates	Raptors[a] and carnivores[b]
Extinct (EX)	17	4
Extinct in the wild (EW)	4	0
Critically endangered (CR)	289	17
Endangered (EN)	532	34
Vulnerable (VU)	446	49
Near threatened (NT or LR/nt)	273	39
Least concern (LC or LR/lc)	1143	117
Data deficient (DD)	200	0
TOTAL	2904	260
Percentage of species threatened by poisoning		
TOTAL threatened vertebrates (CR + EN + VU)	10,437 (12.1 %)	191 (52.4 %)
TOTAL vertebrates	57,155 (5.1 %)	865 (30.1 %)

[a] Orders Accipitriformes, Cathartiformes, Falconiformes and Strigiformes.
[b] Order Carnivora.

Ripple et al., 2014), or the recent collapses of vultures and condors in Africa and South America (Ogada, 2014; Estrada-Pacheco et al., 2020).

While some harmful pesticides for public health and the environment, such as the DDT (dichloro-diphenyl-trichloroethane) or the lindane (both developed in the 1940s), are nowadays banned or severely restricted, several others remain in use worldwide. Highly Hazardous Pesticides (HHPs) are of special concern due to their disproportionate harm on living organisms, including high acute and chronic toxicity (FAO and WHO, 2016). Their use is particularly widespread in low- and middle-income countries, such as in the case of some Southeast Asian and African countries, where HHPs are widely available and poorly regulated. For example, among the 3557 pesticides registered in 13 Asian countries for use in agriculture and public health, 214 products were HHPs (61 different active ingredients included; Yubak-Dhoj et al., 2022). These regions hold also the highest number of declining and threatened terrestrial megafauna (Ripple et al., 2016), many of these species being negatively affected by poisoning (e.g. vultures and large carnivores; Richards, 2011; Ogada, 2014; Ripple et al., 2014).

2. The particular case of Highly Hazardous Pesticides (HHPs) illustrated by carbofuran and aldicarb

Among the different pesticides used in wildlife poisoning (e.g., endosulfan, chlorpyrifos, metamidophos, parathion, warfarin; Martínez-Haro et al., 2008; Ogada, 2014; Estrada-Pacheco et al., 2020), carbofuran and aldicarb are HHPs widely reported in poisoning events worldwide (Richards, 2011; BBC News, 2016; The Zimbabwean, 2017; Hedgpeth, 2019; Estrada-Pacheco et al., 2020; Animal's Health, 2021; The Independent, 2021; Fig. 1; Appendix S1). Remarkably, their use in wildlife poisoning has been reported both in countries where these pesticides are authorized for agricultural purposes (e.g., Bangladesh, China, Uganda) and in countries where banned (e.g., European Union, Zimbabwe). The list of multiple poisoning events involving carbofuran or aldicarb is an indicator of the continued and widespread use of these chemicals (Fig. 1). This includes, for example, six lions (*Panthera leo*) and eight vultures in Uganda in 2021 (The Independent, 2021), 34 Andean condors (*Vultur gryphus*), one rufous-collared sparrow (*Zonotrichia capensis*) and one puma (*Puma concolor*) in Argentina in 2018 (Estrada-Pacheco et al., 2020), 94 African white-backed vultures (*Gyps africanus*) and one elephant (*Loxodonta africana*) in Zimbabwe in 2017 (The Zimbabwean, 2017), 13 bald eagles (*Haliaeetus leucocephalus*) in USA in 2016 (Hedgpeth, 2019), 233 tundra swans (*Cygnus columbianus*) and 26 mallards in China in 2013 (BBC News, 2016) or 92 griffon (*Gyps fulvus*) and 4 cinereous (*Aegypius monachus*) vultures and one black kite (*Milvus migrans*) in Spain in 2021 (Animal's Health, 2021), to name a few. The widespread nature of these examples across species and ecosystems agrees with previous works highlighting the environmental threat posed by carbofuran and aldicarb as a conservation issue worldwide (Fig. 1; Appendix S1; e.g., Richards, 2011 and references therein; Estrada-Pacheco et al., 2020).

Due to their high toxicity, both pesticides are considered as HHPs by the World Health Organization (WHO) Classification of Pesticide Active Ingredients (WHO, 2020). Five grams of carbofuran can kill 13 people, and the same quantity of aldicarb 154 (Pesticide Action Network International, 2021). They contribute also to the total yearly figures of ~385 M people unintentionally poisoned with pesticides, as well as the 110,000–168,000 pesticide suicides (Boedeker et al., 2020). Pesticide suicides are especially frequent in low and medium-income countries in Southeast Asia and Africa (e.g., Gunnell et al., 2017). Furthermore, carbofuran and aldicarb are listed in the Annex III of the Rotterdam Convention, which promotes shared responsibility and cooperation in the international trade of hazardous chemicals to protect human and environmental health (WHO, 2020). Under this convention both, human poisoning cases, and environmental incidents, are considered in the listing criteria for hazardous pesticides (FAO, 2022).

3. On the need of global bans of Highly Hazardous Pesticides (HHPs) for biodiversity conservation

Despite continuous recommendations on awareness-raising and enhancing regulatory control of HHPs, accumulated evidence shows that these actions seem to be insufficient to stop the illicit usage of these chemicals, and there is a real risk of perpetuating their use for wildlife poisoning. Relentless wildlife poisoning with carbofuran and aldicarb (Fig. 1) illustrates that the existing regulations are insufficient to comprehensively address the adverse environmental and health impacts of these and other HHPs, even where banned or heavily restricted (Global Action Plan on Highly Hazardous Pesticides HHPs, 2021). Carbofuran and aldicarb are restricted in 83 and 125 countries, respectively (Pesticide Action Network International, 2021), including total bans (issued in 2007 and 2003) in the European Union, where they are still responsible for wildlife poisoning in countries like Spain, Hungary or Poland, to name a few (Ruiz-Suárez et al., 2015; Animal's Health, 2021; Kitowski et al., 2021). Remaining stocks in countries where banned may contribute to their use on a short-medium term after bans, but the absence of a global ban of these pesticides leaves room for a continuous illegal trade of these chemicals and use in wildlife poisoning (Animal's Health, 2021; Kitowski et al., 2021).

Wildlife crime has become a global concern for biodiversity conservation, and huge efforts are being put into addressing poaching. For example, at EU level, the main funding instrument entirely dedicated to environment, nature protection and climate action is the LIFE program, launched in 1992. Since then, the EU has invested >70 M euros in 43 LIFE projects including measures to fight against wildlife crime, 28 of which dealt with poisoning (European Union, 2018). Besides funding to fight poisoning, or specific regulations on the manufacture and use of these HHPs, wildlife poisoning with carbofuran and aldicarb will continue until bolder actions are taken.

Following FAO's proposal to eliminate all risks from HHPs by 2030 (Global Action Plan on Highly Hazardous Pesticides HHPs, 2021), a global ban of aldicarb and carbofuran must be implemented, aiming at stop manufacturing these HHPs. Viable alternatives already exist (Williamson et al., 2017), from chemical to non-chemical, and even eco-friendly options, e.g., cow dung has recently been proven as effective as carbofuran for protecting plants from nematodes (Zafar et al., 2022). But, while the use of conventional pesticides remains heavily marketed, options usually termed as "bio-pesticides" still lack position in the global pesticides market (ca. 3.5 % of global market; Olson et al., 2013). Ending the use of HHPs globally will require the compromise by national governments, banning their use while incentivizing the switch to safer alternatives (Sachdev and Singh, 2016).

Previous global bans of other pesticides, such as those included in Annex A for elimination under the Stockholm Convention, show the way forward towards stop manufacturing carbofuran and aldicarb (WHO, 2020; Global Action Plan on Highly Hazardous Pesticides HHPs, 2021). Although some specific exemptions still exist for the production and use of some of these compounds (e.g., endosulfan) that would slow their global elimination, other toxic chemicals included in this Annex A (e.g., aldrin and dieldrin) are already considered as obsolete (WHO, 2020). Moderately hazardous pesticides such as lindane, endosulfan or chlorpyrifos (WHO, 2020) are included (or under evaluation for inclusion) in the Annex A of the Stockholm Convention to stop their production and use worldwide. Chlorpyrifos, which are likely to harm 97 % of the >1800 species protected under the US Endangered Species Act (EPA, 2017), cannot be applied to food commodities in USA since February 2022 (EPA, n.d.). Paradoxically, however, extremely and highly hazardous pesticides frequently used in deliberate wildlife poisoning, such as carbofuran and aldicarb (but also metamidophos, warfarin, bromadiolone or difenacum), are still manufactured and legally and illegally used worldwide (e.g., Martínez-Haro et al., 2008; Ogada, 2014; Estrada-Pacheco et al., 2020). The deliberate usage of HHPs for poaching wildlife should be taken into account as an aggravating circumstance in the formal evaluations considering their inclusion in conventions restricting their manufacturing, trade and usage. The US Environmental Protection Agency (EPA) has recently announced that will evaluate the potential effects of new pesticide active ingredients on federally threatened or endangered species, in order to improve compliance with the Endangered Species Act (EPA, 2022).

Insights from national bans illustrate both the multiple benefits and the necessity of a global ban of HHPs. For example, DDT, aldrin and dieldrin bans in 1970s were related to the recovery of raptor populations in Britain (Newton and Wyllie, 1992). More recently, the ban of aldicarb has been considered to contribute to a decrease in wildlife poisoning events in Spain (De la Bodega et al., 2020). On the other side, aldicarb and other banned compounds like carbofuran are still the toxic substances more frequently detected in poisoned animals in Spain and elsewhere; a situation which is attributed to illegal trade from abroad (De la Bodega et al., 2020; Kitowski et al., 2021). Global bans of aldicarb and carbofuran will not end wildlife poisoning, but to wipe out these and other HHPs would result in less harmful substances available for that purpose and a potential reduction of poisoning events (see above; Pesticide Action Network International, 2021). Furthermore, previous evidence shows how removing HHPs from agricultural practices does not threaten food production. For example, the banning of 14 HHPs in the state of Kerala (India) in 2011, did not have an adverse effect on agricultural yields that could be attributed to the banning of these pesticides (Sethi et al., 2022; see also Manuweera et al., 2008). However, this banning (and a previous one in 2005) contributed to reduce the number of deaths from pesticide poisoning (Sethi et al., 2022). Systematic reviews have shown how national bans on HHPs, commonly used in acts of self-poisoning, are effective in reducing pesticide suicides (Gunnell et al., 2017; see also Lee et al., 2021). Contrastingly, evidence is less consistent for sales restrictions or safe storage (Gunnell et al., 2017), which is in line with widely recognized hierarchies of hazard mitigation strategies for chemicals, i.e., eliminate the hazard is the most effective action. This shows how keeping the focus only on restrictions will perpetuate the negative effects of HHPs on both public health and the environment.

A global ban will be therefore the only effective action to stop using HHPs in wildlife poisoning on the medium-long term, contributing to compliance with existing conservation and public health regulations, and the consecution of Agenda 2030 Sustainable Development Goals related to sustainable agriculture, public health and well-being, and biodiversity conservation.

CRediT authorship contribution statement

José Vicente López-Bao and Patricia Mateo-Tomás conceptualized the paper. Both authors contributed equally to writing of the paper.

Ethics statement

The authors conducted no data collection that required ethics approvals.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

All the data used are presented in the manuscript and the Supplementary Information

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Appendix. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2022.109747.

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