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The prevalence and correlates of anticoagulant rodenticide exposure in non-target predators and scavengers in Finland

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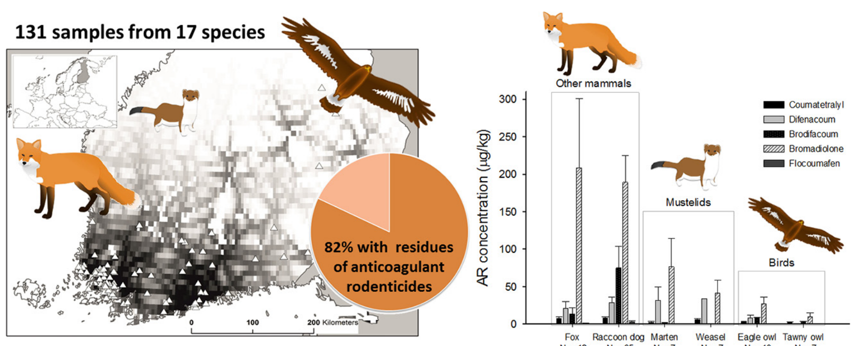
HIGHLIGHTS

- Anticoagulant rodenticides (ARs) were detected in 82% of the samples.
- Bromadiolone was the most prevalent AR and was also found in highest concentrations.
- Species group explained most variation in prevalence and concentrations.
- Group represented by foxes and raccoon dogs had the highest values.

GRAPHICAL ABSTRACT



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ABSTRACT

The most common rodent control method worldwide is anticoagulant rodenticides (ARs), which cause death by internal bleeding. ARs can transfer to non-target predators via secondary exposure, i.e. by consuming contaminated rodents. Here we quantify the prevalence of seven AR substances in the liver tissues of altogether 17 mammalian or avian predator or scavenger species in Finland. In addition, we identify the environmental and biological factors potentially linked to secondary AR poisoning. No previous AR screenings have been conducted in the country, despite the widespread use of ARs and their potential impacts on the high levels of the ecosystem food chain. ARs were detected (≥0.3 μg/kg) in 82% of the 131 samples. The most prevalent and the AR with highest concentrations was bromadiolone (65% of samples). In 77% of the positive samples more than one (2–5) different ARs were detected. Of the environmental variables, we only found a weakly positive relationship between the coumatetralyl concentration and the livestock farm density. Conversely, overall AR concentration and number, as well as the concentration of three separate ARs (coumatetralyl, difenacoum and bromadiolone) differed among the three species groups tested, with the group "other mammals" (largely represented by red fox and raccoon dog) having higher values than the groups presented by mustelids or by birds. ARs are authorized only as biocides in Finland and a national strategy on risk management (e.g. for minimising secondary poisoning of non-target species) of ARs was adopted in 2011. Based on these results it appears that the risk mitigation measures (RMMs) either have

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not been followed or have not been effective in preventing wide scale secondary exposure. Continued monitoring of AR residues in non-target species is needed in order to evaluate the effectiveness of current RMMs and a need for new ones to reduce the risk of secondary poisoning.

1. Introduction

Under the impelling pressure to increase food production after World War II, the farming and food industry has progressively increased the use of chemical substances. Since 1950, the global pesticide use has risen >50-fold (Miller, 2005). Substances such as herbicides and insecticides have become particularly widespread, and their presence in the environment has been often found to have detrimental secondary impacts on wildlife, and also on humans (Carson, 1962; Pain and Pienkowski, 1997). Rodents are among one of the most common, generalist and widespread pests, causing a number of damages to agriculture and public health, and are the target of widespread pest control campaigns (Singleton, 2003). The most common method used for rodent control worldwide is anticoagulant rodenticides (ARs). All ARs have a similar chemical structure and the same mode of action: they act by blocking the vitamin K cycle, resulting in inability to produce essential blood-clotting factors, thereby leading to death by internal bleeding (Berny et al., 2014). These effects are gradual, typically developing over several days.

Anticoagulants can be divided into first and second generation substances. The first generation anticoagulant rodenticides (FGARs) are less toxic and are eliminated within days, thereby requiring multiple doses to be fatal. The second generation anticoagulant rodenticides (SGARs) were developed after rodents started to show resistance to first generation agents, and they are toxic at a much lower dose (IPCS, 1995). SGARs are persistent or very persistent, bioaccumulative or very bioaccumulative and toxic (European Chemicals Agency, Biocidal Products Committee opinions on active substance approval, http://dissemination.echa.europa.eu/Biocides/factsheet?id=0018-14). Anticoagulants have been found to transfer to non-target animals either by direct consumption of baits (primary poisoning) or by consuming contaminated prey animals (secondary poisoning, Lambert et al., 2007). Rodenticides are generally placed within bait boxes inaccessible to large animals. The target rodent that ingested the rodenticide will only die within a few days following the ingestion of lethal dose (Vandenbroucke et al., 2008). During this phase the rodent may be consumed by predators, causing secondary poisoning. Rodents dying aboveground can in turn represent an important risk of secondary poisoning for scavengers (Montaz et al., 2014).

Several species of mammalian and avian predators have been found to be exposed to ARs worldwide (see López-Perea and Mateo, 2018 for a review), for example red foxes (*Vulpes vulpes*; Geduhn et al., 2015), mustelids (*Mustela* sp.; Elmeros et al., 2011), red kites (*Milvus milvus*; Berny and Gaillet, 2008) and barn owls (*Tyto alba*; Newton et al., 1990). Besides in rodent-eating predators, ARs have also been found in non-target small mammals (e.g. Geduhn et al., 2014), and in insectivorous species, like European hedgehogs (*Erinaceus* sp., Dowding et al., 2010, López-Perea et al., 2015), shrews (*Sorex* sp., Geduhn et al., 2014) and passerine birds (Masuda et al., 2014). Anticoagulant poisoning is also a major issue for domestic animals, especially dogs (Berny et al., 2010 and references therein).

Quantifying the prevalence level of secondary AR poisoning in non-target wildlife is challenging, due to biases in the sample collection and to lab techniques to detect the prevalence of the substances. Moreover, the AR dosages acquired by consuming a poisoned rodent, for example, may be too low to have lethal consequences. However, in France intensive bromadiolone control following water vole (*Arvicola terrestris*) outbreaks has been reported to have caused considerable number of deaths of red kites and common buzzards (*Buteo buteo*; Coeurdassier et al., 2014). Wildlife AR poisoning and the unintentional wildlife deaths caused primarily or partially by ARs are systematically monitored only in few countries (e.g. SAGIR network in France, Millot et al., 2017), hence we still lack knowledge on the extension of problems caused by ARs to non-target wildlife from most countries. The potential sublethal and population level effects of secondary AR poisoning are even less known or evaluated (but see Naim et al., 2010, Martínez-Padilla et al., 2017). However, repercussions could be important at the high levels of the food chain, because of the potentially increased dosage, and because the target species may be more sensitive to environmental change, e.g. pollution (as is the case for raptors; Newton, 1998). There is thus a need to establish wider study schemes around the world both to assess the prevalence and associated risks caused by ARs, and to evaluate risk mitigation measures and eventually adjust them based on newly available information.

In Finland anticoagulant rodenticides are only authorized and predominantly used as biocides, and use for the crop protection is scarce. A national strategy on risk management of ARs was adopted in 2011. Rodenticides were regulated under pesticide acts until the end of 2006. They could be used for plant protection use (mainly to protect saplings) and for biocidal use. From beginning of 2007 rodenticides started to be regulated as biocides. The anticoagulant active substances found in this study have been on market in Finland at least since 1998. The most commonly used AR is bromadiolone. There has been no specific strategy or RMMs apart from the label claims. The use of ARs has not been studied in Finland, but it has most likely remained the same until 2011 and even after that despite of attempts of authorities to enlighten users of risk to non-target animals. There is still no surveillance or monitoring of use of ARs.

No AR screenings have ever been conducted in the country, despite the widespread use of ARs and their potential impacts on the high levels of the ecosystem food chain. Here we quantify the prevalence of anticoagulant rodenticide substances (FGARs chlorophacinone and coumatetralyl, SGARs brodifacoum, bromadiolone, difenacoum, difethialone, and flocoumafen) in the liver tissues of altogether 17 mammalian or avian predator or scavenger species (group “other mammals”: domestic cat, raccoon dog, brown rat, red fox; group “mustelids”: stoat, badger, least weasel, otter, pine marten; group “birds”: eagle owl, goshawk, hooded crow, hen harrier, magpie, sparrow hawk, white-tailed sea eagle, tawny owl). In addition, we aim to identify the environmental (e.g. distance to industrial areas, which are typical areas for AR use) and biological factors (e.g. species group reflecting habitat use and diet preferences) that could be linked to secondary AR poisoning.

2. Material and methods

2.1. Sample collection

Liver samples were collected to determine the concentrations of the seven anticoagulant rodenticide substances (brodifacoum, bromadiolone, difenacoum, difethialone, flocoumafen, coumatetralyl, chlorophacinone) approved in Finland from altogether 131 individuals of different predator and scavenger species (group “other mammals”: domestic cat, raccoon dog, brown rat, red fox; group “mustelids”: stoat, badger, least weasel, otter, pine marten; group “birds”: eagle owl, goshawk, hooded crow, hen harrier, magpie, sparrow hawk, white-tailed sea eagle, tawny owl. Please see Table A.1 for more details). Animals were either found dead (e.g. road-kills) or were shot or trapped as part of predator removals from conservation areas (namely raccoon dog *Nyctereutes procyonoides*,