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Rodenticide incidents of exposure and adverse effects on non-raptor birds

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ABSTRACT

Interest in the adverse effects of rodenticides on birds has focused primarily on raptors. However, non-raptor birds are also poisoned (rodenticide exposure resulting in adverse effects including mortality) by rodenticides through consumption of the rodenticide bait and contaminated prey. A literature search for rodenticide incidents (evidence of exposure to a rodenticide, adverse effects, or exposure to placebo baits) involving non-raptor birds returned 641 records spanning the years 1931 to 2016. The incidents included 17 orders, 58 families, and 190 non-raptor bird species. Nineteen anticoagulant and non-anticoagulant rodenticide active ingredients were associated with the incidents. The number of incidents and species detected were compared by surveillance method. An incident was considered to have been reported through passive surveillance if it was voluntarily reported to the authorities whereas the report of an incident found through field work that was conducted with the objective of documenting adverse effects on birds was determined to be from active surveillance. More incidents were reported from passive surveillance than with active surveillance but a significantly greater number of species were detected in proportion to the number of incidents found through active surveillance than with passive surveillance ($z = 7.61$, $p < 0.01$). Results suggest that reliance on only one surveillance method can underestimate the number of incidents that have occurred and the number of species that are affected. Although rodenticides are used worldwide, incident records were found from only 15 countries. Therefore, awareness of the breadth of species diversity of non-raptor bird poisonings from rodenticides may increase incident reportings and can strengthen the predictions of harm characterized by risk assessments.

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1. Introduction

Rodenticides are used worldwide to protect agriculture, human health, and ecosystems from a variety of mammalian pests (Eason et al., 2015; United States Environmental Protection Agency, US EPA, 2008). Rodenticides are broad-spectrum vertebrate control agents and therefore they are also hazardous to birds. Monitoring for rodenticide exposure and adverse effects on birds has generally focused on raptors (e.g. Christensen et al., 2012; Gómez-Ramírez et al., 2014; Thomas et al., 2011; Walker et al., 2015). However non-raptor bird mortalities have occurred from feeding on rodenticide bait (primary exposure) and via secondary exposure through consumption of contaminated prey (Berny et al., 1997; Sánchez-Barbudo et al., 2012; Spurr, 1994; Vyas et al., 2013). Traditionally, the term ‘incident’ has been defined as an adverse effect (e.g. http://www.hc-sc.gc.ca/cps-spc/pest/part/protect-proteger/incident/index-eng.php). Recently, the US EPA expanded this definition to include pesticide exposure or an adverse effect (https://www.epa.gov/pesticide-incidents/introduction-pesticide-incidents). Hereafter I use the term ‘incident’ to also include ingestion of placebo baits that were applied using operational application techniques. Placebo bait trials have been used to predict the risks to non-target birds that may occur from rodenticide applications (e.g. McClelland, 2002; Sztukowski and Kesler, 2013; Torr, 2002). I included placebo bait exposures as incidents because the actual hazards to birds following rodenticide applications may exceed the risks predicted by the placebo bait trials and because rodenticide applications may be conducted despite observations of birds feeding on the placebo bait because the risks are considered to be acceptable with respect to the long-term benefits of the rodenticide application (e.g. Empson and Miskelly, 1999; McIlroy and Gifford, 1991).

Incident data provide insight into the hazards of rodenticides following operational applications. Below I summarize rodenticide incidents of non-raptor bird species from literature spanning 1931–2016; provide an overview of the anthropogenic, abiotic, and biotic factors that contribute to rodenticide exposure and poisoning; and discuss the influence of active and passive surveillance methods on documenting the incidents. The overall objective of this paper is to increase awareness

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of the breadth of rodenticide exposure and adverse effects to non-raptor birds. Knowledge that rodenticides are hazardous to non-raptor birds can benefit their conservation by encouraging conscientious compliance with the rodenticide label; increasing incident reporting by the public; improving or establishing incident monitoring schemes that include non-raptor birds; establishing or improving infrastructure for surveillance of non-raptor bird incidents, determination of their causality, and release of incident records for public access; clarifying routes of rodenticide exposure to raptors (Elliott et al., 2016); and by supporting the predictions of harm characterized by risk assessments.

2. Methods

2.1. Literature search

I used the terms 'rodenticide' and 'bird' to search the following databases to query literature on rodenticide effects on non-raptor birds: US Geological Survey's Digital Desktop Library (http://internal.usgs.gov/library/), United States Department of Agriculture's AGRICultural OnLine Access (http://agricola.nal.usda.gov/), GreenFILE (greeninfoonline.com), ScienceDirect (http://www.sciencedirect.com/), IngeniaConnect (http://www.ingentaconnect.com/), Journal Storage (JSTOR, http://www.jstor.org/), BioOne (http://www.bioone.org/), Scopus (https://www.scopus.com/), Web of Science (http://apps.webofknowledge.com/), Google Scholar (https://scholar.google.com/), United Kingdom Wildlife Incident Investigation Scheme reports.

(http://www.hse.gov.uk/pesticides/topics/reducing-environmental-impact/wildlife/wiis-quarterly-reports.htm; http://www.hse.gov.uk/pesticides/topics/reducing-environmental-impact/wildlife/annual-report-pesticide-poisoning-of-animals.htm; https://www.sasa.gov.uk/animal-poisoning-reports), and the US EPA Incident Data System records (https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/guidance-using-incident-data-evaluating-listed-and). A written request to the US EPA is required to acquire copies of individual incidents from its Incident Data System (R. Miller, US EPA, pers. comm.).

I reviewed all incident records retrieved by my query and discarded incidents from laboratory experiments (e.g. acute toxicity values in Godfrey, 1985; Spurr, 1993), duplications of incidents (e.g. an incident involving Australasian Swamphen (*Porphyrio melanotus*) is cited as Veitch, 2002a in Appendix 1, although the incident was also reported as personal communication in Eason and Spurr, 1995), and unpublished incidents with the exception of records from the US EPA Incident Data System. Therefore, the incidents listed in Appendix 1 represent unique records for free-ranging wild and domesticated non-raptor birds. Furthermore, incidents in non-raptor zoo birds were also included in Appendix 1 because although these birds were not completely free-ranging, they did consume rodenticides of their own volition, thus suggesting that wild conspecifics may also be at risk from rodenticides. The incident records presented in Appendix 1 range in dates from 1931 to 2016.

Based on the information provided in the incident records, I categorized each record, when possible, by the surveillance method (active or passive) that initially detected the incident and by the purpose of the application (human welfare or ecological restoration). I considered an incident to have been documented using passive surveillance if it was, at least initially, voluntarily reported to the authorities (ex. public's serendipitous encounters with poisoned birds) and I identified an incident to be from active surveillance if the initial documentation of the incident was collected through field work with the objective of documenting adverse effects on birds. I defined field work as planned searches for incidents following operational (e.g. van Klink and Crowell, 2015) or experimental rodenticide applications (e.g. Ramey and Sterner, 1995) and systematic interviews with applicators and landowners about wildlife mortalities they may have observed (e.g. Linsdale, 1931).

Rodenticide applications specifically purposed for habitat and species conservation (e.g. (e.g. for eradicating invasive non-target mammals on islands, Eason et al., 2015) were categorized as applications for ecological restoration. The non-raptor bird incident records that either stated or reasonably implied that rodenticide applications were conducted for human enterprises (e.g. agriculture, see Bildfell et al., 2013) were considered to be applications for human welfare. In some cases, operational rodenticide applications were conducted to determine their risks to birds (e.g. Elliott et al., 2014; McIlroy and Gifford, 1991; Ramey and Sterner, 1995). These applications were considered to have been conducted for human welfare because although the studies focused on bird exposure and adverse effects, the applications mimicked those that are operationally conducted for human welfare and not for ecological restoration.

2.2. Data analysis

A Spearman's correlation was run to assess the relationship between the number of incidents documented and the number of species reported in the incidents from 15 countries (http://www.socscistatistics.com/tests/spearman/default2.aspx). Two-tailed, two sample z tests for proportions (http://www.socscistatistics.com/tests/ztest/Default2.aspx) were performed to compare the number of species and the number of incidents reported with respect to the surveillance method and the purpose of the application.

3. Results and discussion

3.1. Overview

My query showed that non-raptor birds consumed rodenticide-containing baits, placebo baits, and rodenticide contaminated prey. I found 641 rodenticide incidents involving 17 Orders, 58 Families, and at least 190 non-raptor bird species (taxa of some birds were not specified to genus and species, ex. duck, Appendix 1). The magnitude of the incidents ranged from a single bird (e.g. Stone et al., 1999) to population declines in areas treated with rodenticides (e.g. Apa et al., 1991; Howald et al., 1999, 2009; McClelland, 2002; Powlesland et al., 2000; Taylor, 1984). Nineteen anticoagulant and non-anticoagulant rodenticide active ingredients were associated with the incidents (Fig. 1). These rodenticides are broad-spectrum vertebrate control agents that pose a significant risk to all bird species.

In 532 incidents, 168 species exhibited overt adverse effects. My tally for adverse effects included birds that were confirmed to have died from rodenticides (e.g. Vyas et al., 2013), birds that were adequately presumed by the author to have died from rodenticide exposure (e.g. Empson and Miskelly, 1999; McClelland, 2002, also see Section 3.5) and moribund birds. The latter group included birds that ultimately died (e.g. Blus et al., 1985) and birds that survived because of medical treatment (e.g. James et al., 1998; Swenson and Bradley, 2013). My query also returned 94 rodenticide incidents involving 41 species (18 of these species were in addition to the 168 tallied above) where only the evidence of rodenticide exposure could be confirmed (Appendix 1). These incidents documented non-raptor bird exposures to rodenticides but did not provide evidence of an adverse effect. Incident reports deemed as exposure included observations of birds feeding on the rodenticide bait (e.g. Veitch, 2002b) or poisoned prey (e.g. James et al., 1990); beak marks on rodenticide stations and blocks (e.g. Taylor and Thomas, 1993); rodenticide-colored droppings (Vyas et al., 2013); presence of tracer dye in droppings (e.g. Fellows et al., 1988); rodenticide residues in live, overtly healthy birds (e.g. Spurr et al., 2015); and rodenticide residues in dead birds that were below the threshold levels expected to cause an adverse effect (e.g. Pitt et al., 2015). Rodenticide residues were measured in the last two categories but were not reported for all incidents. For example, WIIS only reported the active ingredient and whether the detected rodenticides could be considered to be