BRITISH COLUMBIA

Ministry of
Environment and
Climate Change Strategy

A Review of Second-Generation Anticoagulant Rodenticides and Risks to Non-target Wildlife in British Columbia

November 2021

Integrated Pest Management Program

Environmental Standards Branch

Environmental Protection Division

Contents

Preamble

Second-generation anticoagulant rodenticides (SGARs) have been associated with adverse impacts to wildlife, including documented raptor mortalities in British Columbia (B.C.). In July 2021, the Minister of Environment and Climate Change Strategy issued an order banning the sale and use of SGARs for a period of 18 months while the Ministry implemented its Rodenticide Action Plan. This action plan includes a collection of initiatives, such as building partnerships, improving training and education materials, increasing compliance activities, and conducting this Science Review.

The purpose of the Science Review is to better understand the current state of knowledge with respect to risks to wildlife from SGARs and the current use patterns of SGARs in B.C. The Science Review is not intended to generate new data, conduct comprehensive risk assessments, or replicate the evaluation work of Health Canada's Pest Management Regulatory Agency. It reviews what is currently known about SGAR uses and risks to wildlife with a focus on B.C., but also includes information from other jurisdictions. Analyses of human health risks, business or economic impacts, or social impacts from rodent pests and/or SGAR use were out of scope for this report and will be considered during other activities of the Rodenticide Action Plan.

For this Science Review, a literature review was conducted, and an action research method was applied to gather information from a broad variety of sources and to verify learnings from the published literature. Through a combination of interviews, focus groups, and surveys, expertise and perspectives were heard from technical experts (e.g. academic researchers, research scientists, technical government staff), operational experts (e.g. structural pest control operators, agricultural operators, consultants), Indigenous peoples, non-governmental organizations, and members of the community involved in public awareness efforts regarding the impacts of rodenticides to wildlife.

The findings of this review are intended to develop future recommendations to inform policy options for the sale and use of SGARs in B.C. under the *Integrated Pest Management Act* and Regulation.

Executive Summary

Rodent pests can exist nearly everywhere that humans do, and can have significant impacts to structures, infrastructure, human health, agricultural production, and biodiversity. Anticoagulant rodenticides are the most common pesticides used to address rodent issues, and second-generation anticoagulant rodenticides (SGARs) are the preferred option by most pest management professionals. SGARs, formulated as baits, are acutely toxic, persistent, and bioaccumulative substances. When SGARs are ingested by rats or mice, the residues remaining in rodent bodies pose a risk to non-target predators and scavengers that prey on them through the pathway of secondary poisoning. Primary poisoning may also occur if wildlife feed directly on the rodenticide bait.

The use of these products is regulated federally by Health Canada and provincially under the B.C. *Integrated Pest Management Act* and Regulation. In 2010, Health Canada introduced new mitigation measures for SGARs to reduce the risks to non-target wildlife, and will re-evaluate these products again in 2022 to determine whether they continue to have value and meet current health and environmental risk assessment standards. Over and above federal requirements, there are provincial requirements for the sale and certain prescribed uses of SGARs, such as use on public land or by pest control service companies. These requirements include authorizations, record-keeping and reporting, and mandatory Integrated Pest Management (IPM) practices. However, other uses of SGARs (such as use by agricultural operators or by residents on most private property) do not require a provincial use authorization, and therefore are not required to meet the associated regulatory standards. Separate public reporting processes exist in B.C. for non-compliance with provincial pesticide laws (the Report all Poachers and Polluters (RAPP) line), and for reporting dead birds (B.C. Interagency Wild Bird Mortality Line).

Over the last several decades, anticoagulant rodenticide residues have been detected in a wide range of avian and mammalian predators and scavengers around the world. Published literature and data compiled by government wildlife agencies confirms this exposure is occurring in B.C. wildlife, especially in raptors. SGARs are detected more frequently than other rodenticides such as first-generation anticoagulant rodenticides (FGARs), which might be expected given the difference in bioaccumulation capacity between the compounds. Long-term research trends show that this exposure is increasing with time in both degree and scale. Typically, this data is obtained through opportunistic collection of wildlife carcasses; thus, the data is not representative of a natural population, and population-level effects remain unknown. There is clear evidence of wildlife exposure to anticoagulant rodenticides through a number of pathways, but more information is needed to better understand how this occurs for different species and how residues may then spread through the food chain.

While detected anticoagulant rodenticide residues indicates exposure, this does not establish that the animal died from rodenticide toxicity, and there can be significant challenges in diagnosing cause of death. The most common cause of death for raptors and owls collected in B.C. is physical trauma, followed by physiological causes; to a lesser extent, there have been recorded wildlife deaths attributed to acute rodenticide toxicity. However, it is suggested by many researchers that sublethal effects from anticoagulant rodenticide exposure may contribute to other causes of death. More research is needed to better understand the extent to which this occurs. The link between mortality of individual non-target wildlife and SGAR toxicity via primary and secondary exposure pathways is unequivocal. However, the magnitude of this issue and how this may translate into population-level effects for B.C. wildlife warrants further study.

For this review, experiential knowledge was gathered from a variety of sources through interviews, focus groups and surveys. Operational experts stated that anticoagulant rodenticides are essential tools for certain use scenarios, such as extreme rodent population outbreaks that pose a threat to public health or food supply, or for conservation purposes. SGARs are commonly used in both short-term and long-term rodent management programs, as well as permanent, preventative baiting programs. It was also heard that to be successful, rodent management programs must employ ongoing preventative measures, such as exclusion (rodent-proofing structures) and environmental sanitation, and this is affirmed in the published literature. Almost universally, pest management professionals, research scientists, Indigenous peoples, and other community members indicated that they were concerned with the potential impacts of SGARs on wildlife in B.C. Overuse, unnecessary use, and improper use by untrained individuals were cited as specific concerns.

Report findings were synthesized based on the literature and information gathered from the targeted engagement strategy. Select rodent management scenarios were identified where SGARs are a critical tool to protect against substantial impacts from rodent pests, where effective alternatives are lacking or have been exhausted. However, current use patterns indicate a general overreliance and overuse of this tool and inadequate application of Integrated Pest Management (IPM) principles such as preventative measures to address rodent issues and minimize unnecessary use of pesticides. Due to the high-risk properties of SGARs, the use of these products requires heightened diligence and oversight.

There is clear evidence of environmental exposure and wildlife mortalities from SGARs. Data gaps exist, such as the extent to which different exposure pathways contribute to the issue, the scope of the contamination and lethal or sublethal effects in natural populations, and population-level effects. As more research emerges to better understand these data gaps and mitigate the risks to wildlife, a fundamental shift to reduce reliance on rodenticides and implement other rodent management measures within an IPM context would reduce the rate of introduction of these substances to the environment.

Chapter 1: Rodent pests and impacts in B.C.

With over 1700 species of rodents representing 35 families worldwide, only three generally cause issues as commensal pests (i.e. living in or near people): the house mouse (*Mus musculus*), roof rat or black rat (*Rattus rattus*), and Norway rat or brown rat (*Rattus norvegicus*), all belonging to the family Muridae. Rodents attempt to co-exist with humans in nearly every building we live, eat or work in and the cost of rodent management globally is estimated to be in the tens of billions of dollars. Their high reproductive potential, combined with their opportunistic feeding behaviour and selection of diverse harbourages, are all contributing factors to their success adapting and thriving in many different habitats and climates.

Rodents are commonly subject to seasonal population fluctuations, as well as population changes associated with food availability, weather events, competition, and predation pressures, with rat and mouse outbreaks typically occurring at intervals of 4-8 years (Lopez-Perea and Mateo 2018). In commensal settings, rodents do not face the usual pressures of a natural wildland environment. Their high reproductive potential – rapid sexual maturity, short gestation periods, large litters, and potential for year-round breeding – means that population numbers can quickly explode, with rodents producing new litters every 24 days. Mouse populations, in particular, can grow extremely quickly and if left unchecked can result in multiple territories with hundreds or even thousands of individuals living in a single building (Corrigan 2001).

Rodents can easily adapt to a wide variety of habitats and climates, with continuously growing incisor teeth prompting constant gnawing behaviour and contributing to the structural damage associated with these pests. They rely highly on senses of touch, smell, hearing and taste; with poorer vision adapted for nocturnal activity and high sensitivity to motion (Mallis 1990). Rodents are social and highly territorial in their behaviour and scent-marking with feces and body fluids. They adapt to their environments depending on the resources available, and may exhibit both neophilic (exploratory or investigative) or neophobic (fear or shyness) responses to new foods, objects or harbourages. Mice tend to be more exploratory than rats in general, but all species exhibit both types of behaviour. Mice have hoarding tendencies and will commonly collect food to store back at their nests, including rodenticide baits (known as “bait translocation”) (Corrigan 2001).

When comparing typical home ranges – the area frequented by the individual rodent – rats have a much further ranging distance of about 30 meters, compared to a mouse ranging distance of 3 to 6 meters or less. This range varies depending on individual size, sex, season, population density, and resource availability. Given the right conditions, mice can have extremely small territories, and if left undisturbed with suitable resources will stay very close to their nest, sometimes spending their entire lives within a single desk or pallet and presenting extremely challenging control situations (Mallis 1990; Corrigan 2001). Norway rats may nest indoors or outdoors in underground burrows, while roof rats prefer nesting inside or under buildings, or in piles of materials out in the open. Roof rats are also agile climbers, commonly (but not exclusively) found in overhead locations and upper parts of structures (Mallis 1990). In general, mice are much more likely to nest inside than rats (Shore and Coeurdassier, 2018). While rats and mice can potentially both be present in separate parts of the same building, the larger Norway rats may prey on roof rats and both types of rats may prey on mice; therefore, cohabitation in the same area is unlikely (Mallis 1990; pers. comm. C. Day).

Rats and mice can cause structural damage directly with their gnawing behaviour, chewing through wood, plastics, drywall, pipes and electric systems, including both home electronics as well as critical infrastructure such as emergency response, electrical distribution systems, and telecommunications. Burrowing damage can occur in several ways, such as weakening structural supports and foundations, damaging infrastructure (e.g. sewer systems, ditches, or transportation systems), or destroying insulation and nesting within walls. They can damage other household items like books, papers or textiles in search of nesting materials; and can consume or contaminate household foods.

Rats and mice are capable of carrying and spreading diseases to humans, with about 55 different diseases potentially implicated from a wide range of pathogens including viruses, bacterial diseases, and parasites (Corrigan 2001). Commensal rodents can transmit diseases directly by biting or contamination via fur, feet, feces and body fluids; however, this is dependent on the pathogen already existing in the environment and the presence alone of rodents does not necessarily present an immediate health threat. Particularly in developed countries with sanitation infrastructure, health care programs, and pest management programs, the probability of disease transmission from rodents is lower (Corrigan 2001). The risks of health impacts from rodents are significantly higher in areas with poorer sanitary conditions, such as in lower socioeconomic areas or underdeveloped countries (Mallis 1990; Corrigan 2001; Meyer 2003).

Rodent impacts on agricultural operations and the food supply chain can be severe. It’s estimated that 20-30% of the world’s food supply is contaminated or destroyed by rodent pests, reaching losses of $30 billion (Mallis 1990; Corrigan 2001). Commensal rats and mice can directly consume stored grain or other commodities, damage barns and other farm buildings by gnawing and burrowing, directly transmit or contribute to the spread of diseases to humans and animals (or attack animals directly), and contaminate food products (e.g. with urine or feces).

While mice and rats make up the vast majority of structural rodent pests, different rodent species can also cause problems in agricultural settings for field crop and livestock production. In B.C., voles (*Microtus* spp.), northern pocket gophers (*Thomomys talpoides*), and Columbian ground squirrels (*Spermophilus columbianus*) are all field rodent pests that can significantly impact agricultural production (Albert et al. 2010). Field rodents typically live in grasslands but can also be found in agricultural fields and orchards, where they may cause problems by directly chewing and damaging the stems and roots of certain crops like berries or fruit trees. This is in addition to the structural pest issues that may also be experienced from rats and mice damaging barns, storage facilities and other outbuildings in agricultural operations.

From a wildlife conservation perspective, invasive or introduced rodents can have devastating direct and indirect impacts on species and ecosystems, particularly in sensitive ecosystems and for vulnerable native species. As omnivores, rodents may feed on plants, invertebrates, reptiles, mammals, and birds (including eggs, young, and even nesting adults) (Howald et al. 2007; Parks Canada 2021). Rats alone have been implicated in at least 40% of all bird extinctions (Atkinson 1985; Tershy et al. 2015). Isolated island ecosystems are a prime example where rodents are one of the leading causes of species extinction. Rats have been introduced to 90% of the world's islands with significant negative impacts to biodiversity, leading to the extinction of many island mammals, birds, reptiles, and invertebrates (Atkinson 1985; Gill et al. 2014; Tershy et al. 2015).

As one example in B.C., Haida Gwaii is a marine archipelago supporting marine birds and endemic species at risk from the presence of non-native rodents. Isolated from the mainland for thousands of years, the islands of Haida Gwaii are rich with many endemic plant and animal species and a critical nesting location for 13 species of approximately 1.5 million seabirds. Approximately 50% of the global population of ancient murrelets relies on nesting sites in Haida Gwaii and introduced rats have been linked to multiple breeding colony declines and extirpations (Environment and Climate Change Canada 2018).

Chapter 2: Second-generation anticoagulant rodenticides in Canada

2.1 History of SGARs in Canada

Historically, rodent pests were managed with traps and domesticated predators. Over the course of the last two centuries advancements were made to develop chemical compounds that “revolutionized” vertebrate pest control. Based on a naturally occurring plant compound, a number of anticoagulant compounds were synthesized, and by the early 1950s warfarin was registered as the first anticoagulant rodenticide. For the past 50 years rodenticides, especially anticoagulant rodenticides, have been the dominant rodent control option worldwide (Elliott et al. 2016). When consumed as bait, anticoagulant rodenticides function by disrupting the vitamin K cycle and reducing the production of blood-clotting agents. This mode of action ultimately leads to the death of the animal by internal bleeding (Newton 2018; Stone et al. 1999). In case of accidental or non-target poisoning, an antidote of vitamin K_1 is readily available for anticoagulant rodenticides (Corrigan 2001).

Resistance issues became apparent worldwide within a few years of the widespread availability and use of warfarin and other first-generation anticoagulant rodenticides (FGARs). Beginning in Europe and North America and quickly spreading to other areas, resistance appeared to arise independently in different populations but through the same biochemical pathways. This necessitated the development of similarly based, but more powerful second-generation anticoagulant rodenticides (SGARs), that began to replace the FGARs in the 1980s (Newton 2018). These SGARs, including the active ingredients bromadiolone, brodifacoum, and difethialone, are more toxic and persistent than FGARs. Brodifacoum is the most potent of the SGARs, with the lowest acute oral LD_{50} and therefore lowest bait dosages needed for lethal effect (Corrigan 2001). The high acute toxicity of SGARs reduces the likelihood of resistance development (Hindmarch and Elliott 2018); despite this, some resistance to SGARs was documented by the 1980s, although it does not appear to be as widespread as FGAR resistance (Berny et al. 2018).

Rodents may receive a toxic dose with a single feeding of SGARs compared to multiple feedings needed for FGARs, which is an advantage in environments with plentiful food alternatives available to rodents that may prevent them from returning to feed again on FGARs. However, SGARs have considerably longer half-lives in animal blood and tissues, and higher affinity for liver tissue (Parmar et al. 1987). It's been predicted that residues of brodifacoum and bromadiolone could persist 24 months or longer in target and non-target wildlife after consuming a sublethal dose. In contrast, FGARs are known to be metabolized and excreted much more quickly (Eason et al. 2002; Vandenbroucke et al. 2008).

Today, anticoagulant rodenticides available in Canada include FGARs (chlorophacinone, diphacinone, and warfarin) and SGARs (brodifacoum, bromadiolone, and difethialone). SGARs are the most commonly used anticoagulant rodenticides in both urban and rural settings (Hindmarch and Elliott 2018). Table 2.1 indicates the year of first registration of SGARs in Canada, as well as the current number of registered end-use products containing the respective active ingredients.

Table 2.1. Registration history and current product availability of commercial class SGARs in Canada (Pest Management Regulatory Agency 2004; Pest Management Regulatory Agency 2010; Health Canada 2021a).

Active ingredient	**Date of first registration**	**Currently registered commercial end-use products**
brodifacoum	1979	14
bromadiolone	1978	24
difethialone	2000	10

Corrigan (2001) estimated that approximately 90% or more of the bait used in rodent management programs are anticoagulants. Warfarin, the earliest developed and most publicly recognizable FGAR, is still used widely today despite resistance development. Most use is in domestic products intended for use by the general public, whereas SGARs are preferred by professional pest control operators. The toxicity of warfarin varies, with it being most effective against Norway rats, less effective against roof rats, and least effective against house mice. Chlorophacinone and diphacinone, while considered FGARs, belong to a separate class of anticoagulants than warfarin. Nonetheless, warfarin-resistant rodents will also be resistant to these two active ingredients.

2.2 Pesticide regulatory framework in B.C.

Pesticide use in B.C. is regulated by both federal and provincial legislation and some uses may also be regulated by municipalities. Pesticides, including rodenticides, can only be used in Canada if they have been evaluated and registered by Health Canada's Pest Management Regulatory Agency (PMRA). Through extensive health and environmental risk assessments, the PMRA establishes conditions and limitations for the use of pesticides. As required under the federal *Pest Control Products Act*, pesticides are then regularly re-evaluated to consider potential risks, as well as value, to ensure they meet modern safety standards established to protect human health and the environment.

B.C. sets additional standards under the *Integrated Pest Management Act* (*IPM Act*) and Regulation. The legislation establishes conditions for the sale and use of pesticides through a pesticide classification system, requirements for certain individuals to be trained and certified, and regulatory provisions for specific authorizations for prescribed uses. Regulatory requirements also contain public notification, consultation, reporting, and record keeping provisions – as well as standards for use of Integrated Pest Management (IPM) and for human health and environmental protection. Vendors selling commercial rodenticides, such as SGARs, must be licenced and employ certified pesticide dispensers to interact with customers prior to purchase.

Municipalities in B.C. have authority under the *Community Charter* to restrict pesticide use on outdoor trees, shrubs, flowers, other ornamental plants and turf, on private residential land and land vested in the municipality. Generally, this authority does not extend to restricting pesticide use for the management of pests that transmit human diseases or impact agriculture or forestry, on the residential areas of farms, to buildings or inside buildings, or on land used for agriculture, forestry, transportation, public utilities or pipelines (unless the public utility or pipeline is vested in the municipality).

2.3 Requirements for rodenticide sale and use in B.C.

The PMRA re-evaluated six rodenticides (brodifacoum, bromadiolone, chlorophacinone, diphacinone, warfarin, and zinc phosphide) in 2006 (Pest Management Regulatory Agency 2006, 2007). In 2010, following risk assessments and mitigation measures applied by the U.S. Environmental Protection Agency in 2008, the PMRA subsequently required additional risk mitigation measures for eight rodenticides, including all three registered SGARs (Pest Management Regulatory Agency 2010). These new measures included requirements for formulations, sales, and use of domestic and commercial class products. Notably, SGARs were prohibited for domestic class products (i.e., those intended for use by consumers in and around the home). Commercial class products containing SGARs were labeled for use only by certified pest control operators (i.e. a person with a pesticide applicator certificate), farmers and persons authorized in government-approved pest control programs. Two SGARs (brodifacoum and difethialone) were restricted to indoor uses only, and outdoor uses of bromadiolone may only be within 15 meters of a structure (or within 100 m if the bait is enclosed in a secured bait station and placed along a fence-line). The next federal re-evaluation of SGARs is scheduled to begin in 2022.

On July 21, 2021, due to concerns of effects on non-target wildlife, the B.C. Minister of Environment and Climate Change Strategy announced an 18-month ban on the sale and use of SGARs. Exemptions were allowed for identified Essential Services and agricultural operations. With respect to the sale and use of rodenticides, the temporary requirements of the Minister's Order introduced new requirements over and above the regulatory requirements under the provincial *IPM Act*. With that in mind, the standard regulatory requirements *prior* to the temporary Minister's Order are described below.

In B.C., with the exception of excluded pesticides on Schedule 2 of the IPM Regulation (such as corn cellulose), domestic and commercial class rodenticides may only be sold by licenced pesticide vendors. Vendors must employ trained, certified dispensers to interact with customers prior to the sale to confirm the intended pesticide use is appropriate and provide advice on pest management and the safe use of the pesticide. For commercial class pesticides, including SGARs, vendors must keep records for each purchase and submit annual sales summaries to the Ministry of Environment and Climate Change Strategy (ENV). For restricted class or permit-restricted class pesticides, purchasers are required to hold a pesticide applicator certificate to purchase. While SGARs have a label statement restricting the use to certified applicators, farmers, or government-authorized programs, the label does not restrict the sale of the product; and since SGARs are commercial class products and not restricted class, they do not require the purchaser to provide proof at the point of purchase that they meet this legal requirement for use.

The use of pesticides on public land (and some private land) in B.C. requires an authorization. Anyone who provides a service to apply pesticides in B.C. (except for excluded pesticides) requires a licence from ENV. A licence is also required by anyone to use rodenticides for structural pest control on public land, to manage rodents in or around multi-residence properties on private land, and to manage pests of landscaping on public or private land. For other uses of non-excluded rodenticides on public land in B.C. (not already requiring a licence), a Pesticide Use Permit is required from ENV.

Licensees must ensure trained and certified applicators apply pesticides and are required to keep daily use records and submit annual use summaries to ENV. Licensees must also provide public notification for certain uses, follow health and safety standards to protect human health and the environment, and follow the principles of IPM when making treatment decisions. IPM is a decision-making framework that includes steps for prevention, pest identification, monitoring, establishing action thresholds, consideration of treatment options (including pesticide alternatives), and program evaluation. The IPM Regulation has specific requirements for licensees using rodenticides baits including deploying the bait only in labeled, secured, tamper resistant bait stations (or in areas inaccessible to people or pets). Rodenticides applied in certain areas frequented by children, such as residences, schools, or daycares, must contain bittering agents to prevent accidental poisoning and must be removed from the treatment area and destroyed when the baiting program is complete.

Residents wishing to purchase and use commercial SGARs around their own home do not require an authorization from ENV (with the exception of multi-residence buildings). However, per the user requirement on the federal product label, they must complete training and get a pesticide applicator certificate in order to use the product. This certification is a legal requirement for use, but is not required to be shown at the point of purchase in B.C. Note that PMRA states that commercial class pesticides in general are not intended for domestic, personal use in and around the home, but rather are labeled for commercial activities and professional applicators.

Agricultural operators in B.C. are generally not required to hold an authorization from ENV to use pesticides for agricultural activities. Agricultural operators may still require training and certification to use certain products, such as restricted or permit-restricted class products; or for workers to use moderately toxic or toxic pesticides (under B.C. WorkSafe standards and the Occupational Health and Safety Regulation). Agricultural operators do not, however, require certification under the *IPM Act* to purchase or use SGARs.

Municipalities generally do not have the authority to create bylaws restricting the use of rodenticides. However, as of September 2021, several B.C. municipalities had instituted policies banning the use of SGARs for rodent control on municipal-owned properties.

2.4 Reporting pesticide concerns or non-compliance

There are several processes in place for people to report pesticide-related concerns, including reports of non-compliance with provincial or federal laws or concerns for wildlife potentially impacted by pesticide use. Provincial and federal pesticide compliance officers conduct inspections to verify compliance with pesticide regulations. These inspections may be routine or may be in response to a specific compliant or incident. If an inspector finds non-compliance with a requirement, there are a variety of enforcement tools that may be used based on a risk-based model.

In B.C., the primary method recommended for reporting suspected or known non-compliance with provincial laws involving pesticides, including rodenticides, is through the Report All Poachers and Polluters (RAPP) 24-hour telephone hotline at 1-877-952-RAPP (7277). There is also an online form available for reporting. The RAPP line may also be used to report injured or distressed wildlife regardless of any connection to potential pesticide impacts.

Regional Health Canada compliance officers promote and monitor compliance with the *Pest Control Products Act* (PCPA) and regulations in B.C. A person may report a known or suspected health or environmental incident involving a pesticide to either the pesticide registrant listed on the label, or directly to the PMRA via the online Public Engagement Portal Voluntary Incident Reporting form (http://pest-control.canada.ca/en/public-engagement-portal/forms/voluntary-incident-report). Pesticide registrants are required by law to report any pesticide incidents involving their registered pest control products to Health Canada.

B.C. also has a reporting process specifically for bird mortalities. The B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) and Environment and Climate Change Canada's Canadian Wildlife Service (ECCC-CWS) jointly monitor bird health through the Wild Bird Mortality Investigation Protocol, which includes a 24-hour telephone line for public reporting of dead birds. The program is not intended to collect every dead bird and not every reported bird will be submitted for necropsy; rather, the purpose is to monitor for potential avian disease outbreaks or mass mortalities, especially in priority species (e.g. species at risk). Depending on the species, specific case conditions, and condition of the remains, carcasses may be collected and submitted to the Animal Health Lab of the B.C. Ministry of Agriculture, Food and Fisheries in Abbotsford, B.C. Veterinary pathologists perform a necropsy and may conduct further external diagnostic testing (such as laboratory testing for toxins, like rodenticides) at an additional cost, if necessary to determine a cause of death. Final necropsy reports are typically shared with the specimen submitter, and data from the Bird Mortality Line is maintained jointly by both provincial and federal wildlife agencies (FLNRORD and ECCC-CWS). The Animal Health Lab may also collect tissue samples from submitted carcasses if requested by wildlife agencies for other wildlife research projects.

There is no ongoing monitoring of pesticide residues in natural wildlife populations across B.C., and the data available is based on found and submitted dead or moribund birds. Therefore, data available must be considered within the context of these limitations. Specimens will generally be collected more frequently in regions with higher human population densities, which also tend to have higher amounts of rodenticide use. Furthermore, birds already dead or moribund are thus more likely to be affected by toxins than a natural randomized population sample, which can bias the data towards a higher proportion affected. On the other hand, potentially affected birds and other wildlife outside of major population areas are less likely to be found and reported which may lead to under-reporting of the actual exposure rates. As a result, it is challenging to establish the potential population-level exposure and mortality rates in B.C. from rodenticide toxicity, as discussed in more detail in Chapter 5.

Chapter 3: Risks to wildlife

3.1 Pathways for non-target exposure to anticoagulant rodenticides

Since their introduction in the 1970s, SGARs have been widely adopted worldwide as standard rodent control tools and are now the primary pesticides used to control rodents in both agricultural and urban landscapes. By the 1980s-1990s, potential hazards and exposure pathways of rodenticides to non-target wildlife were being investigated (e.g. owls in the eastern United States; see Hegdal and Blaskiewicz 1984; Colvin et al. 1988; Hegdal and Colvin 1988) and reports emerged of anticoagulant rodenticide residues discovered in non-target wildlife (e.g. raptors in Britain; see Newton et al. 1990). Since then, and especially over the last two decades, SGAR residues have been detected in a wide range of avian and mammalian predators and scavengers around the world (Lopez-Perea and Mateo 2018). Long-term trends from studies in Canada, the United States, and Europe show increasing incidences of SGAR residue detections in the livers of non-target predatory birds and scavengers, with exposure to individual or multiple types of anticoagulant rodenticides (Thomas et al. 2011; Hindmarch et al. 2019; Hindmarch and Elliott 2018; Nakayama et al. 2019).

In contrast to FGARs, SGARs are more acutely toxic at lower doses and are also more persistent in vertebrate body tissues, especially in the liver. Residues can persist for many months, with half-lives ranging from 15.8-55 days for FGARs and 108-307 days for SGARs (Eason et al. 2002; Vandenbroucke et al. 2008; Lopez-Perea and Mateo 2018). It is these characteristics that allow SGARs to work more efficiently than FGARs, as SGARs often deliver a lethal dose with a single bait feeding. However, this also increases the potential for impact to non-target organisms from both primary poisoning (by direct ingestion of bait) and secondary poisoning (by consumption of a poisoned rodent pest or other species), as well as accumulation in predators and scavengers of poisoned rodents. The difference in acute toxicity between FGARs and SGARs appears to be especially greater for birds (compared to non-target mammals) (Erickson and Urban 2004).

Avian and mammalian predators are increasingly present in urban environments, as well as urban-wildland interfaces. This is at least partially due to increased development and construction activities encroaching on their natural habitats and forcing wildlife adaptation to new environments (Hindmarch and Elliott 2018). These areas of higher human population density and more intensive agricultural activity are also more likely to use anticoagulant rodenticides as pest issues are more prevalent. This increases the potential for non-target exposure through several different pathways, and therefore increases the risk presented from the use of these products. Indeed, studies have found a positive correlation between areas of higher human population density and the occurrence and concentration of anticoagulant rodenticide residues in non-target wildlife (Lopez-Perea et al. 2015; Lohr 2018).

Due to the high affinity and long-term accumulation of anticoagulant rodenticides in liver tissues, sampling for residues in studies of non-target exposure usually occurs in the livers of deceased animals. Residues can be detected in other animal tissues, such as muscle. With the advancement of more refined analytical techniques over the last few decades, current limits of detection may be as low as 0.001 mg/kg with certain methods and also provide high specificity for the compound (active ingredient) in biological samples (Lopez-Perea and Mateo 2018).

The typical method of analyzing tissues of animals found dead may introduce a bias into the overall average body burden residue values for a given species. Deceased animals may be more likely to have been poisoned than the baseline population. Some other sampling methods include testing regurgitated pellets or blood, which can potentially be used to detect exposure in living animals. For example, Hindmarch et al. (2019) tested coagulopathy (impaired blood clotting) in blood samples collected from raptors at a wildlife rehabilitation centre as an indirect indicator for potential anticoagulant rodenticide exposure. However, more work is needed to standardize test protocols and reference values for different species so that results can be compared among different studies.

Primary exposure

Primary exposure occurs when a non-target organism (e.g. wildlife or companion animal) feeds directly on the bait intended for rodent pests. The mode of action of anticoagulant baits is to inhibit blood clotting, and this mechanism is highly conserved in vertebrate animals; therefore, anticoagulant rodenticides are potentially toxic to many other animals besides the target rodent pests (Shore and Coeurdassier 2018). Invertebrates may feed directly on bait in bait stations and are less sensitive to anticoagulant effects of bait due to the physiological differences in their circulatory systems (Hindmarch and Elliott 2018). However, bioaccumulation and ecologically relevant physiological impacts have been observed in some invertebrate species exposed to SGARs (e.g. in laboratory testing of earthworms, Liu et al. 2015). Invertebrates may also be able to consume large amounts of bait without lethal effects, potentially posing a secondary poisoning risk to insectivores; however, more studies are needed on this topic.

Mitigation measures implemented by regulatory authorities include the deployment of SGARs only in tamper-resistant bait stations, or in places inaccessible to people, pets, and/or wildlife. However, studies have shown that even when bait is contained within a tamper-resistant bait box, primary exposure still may occur to wildlife including small mammals, birds, reptiles, insects, earthworms and other invertebrates (Shore and Coeurdassier 2018). If similar or smaller in size to target rodents, other animals may be able to enter the bait station itself and feed on the bait (e.g. songbirds observed by Elliott et al. 2014), or a range of species may be exposed if the bait itself is dragged out and left accessible. Primary exposure can also occur with illegal, intentional use of rodenticides to poison wildlife.

Secondary exposure

Much of the research on non-target exposure has focused on impacts to predators and scavengers exposed via secondary poisoning. Secondary poisoning can occur by the consumption of contaminated rats and mice (target pests), but may also occur if animals ingest any organism primarily exposed to the bait, as described above. Furthermore, poisoned rodents may survive for several days even after consuming a lethal dose (by intentional design of anticoagulant rodenticide baits to be slow-acting, thus avoiding bait shyness in targeted rodents). In the meantime, rodents may continue to feed on the bait and increase the anticoagulant rodenticide residue load in their body tissues. Behavioural changes associated with rodenticide toxicity (e.g. spending more time in open areas in a lethargic state) may present an increased likelihood of capture by predators, who are themselves subsequently exposed to the SGAR residues (Cox and Smith 1992). Resistant rodent populations can also consume greater amounts of bait without adverse effects (Hindmarch and Elliott 2018). Poisoned rodents frequently die in their nests and burrows but may also be found in open areas or even in and around bait boxes (Corrigan 2001).

Small non-target mammals, reptiles, and invertebrates can also feed on and retain rodenticide residues and create an additional source of exposure to a wide range of animals including predators, scavengers, and insectivores. In one study, Elliott et al. (2014) found anticoagulant rodenticide residues in carrion beetles that fed on the carcasses of poisoned animals, which suggests other possible exposure pathways of residues present in animal feces or soil.

Lopez-Perea and Mateo (2018) reviewed different studies detecting rodenticide residues in non-target wildlife that serve as potential prey of predators, and concluded that the highest residue levels were in small mammals, following by birds and reptiles. Of these residues, the SGARs were the most frequently reported (with bromadiolone being the most prominent, followed by brodifacoum). FGARs were generally detected less frequently, which might be expected given their shorter half-life in animal tissues. These prey species then pose a risk to predators that may bioaccumulate residues in their own tissues. The risk of reaching a residue concentration level resulting in adverse effects is dependent on a number of factors, such as how frequently residues are present in prey, the concentration of the residues in the prey, the species-specific ability to absorb or eliminate residues, and the excretion rate of the accumulated residues (which can vary depending on the species as well as the compound itself). Using these factors to develop a bioaccumulation model for a sample species – the barn owl (*Tyto alba*) – researchers suggested that bioaccumulation of anticoagulant rodenticide residues in owl livers may reach levels of concern after 3-4 days of continuous ingestion of exposed prey, or after 12-21 days of ingesting exposed prey every few days, depending on the owl's excretion rate (Lopez-Perea and Mateo 2018). This demonstrates that for predators feeding on prey sources continuously exposed to rodenticides (such as in areas of permanent baiting systems or adjacent, abundant control programs), non-target wildlife can quickly consume potentially harmful residue levels through secondary poisoning. Furthermore, with some predators (including birds of prey) adapting to benefit from known prey population cycles (Lopez-Perea and Mateo 2018), a rodent population outbreak may initiate a need for a targeted rodenticide treatment while simultaneously attracting natural predators and creating a heightened exposure risk scenario.

Certain predators may be more at risk from secondary poisoning than others. This depends on several factors, including diet type (rodent-specialist or generalist), scavenging behaviour, and habitat overlap with areas of sustained rodenticide usage, such as urban areas or areas of heavy agricultural production (Lopez-Perea and Mateo 2018; Hindmarch and Elliott 2018). However, the global increase of detected rodenticide exposures in wildlife populations also demonstrates that contamination is occurring in a wide range of habitats, including wildlands and national parks distant from human activity (albeit to a lesser extent) (Gabriel et al. 2012).

Tertiary exposure

Tertiary exposure is also a potential pathway for non-target wildlife exposure; for example, if predators consume birds that have ingested rodenticide-exposed insects. Anticoagulant rodenticide residues are increasingly being detected in birds of prey that feed primarily on songbirds (Hindmarch and Elliott 2018). Reptiles, subject to secondary exposure from feeding on poisoned rodents, may subsequently be predated themselves (Lopez-Perea and Mateo 2018). At urban-wildland interfaces, tertiary exposure is possible for large apex predators like mountain lions consuming smaller exposed predators (e.g. coyotes that fed on anticoagulant-exposed rodents; Riley et al. 2007). While these form potential exposure pathways, more information is needed to verify the extent to which these occur and how residues may spread through the food chain.

Other exposure routes

The majority of research on non-target effects has focused on terrestrial exposure pathways where baiting occurs. Other exposure routes, such as through aquatic environments, are lesser known. When anticoagulant rodenticides are used in sewer systems or near bodies of water there may be the potential for contaminating aquatic ecosystems either through bait or dead rodents entering the water. Anticoagulant rodenticide residues have been detected in urban waste waters, which may be attributed to a pesticidal usage as well as excretion from therapeutic use in humans, as compounds such as warfarin may also be used by people as clinical anticoagulants (Shore and Coeurdassier 2018). Regnery et al. (2019) reviewed low amounts of anticoagulant rodenticide residues found in various aquatic organisms, including marine invertebrates and fish.

In broad scale applications where bait may be applied directly to the soil, or where poisoned rodents die in or on the soil, there may also be a risk of soil contamination. When baits are deployed in tamper-resistant bait boxes the risk of unintentional introduction is reduced; however, in certain circumstances this is not always practical or effective (e.g. island eradication projects or agricultural landscapes during rodent outbreaks). Mitigation measures such as hand applying bait are possible to ensure precise placement near sensitive environments, like waterways or coastlines. If bait does drift into the water, in cold water systems SGARs are hydrophobic compounds expected to bind to organic matter and settle out of the water column in sediment (Regnery et al. 2019; pers. comm. G. Howald).

Overall, many non-target wildlife can be exposed to anticoagulant rodenticides via a combination of primary, secondary and possibly tertiary pathways due to their opportunistic diets and behaviours. For example, a granivorous species will readily feed on cereal-based baits in or out of a bait station if given the opportunity (e.g. Sánchez-Barbudo et al. 2012), or unintentionally ingest loose bait pieces from soil while feeding on other organisms (primary exposure); while also feeding on potentially exposed invertebrates, or even scavenge (secondary exposure) (Shore and Coeurdassier, 2018).

3.2 Lethal and sublethal effects from anticoagulant rodenticide exposure

Wildlife may be exposed to anticoagulant rodenticides at sublethal levels, which do not have directly lethal effects but may cause adverse effects or impair the fitness of the exposed individual in another way. Coagulopathy, impaired body condition, susceptibility to disease or environmental stressors, and sensitivity to other toxicants are some of the effects attributed to sublethal rodenticide exposure (Rattner et al. 2014). The extent to which sublethal effects from SGARs may indirectly contribute to other mortalities from natural or accidental causes has been widely hypothesized but requires further investigation. For example, sublethal exposures may reduce the ability of wildlife to recover from collisions or other trauma if coagulopathy exacerbates hemorrhage; or lethargic behaviour (which is often observed in birds of prey undergoing rehabilitation from rodenticide exposure) may reduce hunting ability, increasing the probability of starvation (Thomas et al. 2011; Rattner et al. 2014).

Several studies examined potential reproductive effects in predator populations inhabiting areas where anticoagulant rodenticide treatments have occurred. In some cases, they found reduced breeding success compared to animals in untreated areas (e.g. Naim et al. 2011); however, this may be an indirect effect to the treatment itself reducing rodent prey availability. Studies have also shown the potential transfer of anticoagulant residues from exposed females to their offspring in both birds and mammals (Fisher 2009; Gabriel et al. 2012).

There can be significant challenges in diagnosing cause of death potentially linked to rodenticide toxicity. Mortalities attributed to secondary rodenticide exposure have been recorded around the world in many non-target wildlife species, with the most common compounds involved being the SGARs bromadiolone and brodifacoum. In a compilation of studies examining anticoagulant rodenticide exposure in non-target wildlife, residue levels in animals determined to have succumbed to toxic effects of SGARs ranged widely from 0.01 to 5.3 mg/kg in the liver (Lopez-Perea and Mateo 2018).

With wide ranging values, more research is needed on what anticoagulant rodenticide residue concentrations in animal tissues are likely to result in a potentially lethal dose. Newton et al. conducted field and experimental dose studies on barn owls and reported potentially lethal levels of SGAR liver residues of “greater than 0.1 to 0.2 mg/kg wet weight” (Newton et al. 1999a, 1999b; cited in Thomas et al. 2011). However, subsequent studies have shown much lower levels associated with lethal poisonings; for example, as low as 0.01 mg/kg wet weight in one great horned owl in a study by Stone et al. (1999). With residue concentrations ranging over two orders of magnitude in tested species, the data available suggests that the value is both interspecific and intraspecific, with only a small number of studies on select species to date. Furthermore, since most ecotoxicity studies associated with regulatory requirements examine the toxicity from acute exposures, even less is known about chronic exposure to sublethal amounts of anticoagulant rodenticides. It does appear that while SGARs are much more acutely toxic than FGARs, there is more to learn about the impacts of chronic exposure to either type (van den Brink et al. 2018), and repeatedly exposed animals may be more susceptible to subsequent exposure even after a recovery period (Rattner et al. 2020).

Given the marked variation in sensitivity to anticoagulant rodenticides within and among species, detected residue concentrations alone are not sufficient diagnostic factors for death due to rodenticide toxicity. While detected residues from animal carcasses may indicate exposure, this does not demonstrate that the animal died from rodenticide toxicity, and the extent to which exposure leads to non-target wildlife death is uncertain. Only necropsies combined with residue exposure data can confirm the role of the anticoagulant rodenticides in the mortality event.

3.3 Population-level effects

Non-target wildlife mortalities from both primary exposure and secondary exposure are well-documented in various studies. Whether these mortalities translate into population-level impacts, such as population reductions, remains a key research question.

Shore and Coeurdassier (2018) reviewed a number of studies to report on potential population level effects due to primary anticoagulant rodenticide exposure. Since exposure events are not typically observed, most studies infer the most likely pathway (e.g. primary versus secondary) based on the known dietary preferences of the study species. In several island rodent eradication projects, declines in non-target bird or mammal species thought to be attributed to primary and/or secondary exposure were noted after treatment. In at least one case with monitoring after treatment, an impacted shrew population appeared to rebound after baiting stopped, with documented recoveries on other islands around the world. In other studies from agricultural rat control programs involving anticoagulant rodenticide baiting, non-target field rodent populations (such as wood mice or voles) were reduced after treatment, with populations showing recovery three months later. No studies demonstrated significant impacts to long-term survival, reproduction, or immigration of non-target species attributed to primary exposure to anticoagulant rodenticides. Therefore, the major impacts from primary exposure appear to be acute toxicity to, and potentially mortality of, the exposed individuals. Nonetheless, this can be significant and must be considered carefully in certain conservation settings (for example, species at risk), and/or for isolated or small populations (for example, on islands), with limited opportunity for immigration from surrounding areas to help rebuild impacted populations (Rattner et al. 2014; Shore and Coeurdassier 2018).

In a dramatic example of impacts to predator populations, a Malaysian plantation replaced warfarin baiting with the SGAR brodifacoum in the early 1980s. Barn owls, whose diet was made up of 98% Norway rats, nested in the plantation. Soon after brodifacoum baiting was introduced, the barn owl population went into significant decline and eventually disappeared from select regions (Lenton 1984; Duckett 1990; cited in Hindmarch and Elliott 2018). Lopez-Perea and Mateo (2018) suggested that cosmopolitan species such as barn owls can serve as bioindicators for the risk of secondary poisoning to other predators. In France, large areas of grasslands treated with bromadiolone were correlated with a decrease in red fox abundance, with a partial population recovery not observed until 2 years after a period of intense bait application (Jacquot et al. 2013). In both cases above, indirect effects from the loss of a primary prey source are also possible (although Jacquot et al. suggested this was less likely to be a confounding factor for their 2013 study).

Other factors influencing the ability of a non-target species population to recover following a major disturbance, such as anticoagulant rodenticide exposure, include the scale of the baiting program (area covered, application rate, and duration), type of application (above or below ground, with or without bait stations), habitat connectivity (affecting immigration potential from surrounding areas), and intrinsic rate of population growth (e.g. *r*-selected species with high reproductive potential, such as non-target rodents, versus *K*-selected species who produce fewer offspring, as is the case with many predator species) (Shore and Coeurdassier 2018).

Lopez-Perea and Mateo (2018) reviewed 40 published studies of anticoagulant rodenticide residues detected in various non-target animals. The studies included data on 53 species of predatory birds and mammals with various feeding habits and from different geographical areas. Of these, the occurrence of residue detections averaged 58%. The researchers suggested this is a value of concern based on the potential effects on biodiversity and potential food chain effects from the impacts to top predators. As well, the loss of natural rodent predators may lead to increases in rodent abundance.

Using data from published studies on SGAR poisoning in raptors, Thomas et al. (2011) developed probability curves to estimate the species-specific liver concentration expected to result in toxic effects, as well as the percent of the species population expected to be at risk of being killed from SGARs. This modelling estimated, for example, a predicted mortality of 11% of the sampled great horned owl population; however, the authors acknowledge the inherent biases and uncertainties due to sampling methods as well as the lack of any information on sublethal effects contributing to the overall population mortality.

While there is clear evidence of wildlife exposure to anticoagulant rodenticides via a number of pathways, more information is needed about how residues spread throughout the food chain, particularly in urban environments and urban-wildland interfaces, and how these exposures may translate into population-level effects (Hindmarch and Elliott 2018). Some studies demonstrate a reduction in species abundance following area treatment with SGARs, which may be due to direct or indirect effects of the baiting. The link between mortality of individual non-target species and SGARs via primary and secondary pathways is unequivocal; however, the role of SGARs in permanent population declines warrants further study (van den Brink et al. 2018).

Chapter 4: Rodent management in B.C.

4.1 General use practices: Anticoagulant rodenticides

As introduced in Chapter 1, rodent management practices are used in B.C. to protect structures, infrastructure, agricultural commodities, and biodiversity from impacts of rodent pests. SGARs are used across all sectors and remain the primary pesticides used across all landscapes, including urban and rural/agricultural areas (Hindmarch and Elliott 2018; Hindmarch et al. 2018). This section will summarize general use practices as described in the literature, while section 4.3 will outline details of what was heard about specific practices currently used in B.C.

Agriculture

For agricultural operations, methods of applying anticoagulant rodenticides (including both FGARs and SGARs) include deploying in bait stations in and around barns, buildings, and other farm structures; in bait stations securely fastened along fence lines; placing directly in underground rodent burrows in fields; or broad scale application in fields and orchards (Corrigan 2001; Rattner et al. 2014). Certain crops, like some berry species, may require more intensive rodent control than grass fields as the plants are susceptible to direct root damage from rodents (Hindmarch et al. 2018). Bait application may be to a small, targeted area or a mass application area thousands of square kilometers in size in the case of large rodent population outbreaks (Hindmarch and Elliott 2018). In the cases of large-scale outbreaks or infestations, anticoagulant rodenticides tend to be more effective than the alternative control measures available (van den Brink et al. 2018). Bait application may be occasional or seasonal depending on pest pressures, but many operations have long-term or permanent baiting programs in place. Permanent rodent management programs are frequently required to meet government or third-party auditor requirements for ensuring food safety standards (e.g. CanadaGAP 2020a, 2020b), especially for greenhouse production and the food processing industry. These programs do not necessarily mandate rodenticide use, but that is a common practice to meet the requirements. A 2013 survey of farmers around Delta, B.C. found that 94% of farmers used anticoagulant rodenticides, of which 37% were applying SGARs as a permanent rodent management program to meet food safety standards (Hindmarch et al. 2018). Rodenticides are generally not permitted for use in organic production; however, some certification bodies may allow non-permitted substances in “last resort” cases and the extent to which this occurs is not known (pers. comm. E. Holmes).

Urban rodent management

SGARs are the primary tool used to manage rodent pests in urban areas (Corrigan 2001). Federal requirements restrict SGARs to commercial class products for use only by certified pesticide applicators, government control programs or farmers. FGARs are available to the general public as both domestic or commercial class formulations; but SGARs are preferred by professionals. Commercial anticoagulant rodenticides may only be applied in locked, labeled, tamper-resistant bait stations or in places inaccessible to children or pets. For the vast majority, baiting is standard for both commercial and residential rodent problems and may be done either indoors or outdoors. As with agricultural uses, baiting programs are often permanent with bait stations monitored and re-filled on a regular and ongoing basis. However, with the increasing public awareness of the risks to wildlife from anticoagulant rodenticides, there is a growing demand for pesticide-free rodent management programs. Some pest control companies are now offering this service either as an alternative option to traditional baiting programs or as their exclusive approach, highlighting exclusion and trapping as solutions for rodent infestations (pers. comm. J. Abercrombie and E. Harris).

Conservation

Rodent management is conducted for conservation purposes to protect biodiversity, and this is very distinct from the agricultural or urban practices described above. Generally speaking, there are three main types of conservation projects involving rodent management: targeted protection measures (for example, rodent management to protect a select critical habitat or species such as individual nests of threatened birds), early detection rapid response (EDRR; for example, shipwrecks that pose an immediate threat of newly introduced rodents to isolated habitats), and island eradication (i.e. targeting 100% removal of rodents from the island ecosystem). Of these, the first – targeted protection – may be limited to one section of an island or land area, and may also be recurring (but time-limited) to align with seasonal events, such as critical nesting periods. In contrast, EDRR or island eradication projects are generally "one-time" only treatments meticulously planned and executed with highly trained project managers and technical staff. In particular, island rodent eradications can be multi-million dollar projects with many years of planning, including complex feasibility and technical studies, methodology development, impact assessments and mitigation measures, and peer review by a global technical network, to maximize the probability of success while minimizing potential impacts to non-target wildlife (Howald et al. 2007; Keitt et al. 2015).

Anticoagulant rodenticides (typically SGARs) are either hand-applied or aerial broadcast over affected areas. In recent years in B.C., Parks Canada partnered with world leading experts in island conservation to undertake rat eradication projects involving SGAR applications in Gwaii Haanas national park, while ramping up biosecurity efforts to prevent the spread and introduction of invasive rodents to these extremely sensitive ecosystems (Parks Canada 2021).

Conservation programs using SGARs are unique and distinct from ongoing SGAR baiting programs used in other sectors. Until newer, safer control options are available to replace SGARs, wildlife managers will likely need continued use of this tool in their efforts, and accept the risk of some local impacts to non-target species for the greater benefit of conserving critical habitats and species at risk (Elliott et al. 2016).

4.2 Rodenticide sales data

Licenced pesticide users and pesticide vendors in B.C. are required to keep records and submit annual reports to the ministry. For licenced pesticide users, these reports summarize the type and quantity of active ingredients used, the number of times the active ingredient was reported used, and the area treated (for certain uses). Use data is not collected for pesticide uses where an authorization is not required; for example, rodenticide use data would not be collected by residents treating their own private properties or for agricultural operators that are not required to hold an authorization under the IPM Regulation. Therefore, sales data is often a better proxy for estimating trends in pesticide use, as it includes total pesticide quantities sold into (and subsequently used by) all use sectors.

For licenced pesticide vendors, sales of commercial and restricted class pesticides are reported annually as the total quantity of formulated product and active ingredient sold. Sales of domestic class pesticides or Excluded (Schedule 2) pesticides are not reported. From time to time, the ministry will complete pesticide survey reports summarizing the use and/or sales data for a given year. These reports were completed for pesticide sales in 2010 and 2015 (British Columbia Ministry of Environment and Climate Change Strategy 2013, 2019), and a report is currently in preparation for 2020 data. Rodenticide sales for these years are summarized in Table 4.1.

The summarized values are quantity in kilograms of active ingredient. The percent active ingredient in the final formulated product will vary depending on a number of factors, such as the mode of action, and anticoagulant rodenticides have relatively low percent active ingredients. For example, a typical active ingredient concentration for end-use anticoagulant rodenticides may be around 0.005%, while for non-anticoagulants like zinc phosphide it may be 2%. This should be considered when comparing active ingredient quantities of commercial rodenticides with different modes of action.

Assessment of SGAR sales trends from the three years indicate that sales of bromadiolone have increased significantly, while sales of difethialone slightly increased and brodifacoum sales slightly decreased. For the FGARs, chlorophacinone and diphacinone sales both increased in 2020 compared to previous years. For non-anticoagulant rodenticides (non-AR), sales of zinc phosphide decreased, while sales of bromethalin remained steady.

Table 4.1. Summary of non-excluded commercial rodenticide sales in 2010, 2015, and 2020 in B.C.

a.i.	**Type**	**Quantity Active Ingredient Sold (kg)**		
		2010	**2015**	**2020**
Zinc phosphide	Non-AR	116.07	87.60	81.60
Bromadiolone	SGAR	1.25	2.01	5.40
Chlorophacinone	FGAR	0.21	0.69	0.90
Sodium salt of Diphacinone	FGAR	N/A	N/A	0.06
Diphacinone	FGAR	0.16	0.13	0.29
Difethialone	SGAR	0.17	0.26	0.30
Brodifacoum	SGAR	0.57	0.50	0.40
Bromethalin	Non-AR	0.03	0.03	0.03

4.3 Action research results: Use patterns

Section 4.1 introduced the general methods anticoagulant rodenticides may be used in different sectors. As part of an action research engagement method, this section describes what was heard in surveys or interviews with operational experts regarding typical rodent management practices in B.C. today. Operational experts consisted of professional pest control operators, agricultural operators and specialists, Indigenous peoples involved in rodent management, and pest management consultants or managers involved in largescale projects (e.g. conservation initiatives or multi-resident housing programs). Of important note: operational experts surveyed or interviewed were asked to describe their typical rodent management practices *before* the July 2021 Minister's Order restricted many uses of SGARs in B.C. Respondents represented operational experts managing rodent pests in residential, commercial, industrial, agricultural and conservation settings.

By far, the rodent pest most commonly dealt with is the house mouse, which was listed by 90% of operational experts in a survey. Norway rats and roof rats are also very common rodent pests. Other "field rodent" species such as voles, ground squirrels, pocket gophers, deer mice, and woodrats (packrats) were also listed to a lesser degree. Structural pest control operators usually service both commercial and residential customers, and some also provide service to agricultural operators (but the proportion of each varies by region). Pest control companies are usually called to manage rats and mice, with very infrequent calls for other rodent pests like voles. Nearly all operational experts reported seeing an increase in rodent population numbers in recent years and decreased seasonality of rodent issues, meaning year-round rodent pressures are now common. This was frequently associated with construction activities and urban development (and associated rodent habitat loss), wildfires (as smoke and habitat loss forces rodent populations to seek new harbourage and food sources), as well as changes in municipal programs such as the introduction of new waste management streams (green waste and compost pickups) or residential chicken coops. One Indigenous survey respondent described not historically having rodent problems, and that this is largely a product of colonization. In many regions the year-round temperate climate may contribute to unrelenting pest pressure, with continuing opportunities for rodent access through open doors and windows.

Exclusion and trapping were reported as common methods to prevent rodent pests, with exclusion cited as the most important portion of an integrated rodent management approach with the ultimate goal to exclude the pest from a given property. Eliminating entry points, ensuring doors and windows are shut or screened and adding doors sweeps are specific actions taken. Sanitation (removing attractants) and habitat modification (e.g. cutting back foliage and maintaining a barrier space) are also practiced. Education and providing specific recommendations on preventative measures were mentioned by service providers in order to reduce the need for rodenticides or traps with their customers. If structural deficiencies are not addressed, implementing a successful rodent management program is challenging, and service providers reported difficulties if customers do not complete the preventative actions that were advised. Rodenticides themselves as a preventative measure were also cited by about a third of survey respondents. From a conservation perspective, the focus is on biosecurity efforts to prevent rodents from getting to new areas in the first place – for example, checking and keeping clean supplies and equipment when visiting islands, and having traps or bait stations on boats.

To monitor pests, traps, visual inspections, and rodenticides were the top three methods cited in the survey of operational experts. Visual inspections typically look for chew or gnaw marks, rub marks, new holes or damage, or droppings. One of the benefits of using baits for monitoring is the ability to get a better idea of population density by measuring the bait consumed – in contrast, a trap may catch one rodent without getting an idea of how many others are there. Bait feeding marks can also be used as an identification technique, with mice typically “nibbling” bait and leaving packaging behind while rats often taking an entire bait block and label with them. While inactive (pesticide-free) monitoring baits are available, they are not as common as using rodenticide itself, possibly due to the fear of “feeding” the problem rodents with non-toxic bait. Video surveillance, tracking powders or boards, and customer reports or logs are other rodent monitoring methods.

Pest control operators indicated that for rodent pests, there is zero tolerance – that is, even one rodent pest is enough to initiate a management plan. In some cases, preventative rodent management plans must be in place to meet industry audit requirements, such as food processing facilities. Many operations use a permanent exterior baiting program to meet these requirements. Even a rodent sighted outside of the building may present concerns to these commercial facilities with strict requirements. Some residential clients also grow concerned if seeing a single rodent outside their home and that may be enough to initiate a call for service (out of fear of structural infestation).

After a rodent issue has been identified, the most common treatment approaches are exclusion and sanitation (which also serve as preventative measures for future problems), and trapping, with mechanical snap traps used by 90% of survey respondents. When rodenticides are used, by far the most frequently used type are SGARs (72%) compared with FGARs (21%) or non-anticoagulant rodenticides (17%). A small number of survey respondents use rodenticides but were unsure of the active ingredient. In general, people doing rodent management in Indigenous communities reported using rodenticides less often than other survey respondents. One respondent noted encouraging predation on farms as a control method. On organic farms where SGARs are generally not permitted, other methods that may be used are traps, physical barriers, and repellants. Interestingly, strychnine and contraceptives were also noted as control methods but are currently not registered for use in B.C.

The majority of service providers reported that clients occasionally have special requests for how their rodent problem is managed. While not frequent, of those requests, rodenticide-free, exclusion-based and/or humane control (e.g. live traps or no glue boards) were most commonly reported and some companies offer specialized programs to address wildlife concerns. In contrast, other customers specifically request that rodenticide *is* used to maximize efficacy and eliminate the problem as quickly as possible. Some Indigenous respondents reported challenges in obtaining the services of professional pest control operators, especially in rural or remote areas.

When rodenticides are used, they are primarily used in bait stations both indoors and outdoors. Pest control operators suggested that use without a bait station (for example, placed in inaccessible places) is uncommon. They explained that this is due to higher risks of accidental non-target exposure in urban environments, primarily to children or pets, but also the potential for “free bait” to attract secondary non-target pests (e.g. grain beetles, meal moths, or ants). Agricultural operations may also place baits underground directly in rodent burrows. Conservation programs use a variety of application methods including bait stations, hand broadcast, and aerial broadcast.

While survey respondents reported approximate equal usage of indoor and outdoor rodenticide bait stations, many said that they avoid the use of rodenticides indoors, especially for rats (primarily to avoid decomposition odour due to their larger body masses). Indoor mice were described as a control challenge due to being more difficult to trap, and once nested unlikely to travel far from it. Many pest control operators stated that once established indoors, mice will not move outdoors again. With some use settings precluding the indoor use of rodenticides at all (e.g. commercial kitchens or food processing facilities), indoor rodents can be extremely challenging to control and the focus is on exclusion and preventative exterior baiting programs.

The longevity of baiting programs varies and is very site-dependent. Short-term (days or weeks), long-term (months), and permanent ongoing treatment systems were all described. It is common for programs to be site-specific or activity-based and there is a distinction between residential and commercial sites. Typically baiting programs will remain in place until there is a clear decrease or cessation of feeding activity based on bait consumption; however, some permanent baiting programs are in place (for example, to meet industry requirements in food processing or healthcare). Seasonal applications are common in agricultural settings to coincide with growing seasons and/or known rodent population or activity cycles.

After treatment with rodenticides, many people said that they try to find and dispose of dead rodents. However, in practice, most rodents return to their nests or burrows to die and are rarely recovered out in the open. If found, the vast majority said that they seal the dead rodent in a plastic bag or container and dispose in the garbage or landfill. Two respondents said that they bury dead rodents. When asked about disposal of leftover or unwanted rodenticides, responses were mixed. Many respondents make an effort to reuse bait, and others dispose of bait in the garbage, via Clean Farms pesticide collections or take to a specialized disposal facility. Returning to the supplier or incinerating waste were also mentioned. Several respondents specifically referred to following product label directions for disposal instructions.

Of all operational experts surveyed, the majority said they were very concerned (62%) or somewhat concerned (24%) about the impacts of rodenticides on wildlife. However, SGARs were specifically recognized as critical rodent control tools and the most efficacious and cost-effective option in many cases, particularly for managing extreme population outbreaks, indoor mouse control, protecting the food supply chain and critical infrastructure, conservation, and for certain equity groups that face unique rodent management challenges (e.g. supportive housing). A general theme heard from operational experts is a fear that rodent populations will get out of control without SGARs as a tool in the integrated pest management tool box. Still, others felt there were multiple alternative rodenticides and other tools available in the marketplace and that there is overreliance on SGARs.

Many operational experts suggested that these products be restricted for sale and use only by licenced or trained people and that more education should be provided to residents and agricultural operators. Some respondents support the temporary ban on SGARs and believe it should be maintained, and highlighted the need to de-couple rodent management and routine rodenticide use. Others advocated for reserving SGARs as a tool for critical uses only, such as for conservation purposes or extreme infestations, with heavy oversight and time-limited use to decrease the rate at which these substances enter the environment. Other suggestions to improve rodent management practices in B.C. include ramping up compliance enforcement, encouraging natural predators, bringing new innovative traps and treatment options to B.C., conducting more research and monitoring of the environmental impacts from SGARs, and providing additional funding for rodenticide alternatives in agriculture.

Chapter 5: Reports and observations of wildlife impacts in B.C.

5.1 Research studies

Anticoagulant rodenticide residues have been found in B.C. wildlife, which indicates exposure is occurring locally (as well as in regions across Canada and globally) (Thomas et al. 2011; Nakayama et al. 2019). Several published studies have examined wildlife exposure to rodenticides in B.C., with most of the research conducted in the coastal and southwestern regions of the province. These regions consist of both densely populated urban areas and areas of intensive agricultural production, in some cases with close interfaces between. Some of the findings from these studies are outlined in Table 5.1 and summarized here.

For the research studies that have been conducted, anticoagulant rodenticide residues are consistently being detected in non-target wildlife in B.C. (Albert et al. 2010; Thomas et al. 2011; Elliott et al. 2014; Huang et al. 2016). In an analysis of 164 owls collected from 1988-2003 in B.C., Albert et. al (2010) found that 70% of owls had detectable liver residues of at least one anticoagulant rodenticide; of those, 41% had residues of more than one anticoagulant rodenticide detected. Of the barred owls collected, 92% had anticoagulant rodenticide residues detected. However, only six of the 164 owls (4%) were diagnosed with rodenticide toxicity as the cause of death. Thomas et al. (2011) found that of four raptor species examined across Canada, great horned owls were most consistently exposure to SGARs (65%) and often had multiple compounds detected. In other work, 100% of 29 great horned owls collected in southwest B.C. from 2005-2011 tested positive for one or more SGARs (J.E. Elliott unpublished data; cited in Hindmarch and Elliott 2014). For barn owls, both the incidence of exposure as well as the concentration of rodenticide residues detected appears to be increasing with time (Huang et al. 2016). Huang et al. (2016) compared barn owls from two time periods collected from the Lower Mainland, Fraser Valley, and Vancouver Island. They found total SGAR residues detected were significantly higher in owls collected from 2006-2013 compared to those collected from 1992-2003. The proportion of owls exposed to multiple SGARs was also higher in owls collected from the later time period.

Based on the typically fortuitous nature of the wildlife data collection, there can be challenges in elucidating exposure pathways and trends. However, there have been general findings of interest in the literature. Based on the known limited home ranges of some resident wildlife species in B.C. and the locations where wildlife carcasses are found, exposure is occurring locally in B.C. (pers. comm. S. Hindmarch), in both urban landscapes and agricultural areas. Residues have been detected across a wide range of taxa including mammals, birds, reptiles, and invertebrates. Residue data from the B.C. interior shows anticoagulant rodenticide exposure in fur bearers like badgers and fishers (pers. comm. S. Hindmarch and S. Lee). Much of the work to date has focused on raptors, which may be more susceptible to the effects of anticoagulant rodenticides than mammals (Nakayama et al. 2019).

Rats are likely one of the main exposure pathways for raptors in B.C. (Hindmarch and Elliott 2014; Elliott et al. 2014; Hindmarch and Elliott 2015); however, exposure is expected to be occurring through a number of pathways that have yet to be well established. Some non-target small mammals, birds, and invertebrates have also had rodenticide residues detected and therefore may provide additional exposure pathways to non-target predators and consumers (Elliott et al. 2014). Voles are a key prey source for many wildlife species (including owls, raptors, other bird species and mammalian predators), and can make up a significant portion of the diet, particularly in rural and agricultural areas (pers. comm. S. Hindmarch). Voles may be a target species for control with FGARs, but not typically with SGARs due to label restrictions. However, they may be unintentionally exposed to SGARs if they enter bait stations in or around structures, or if SGARs are illegally used in fields (as documented in Hindmarch et al. 2018). Elliott et al. (2014) found one vole contained high brodifacoum residues in their study. The role of voles as an exposure route needs to be further investigated. In two owl studies, house mice were much less likely to be preyed upon than voles or rats (Hindmarch and Elliott 2014; Hindmarch and Elliott 2015), which corresponds with the assumption that house mice tend to stay indoors. However, diet (and the potential for associated exposure with different prey types) may be at least partially influenced by the diversity of prey available in a given area (Thomas et al. 2011). For example, great horned owls living in urban areas have been found to have a greater proportion of rats in their diet compared to those living in rural or wildland areas (Hindmarch and Elliott 2014).

The proportion of mortalities documented from rodenticide toxicity are typically much lower than the proportion of sampled individuals with detectable anticoagulant rodenticide residues. Albert et al. (2010) found that there was no significant relationship between the presence or absence of anticoagulant rodenticide residues and the final diagnosed cause of death, nor was there a relationship between the body condition of the collected owls and the residues detected. Owl carcasses with high levels of anticoagulant rodenticides detected did not necessarily have poor body condition recorded, and in some cases bodies appeared to be in excellent condition. In some cases, wildlife that were diagnosed as rodenticide toxicity had low residues detected in the liver while other animals had high residue concentrations but were diagnosed with other causes of death (Albert et al. 2010; pers. comm. S. Lee). Trauma (e.g. vehicle collision, window strike, electrocution) is the most common cause of death of raptors cited in many studies (Albert et al. 2010; Dwyer et al. 2018). However, the possible contributions of sublethal effects from rodenticide exposure, or intersection between ultimate causative factors to proximate cause of death are uncertain.

Data on wildlife exposure and mortalities are almost exclusively based on opportunistic necropsies of found carcasses, which presents some challenges. Most of the available data is subject to inherent sampling bias that must be considered in any analysis, and such exposure data cannot be used as an indicator of natural population level exposure without broader population surveillance systems in place. Different sampling methods for live organisms are possible, such as blood tests for coagulopathy as an indirect indicator of anticoagulant rodenticide exposure, but more work is needed to standardize methods and establish species-specific reference values (Hindmarch et al. 2019). Detecting residues in blood may be more time-limited than the liver (Huang et al. 2016); currently, methods for measuring rodenticide residues in blood of specific raptor species have not been developed for the federal laboratory analyzing animal tissues collected in B.C. (pers. comm. S. Lee).

The risk of anticoagulant rodenticide toxicity is one of many environmental stressors placed on wildlife today, including severe weather events associated with climate change and loss of habitat and nest sites to urban development and agricultural intensification. In the Fraser River Delta region for example, there has been a shift over the past 60 years in agricultural production from pasture and hay production to greenhouse vegetable production and berries, resulting in decreased grassland-type habitat suitable for raptors (as well as increased need for more intensive rodent control) (Hindmarch 2021). Other pesticide use, such as increased herbicide use associated with urban landscaping and agricultural operations, may also contribute to potential habitat loss through decreased vegetation (Albert et al. 2010).

Currently, federal research scientists with Environment and Climate Change Canada's Science and Technology Branch are analyzing a large dataset of wildlife tissue samples including over 700 raptors collected over several decades. The results will update knowledge on exposure patterns in B.C. including landscape or temporal trends (pers. comm. S. Hindmarch and J. Elliott). These data are in preparation for publication in the near future.

Table 5.1. Summary of published literature on anticoagulant rodenticide exposure and potential exposure pathways in B.C.

Reference	**Regions**	**Species**	**Findings**
Albert et al. 2010	B.C. (Vancouver Island, Upper Fraser Valley, Fraser Delta-Urban, Fraser Delta-Agricultural, North coast, Okanagan, Interior); Yukon	Barn owl (*Tyto alba*), Barred owl (*Strix varia*), Great horned owl (*Bubo virginianus*); (n=164 specimens collected from 1988-2003)	• Most common cause of death was trauma • 6 out of 164 owls died of rodenticide toxicity • 70% of specimens had at least one rodenticide detected; of those, 41% had more than one rodenticide detected • Brodifacoum and bromadiolone were most commonly detected • 92% of barred owls had rodenticide residues detected (n=23)
Thomas et al. 2011	Canada-wide (B.C.*, Prairies, Ontario, Quebec) *B.C. data from Albert et al. (2010)	Barn owl (*Tyto alba*), Barred owl (*Strix varia*), Great horned owl (*Bubo virginianus*), Red-tailed hawk (*Buteo jamaicensis*); (n=196)	• Across Canada, great horned owls were most consistently exposed to SGARs (65%) and often had multiple compounds detected • Red tailed hawks had increased detectable liver residues moving eastward, possibly due to differences in prey availability • A proposed probability model estimated that 11% of the sampled great horned owl population is at risk of being killed from SGARs
Hindmarch and Elliott 2014	B.C.: Fraser Delta, Upper Fraser Valley	Great horned owl (*Bubo virginianus*) – diet	• Voles (65.9%) and rats (13.1%) were the main prey items of great horned owls; house mice were a negligible part of the diet • The proportion of rats in the diet was correlated with the degree of urban development in the home range • Rats are likely a main exposure pathway for SGARs, and voles should also be considered
Elliott, J.E. (unpublished data); cited in Hindmarch and Elliott 2014	Southwest B.C.	Great horned owl (*Bubo virginianus*); (n=29)	• 100% of great horned owls collected from 2005-2011 tested positive for one or more SGARs

Elliott et al. 2014	B.C.: Fraser Valley	Rodents: Norway rat (*Rattus norvegicus*), Vole (*Microtus* spp.), Shrew (*Arion* spp.), Deer mouse (*Peramyscus* spp.); Birds: Sparrow (*Melospiza melodia*); Invertebrates: Slug (*Arion* spp.) Carabid beetle (*Carabidae* spp.), Snail (*Monadenia* spp.), Worm (*Eisenia* spp.), Wasp (*Paravespula* spp.), Carrion beetle (*Dermestes* spp.), Fly maggot (*Musca* spp.)	• Various wildlife were sampled at baited farms, and non-baited farms in proximity to areas with intensive poultry farming • Rodenticide residues were detected in target species (Norway rats) as well as some non-target species (small mammals, birds, and invertebrates) • Rats were identified as the greatest potential exposure pathway of SGARs to non-target predators; small non-target mammals, songbirds, and invertebrates are also possible exposure pathways to secondary consumers
Huang et al. 2016	B.C.: Lower Mainland, Fraser Valley, Vancouver Island	Barn owl (*Tyto alba*); (n=119)	• Long-term data collected from two time periods (1992-2003 and 2006-2013) were compared • Total SGAR residues detected were significantly higher in 2006-2013 (141 ng/g) compared to 1992-2003 (57 ng/g), primarily driven by an increase in difethialone residues detected • The proportion of owls exposed to multiple SGARs was higher in 2006-2013 compared to 1992-2003 • Both the incidence of exposure as well as the concentration of rodenticide residues detected appears to be increasing with time in barn owls • Adult females had lower residue concentrations than adult males • Juveniles were more likely to show signs of toxicosis than adults

Hindmarch et al. 2019	B.C.: Lower Mainland	Bald eagle (*Haliaeetus leucocephalus*), Cooper's hawk (*Accipiter cooperii*), Red-tailed hawk (*Buteo jamaicensis*), Barred owl (*Strix varia*), Great horned owl (*Bubo virginianus*), Barn owl (*Tyto furcata*); (n=62) Barn owl (pre-fledgling) (*Tyto furcata*); (n=19)	• Potential sublethal effects of rodenticide exposure tested from blood samples of live wild raptors admitted to a wildlife rehabilitation center, and compared with pre-fledgling chicks from nest sites • 23% of sampled raptors demonstrated coagulopathy which may be associated with rodenticide exposure • Of the 11 raptors that died and were necropsied, trauma was the principal cause of death; 9/10 tested had detectable rodenticide residues • There was little evidence of coagulopathy in chicks

5.2 Incident and mortality reports

Health Canada Pesticide Incident Reporting Database

PMRA's Canadian Pesticide Incident Reporting database (Health Canada 2021b) provides public access to information on known or suspected adverse effects due to registered pest control products, as introduced in Chapter 2. Incidents are classified into major categories, such as effects on humans, effects on domestic animals, or effects on the environment, and are further classified by severity. Health Canada uses the incident reports to help identify potential risks from the use of registered pesticides by monitoring for trends or serious incidents. However, reports may be submitted based on suspicion or opinion of the reporter and therefore do not necessarily indicate that a causal relationship exists between the adverse effect and a registered pest control product. PMRA also receives a wide range of information from other sources and through many other processes outside of the incident reporting database. PMRA considers all of this information when conducting scientific evaluations.

An October 2021 query of public incident reports with the search variables "environment" effect and active ingredient of "brodifacoum, bromadiolone, or difethialone" is summarized in Table 5.2. A total of eight incident reports were found involving one or more SGARs and possible impacts to birds, mammals, and fish. Report details varied from necropsy and lab confirmation of SGAR residues, speculation based on carcass proximity to suspected SGAR use, suspected impacts from intentional non-compliant use against wildlife, and, in the case of the fish, potential impacts from runoff from a chemical factory fire with many different pesticides involved.

Table 5.2. Health Canada Pesticide Incident Reports for SGARs and Environment Effects (2007 to October 2021).

Active ingredient	Number of reports	Application number	Animal affected	Region
Bromadiolone	3	2011-3690	Hawk, Songbird	New Mexico (USA)
		2017-7199	Hawk	California (USA)

		2020-1104	Great horned owl	B.C.
Difethialone	2	2007-5823	Fish	Ontario
		2015-2807	Squirrel, Songbird	Ontario
Brodifacoum / Bromadiolone	1	2020-0280	Barred owl	B.C.
Brodifacoum / Bromadiolone / Difethialone	2	2013-1882	Coyote	B.C.
		2020-1486	Great horned owl	B.C.

B.C. Interagency Wild Bird Mortality Line

Data from the B.C. Interagency Wild Bird Mortality Line is jointly managed by the federal Environment and Climate Change Canada – Canadian Wildlife Service and the provincial Ministry of Forests, Lands, Natural Resource Operations and Rural Development. A summary of reports received from January 2017 to July 2021 is provided in Table 5.3 (unpublished data, L. Wilson). This data includes only submissions received through the Bird Mortality Line for owls and raptors that were submitted to the provincial B.C. Ministry of Agriculture, Food and Fisheries Animal Health Lab for necropsy. These mortalities are typically reported to the call-line by the general public and may be collected by wildlife agencies for necropsy based on specific case details, as described in Chapter 2. As this is a living dataset continuously updated as specimens are processed, Table 5.3 provides a single point-in-time view.

The leading cause of death for submitted owls and raptors was physical trauma (48%), followed by physiological causes such as starvation (21%). This is consistent with other research findings of trauma as the primary cause of death for urban raptors across North America (Dwyer et al. 2018). Hindmarch et al. (2019) also identified trauma as the primary cause of death of raptors submitted to one wildlife rehabilitation center in the Lower Mainland (but also noted that major trauma could obscure physical signs of anticoagulant rodenticide toxicity during necropsy).

Acute anticoagulant rodenticide toxicity was diagnosed in 22 of the 190 submissions (12%). An additional three birds had anticoagulant rodenticide residues detected in laboratory testing but were diagnosed by avian veterinary pathologists to have succumbed to other causes of death (two to physical causes and one to starvation).

Table 5.3. Cause of death for owls and raptors submitted to the Ministry of Agriculture, Food and Fisheries Animal Health Lab for necropsy from 2017 to July 2021. Submissions received through the B.C. Interagency Wild Bird Mortality Reporting Line.

Year	**n**	**Cause of Death**						**% COD = Rodenticides, by year**
		Infectious	Physical	Physiologic	Toxic (Rodenticides)	Toxic (Other)	Undetermined	
2017	26	1	8	9	5	0	3	19%
2018	27	3	10	9	3	1	1	11%
2019	32	1	16	2	2	9	2	6%
2020	76	5	43	11	11	2	4	15%
2021 (Jan-July)	29	5	15	8	1	0	0	3%
Total	**190**	15 **8%**	92 **48%**	39 **21%**	22 **12%**	12 **6%**	10 **5%**	

Categories include: Infectious (trichomoniasis, aspergillosis, etc), Physical (collisions, electrocutions, etc), Physiologic (starvation, stress hemorrhage, etc), Toxic - rodenticides, Toxic - Other (barbiturates, lead, etc), Undetermined (pathologist unable to ascertain cause of death; often carcass unsuitable for necropsy (i.e. rotten)

Owls include: Barred 58, Great Horned 29, Barn 9, Northern Saw-whet 14, Long-eared 1, Unknown 4 = 115 total for ~4.5 yrs
Raptors include: Bald Eagle 33, Red-tailed Hawk 14, Cooper's Hawk 16, Sharp-shinned Hawk 6, single of Peregrine Falcon, American Kestrel, Eagle, Merlin, Northern Goshawk, Osprey, Turkey Vulture = 75 total for ~4.5 yrs

5.3 Action research results: Community observations and concerns

This section describes what was heard from selected representatives in B.C. on the subjects of rodent management, rodenticide use, and concerns regarding the risks to wildlife from rodenticides. Participants, including Indigenous Peoples, non-governmental organizations and community members involved in public awareness programs on the risks of rodenticides to wildlife, shared their perspectives through an online survey and focus groups. This was not intended to be an exhaustive public consultation and the majority of interview perspectives came from the coastal and Lower Mainland areas of the province. Survey responses were anonymous and therefore regions are unknown.

Community representatives shared that there is increasing awareness of the risks of rodenticides to wildlife by the general public, and that many people have concerns over the ubiquitous use of these products. They said that this is reflected in multiple petitions calling for a provincial ban on the use, as well as several local government initiatives to ban the use of rodenticides around city facilities. This was also evident in a survey of Indigenous peoples, where 100% of respondents indicated that they were "very concerned" about the potential impacts of rodenticides to wildlife. People working on public awareness campaigns were worried over dead raptors being found, and there has been a significant increase in media coverage suggesting these bird mortalities could potentially be linked to rodenticide toxicity. Community representatives also expressed concerns over the non-compliant use of anticoagulant rodenticides and the lack of IPM practices such as preventative measures.

It was suggested by respondents that for the general public, there may be some confusion over proper IPM practices for rodent management, and that this may be attributed in part to misinformation or misunderstanding from some pest control companies. They said that contracts for recurring baiting programs are common and do not necessarily take action to address the root causes of the problem to prevent future problems. For large-scale rodent management contracts, they expressed concerns that contracts are often awarded to the lowest bid without considering long-term efficacy or environmental impacts, and that this limits the ability to address exclusion and sanitation measures that may be more expensive in the short-term but are more effective and cost-effective in the long-term. It was suggested that awareness and education programs would benefit members of the public who are making decisions about rodent prevention and management. Some Indigenous survey respondents reported difficulties in managing high rodent populations as well as concerns with health and structural damage associated with rodent pests. They also suggested education to improve knowledge of effective rodent IPM for their communities would be helpful.

Some community members said that the public reporting system for pesticide non-compliance or wildlife concerns is convoluted, inconsistent, and not well known. Less than half of Indigenous survey respondents knew how to report such concerns to the province. It was suggested that the reporting processes be more streamlined, better advertised, and include follow up for the reporter to have closure on the outcomes. It was also suggested that strengthening the provincial legislation and enforcement would reduce the need for public reporting at all.

People working in public awareness campaigns have called for an outright ban of all rodenticides, with increased focus on IPM, proactive enforcement, and prioritization of new research on humane alternatives to rodenticides. Some suggested an IPM “checklist” for residential or commercial buildings to follow for adequate rodent-proofing and prevention would help. Some Indigenous survey respondents supported banning or restricting the use of SGARs. Most respondents recommended improving education by training and resourcing residents and commercial operators alike on rodent IPM and rodenticide alternatives.

Chapter 6: Rodent Integrated Pest Management

Under the B.C. *Integrated Pest Management Act* and Regulation, authorization holders are required to apply Integrated Pest Management (IPM) principles when making decisions about pesticide use. As introduced in Chapter 1, IPM is a decision-making process with defined steps for pest prevention, identification, monitoring, establishing action thresholds, consideration of treatment options, and evaluation. This framework helps base pest management decisions on real data and guides people in managing a pest problem, while continuously improving a program over time. IPM is also a means to reduce risks from pesticides to people and the environment, by limiting pesticide use to the right pesticide, for the right pest, at the right time, and only when necessary.

Measures for rodent prevention and management within the context of an IPM approach are described below. Although IPM may be applied to rodent management in any setting, this section is primarily focused on structural rodent management in urban environments.

6.1 Prevention measures

Preventative measures are critical steps to avoiding rodent pest issues and for resolving existing issues in the long-term. However, these steps are often overlooked or under-implemented due to the perceived cost or time investment involved. For urban rodent pests, Corrigan (2001) stated: “Rodent-proofing programs, when combined with effective and ongoing environmental sanitation programs, provide the most cost-effective and long-term infestation control.” With emphasis on rodent-proofing residential and commercial buildings through practical rodent exclusion and sanitation efforts inside and outside structures, the majority of rodent problems would likely be avoided or significantly reduced. Research has demonstrated that exclusion measures alone significantly reduce or eliminate rodent entry, even for smaller mice (Mallis 1990; Corrigan 2001).

Ground-floor structural exclusion efforts focus on doors and windows. Most rodents gain entry through doors that are either left open or lack sufficient rodent proofing underneath. For commercial buildings, large doors must be flush to the ground, which can be checked from the inside by looking for lines of light coming through beneath the doors (Corrigan 2001). For residential buildings, by using rodent skull sizes as a guide, it is recommended that spaces beneath doors should be closed down to 6 mm or less to exclude mice, and down to 12 mm to exclude rats (Mallis 1990; Corrigan 2001). As a rule of thumb: any crevices the width of a yellow pencil and any holes the size of a dime will allow mice in, while holes the size of a quarter will allow rats in (Corrigan 2001).

Cracks or holes should be patched in foundations and dry wall and the right materials are essential. Steel wool or copper mesh are often used as “plugging” materials for small holes or gaps. For larger holes, while this method may be used as a temporary measure until permanent repairs can be made, it will not be sufficient in the long-term (Corrigan 2001). Larger holes may be patched with hardware cloth, ideally woven and galvanized to prevent edges from being gnawed and to prevent rust (Frye 2021). Elastomeric sealants (not caulk) can be used to seal long gaps (e.g. between walls and floors). Escutcheon plates should be used to seal gaps anywhere pipes meet walls, and secured to the wall with screws or sealant (pers. comm. E. A. Ryan). At the building exterior, rodents may be deterred from climbing walls (especially brick or stone walls) by painting a 30 cm band of hard, glossy paint to heights reaching 1 m off the ground. Rats may burrow under the foundation of buildings without basements, and may be deterred by metal, concrete, brick, or stone barriers around and below the foundation at least 60 cm from the surface (Mallis 1990).

Rodents travel linearly, and all types of structural lines that connect with or enter buildings at any level must be inspected regularly and tightly sealed. This includes utility lines and vents, pipes, electrical lines, sewer lines and drains, cable lines, dryer vents and exhaust vents. Roof inspections are often overlooked due to inaccessibility or extra time required; however, roofs provide many potential access points such as attic eaves or gaping fascia boards. Any tree limbs touching the roof should be pruned back at least 2 meters to avoid bridges for climbing rats or other wildlife, such as squirrels or raccoons that can also cause conflict issues and be mistaken for rodent problems (Mallis 1990; Corrigan 2001; pers. comm. E. A. Ryan).

Sanitation efforts to reduce potential attractants or harbourage for rodents are key to reducing pest populations. At the exterior, thoughtful landscaping near structures is critical to avoid the heavy vegetation, climbing ivy, or ground cover conducive to rodent nesting and travel. Garbage, pet food or feces, food gardens, bird feeders and compost bins or piles are common attractants in residential areas, particularly for rats that are more active outdoors compared to house mice that prefer indoor environments. Outdoor compost bins should be kept in good repair, away from buildings, and ideally on a concrete pad instead of bare ground or surrounded by vegetation (pers. comm. E. A. Ryan). Building exteriors and alleyways should be kept clear of clutter, waste or other debris. For commercial facilities, dumpsters associated with food handling establishments are one of the most common attractants for urban rat populations, and therefore should be kept clean, covered, and in good repair (Mallis 1990; Corrigan 2001). Roof rats are less dependent on human food waste than Norway rats, and may therefore be sufficiently resourced with natural foods found in overgrown vegetation, food gardens and in tree canopies (Corrigan 2001). In residential areas, single home rodent problems can quickly become neighbourhood problems; for example, cleanup efforts at one home will cause rats to disperse to nearby yards seeking new food and harbourage. In urban buildings, eliminating indoor mouse colonies in one area of the building may simply cause mice to move to another area of the same building, or to a nearby connected building. New mice will quickly colonize areas left vacant by rodent treatments if measures are not put in place to prevent recurrence (Corrigan 2001; Meyer 2003). In these cases, co-ordinated efforts are required for area-wide rodent management planning to be successful, which will be described in greater detail in section 6.3.

Sanitation efforts in interior areas are similar in principle to those outdoors: eliminate food sources and potential harbourage areas. The house mouse is the primary pest rodent inside residences, and will typically be associated with cluttered areas (e.g. garages, attics, or basements). House mice usually enter residential homes from exterior areas in suburban or rural areas. However, for urban city buildings, mice may be coming from other areas of the same building, or moving from nearby buildings through utility lines or other connected structural components (Corrigan 2001). Serious indoor rat infestations are less common than mice and are more likely to be associated with obvious sanitation issues (Corrigan 2001). To clean up interiors, all items should be moved off the floor at least 15-45 cm, and away from the walls at least 30-45 cm, with any food or other attractants kept in hard-walled, rodent-resistant containers. This also allows for easier inspections and trap placement along walls (Mallis 1990).

Optimal efficacy is achieved when professional pest control operators work together with clients to achieve long-term success. Pest control operators are best positioned to conduct thorough inspections and identify structural deficiencies, likely areas of infestation, and recommend control strategies if necessary. Ideally, there is an opportunity to offer proactive inspections and ameliorate any structural issues to avoid rodents from becoming a pest problem at all. In turn, clients can be made aware of any structural or sanitation issues to be addressed and given advice on how to rectify these issues, to prevent rodent problems from occurring (or recurring). If these preventative measures are not adequately carried out, a trapping or baiting program is unlikely to result in long-term success (Corrigan 2001).

6.2 Treatment methods

Once a rodent pest or pests have been identified and established to have a likelihood of causing adverse impacts (based on a defined tolerance threshold), the next step in the IPM framework is to consider treatment options. A variety of treatment approaches should be considered, including pesticide alternatives; and a selection process should also consider the treatment methods that are least likely to impact human health, non-target animals, and the environment. Within an IPM framework, the goal is not a continuous treatment program; rather, with prevention and monitoring methods in place, treatment methods should be incorporated only when necessary.

Traps

Exclusion and sanitation measures, as described above, are used as preventative measures as well as control measures for existing infestations. Along with exclusion and sanitation efforts, trapping is one of the most common methods to address existing rodent problems. Traps are a cost-effective approach for the typical (minor to moderate) rodent issue for both commercial and residential settings, and a non-chemical approach may be necessary or preferable for certain situations (e.g. for commercial kitchens, schools or daycares; or to accommodate growing public interest in non-chemical approaches). Other advantages of traps over rodenticides are the quick and confirmed kill, recovery of the rodent, and a re-usable method. The disadvantages are that a trapping program may require more time and effort than a baiting program, traps may need to re-set after activation, some traps are considered inhumane, and traps must be checked frequently. Trapping programs can also be a more costly and labour-intensive approach when it comes to large infestations (Corrigan 2001).

There are three main types of mechanical traps: snap traps, multiple catch traps, and glue traps. The most important consideration for success is effective trap placement in areas of high rodent activity, and poorly placed traps may not catch any rodents at all, even in heavy infestations (Corrigan 2001). Eliminating alternative rodent resource availability through sanitation and exclusion efforts will further encourage rodents to explore and encounter traps (pers. comm. J. Abercrombie). Traps should be handled with gloves to avoid human scents, as this may repel rodents from traps. Many traps should be set early in the program to achieve quick population knockdown.

To bait traps, offer multiple bait choices to appeal to different dietary preferences. Typically, Norway rats are omnivores, roof rats are vegetarian, and house mice granivorous (Takács et al. 2018), and the best baits will be those that they are already familiar with and feeding on. Nesting materials (especially those that have already been used) can also be used as bait to attract reproductive females (Murphy 2021). For mice, “double sets” with traps placed close to each other will catch a mouse jumping over the first trap (Corrigan 2001). Traps with expanded triggers may be used to produce higher captures, which can be placed next to the wall where rodents travel with about 2-5 cm of space between the wall and the trap. Another technique is to use “program pauses and trap shuffles”: every 2 to 3 days in cases of severe infestations, removing traps for a few days and then shuffling placement may increase capture rates (Corrigan 2001).

When comparing trap techniques for mice and rats, Norway rats in particular are more neophobic and likely to become trap-shy in cases of a near-kill, so more involved trapping programs may be required (Corrigan 2001). Introducing baited, but unset traps for rats to become familiar may help; and previously used traps are more effective than clean, unused traps. Baited traps should be slightly offset from the regular rat travel lanes, because rats may be wary of interruptions to their memorized routes (Corrigan 2001). For roof rats, in general, achieving total trapping success can be even more difficult than with Norway rats. Traps may need to be set in aerial locations, such as attached to rafters or beams. Natural foods such as fruits, nuts, insects, slugs or snails may be more effective baits than processed human foods (Corrigan 2001). To avoid accidental non-target captures with any snap traps, traps can be placed in enclosed stations.

Multiple-catch traps are designed for the live capture of house mice, and may catch and hold more than one live mouse at the same time. Like other traps, they tend to become more effective after being used for a few days, once “scented” with rodent odours (Mallis 1990). While mice may be caught live, they typically die in the trap from hypothermia, “capture stress” (e.g. confinement and lack of food and water), or cannibalism (Corrigan 2001). Alternatively, live-caught mice may be destroyed by other means, such as drowning or disposing of traps while animals are still inside; therefore, there are concerns with the humaneness of these traps (Mason and Littin 2003). Multiple-catch traps may also be used in conjunction with glue boards to facilitate rodent removal from traps (Corrigan 2001).

Glue traps or glue boards may also be used alone, usually for house mice (and especially capture juveniles); but are generally not effective alone for severe infestations unless combined with another trapping technique. Glue traps are also considered to be inhumane if unmonitored as they are not designed to kill quickly, and animals may be trapped for many hours or days after capture with significant stress and eventual death from starvation, dehydration, exposure, or suffocation (Mallis 1990; Corrigan 2001; Mason and Littin 2003).

Other traps, including electrocution traps, live cage traps, and piston traps are available. There is some question to the humaneness of electrocution traps. Cage traps are more effective for mice and sometimes juvenile rats, but tend to be impractical against grown rats. Cage traps must be frequently checked and some consideration must be given to the method and place for disposal or release of caught rodents. Recent research has explored a newer self-resetting piston trap pressurized by carbon dioxide as a more humane alternative to other control methods, with less impact to non-target wildlife (Boase and Nassichuk 2019, Hindmarch 2021, Ryan 2021).

Other non-chemical treatments

Odour repellents may discourage rodents from occupying structures but are not a substitute for good prevention and exclusion measures. They must be re-applied to maintain effect, may simply move rodents from one area to another, and may be objectionable to residents (Mallis 1990). Ultrasonic devices and electromagnetic devices are available but are usually impractical and/or ineffective for the majority of infestations (Mallis 1990; Corrigan 2001).

Predators such as raccoons, skunks, feral dogs and cats, foxes, coyotes, snakes, and raptors prey on mice and rats and help keep rodent populations in check in the natural environment. Owls are among the most effective natural rodent predators (Mallis 1990), and steps can be taken to encourage their presence in rural or agricultural areas (Barn Owls BC 2015). However, in developed areas, these natural predators do not sufficiently control established urban rodent populations where rodents can escape and hide in readily available structural harbourages (Mallis 1990; Corrigan 2001). Furthermore, free-roaming cats will also kill birds, other small mammals, reptiles and amphibians (McDonald et al. 2015), potentially causing far more harm to the environment than any benefit obtained from minimal rodent control.

Rodenticides

Rodenticides have several advantages over other treatment methods: they are an economical approach for moderate to heavy infestations and they are usually well-accepted by rodents in many site scenarios (Corrigan 2001). However, most rodenticides also carry a significantly higher hazard potential to impact human health or the environment compared to non-pesticide options, and caution must be exercised when considering rodenticides as a treatment option. Planning the overall treatment approach should reflect the rodent species (and behaviour), location, severity of the infestation, likelihood and severity of impacts from the pests, as well as the potential for non-target impacts of rodenticides to people, pets, or wildlife.

Acute, non-anticoagulant rodenticides include strychnine, bromethalin and zinc phosphide. Strychnine is no longer registered for use in B.C. and has very limited uses in other areas of Canada. Bromethalin acts as a nerve poison, disrupting energy production at the cellular level (Corrigan 2001), and can be fast-acting with death occurring within 12 hours to 4 days after a lethal dose. The rapid knockdown can be effective against heavy rodent populations before switching to another control tactic (Murphy 2021). In case of accidental exposure, no antidote is available, which may present an increased risk to people, livestock, and pets (Van den Brink et al. 2018). Generally a large dose of bait would be required for lethal effect though, and toxic effects may be treated with charcoal, a diuretic and general supportive therapy (Corrigan 2001). Bromethalin is effective against warfarin-resistant rodents and there is less concern with secondary poisoning compared to anticoagulant rodenticides (Corrigan 2001).

Zinc phosphide is effective against mice, and more effective against roof rats than Norway rats. It is fast acting, with some rodents succumbing within 17 minutes, and typical mortality occurring within 12-24 hours as poisoned rodents eventually die from heart failure (Mallis 1990; Corrigan 2001). With the rapid intoxication effect, bait shyness may quickly develop if sublethal doses are ingested. Secondary poisoning is less likely than with anticoagulant rodenticides, as zinc phosphide rapidly breaks down in the rodent’s stomach after ingestion (Mallis 1990).

Anticoagulant rodenticides include first-generation (FGARs) and second-generation (SGARs) introduced in Chapter 2. Bait shyness does not occur with anticoagulant rodenticides due to the delayed mode of action, with lethal results in 3-18 days following ingestion, with most death occurring within 7 days. During that time, rodents may continue to feed on the bait even after ingesting a toxic dose

(Corrigan 2001). Of the FGARs, diphacinone and chlorophacinone are most commonly used commercially. Diphacinone is more toxic to rats than to mice, and is also significantly more toxic to dogs, so care must be taken when using around pets (Corrigan 2001). In case of accidental exposure to people or pets, an antidote (vitamin K) is readily available for anticoagulant rodenticides (Corrigan 2001). Of the SGARs, brodifacoum is the most toxic to rats and mice and requires the lowest dosages to kill with a single feed (Corrigan 2001).

Using SGARs indoors can be effective in controlling house mouse infestations and reduces non-target wildlife exposure. However, indoor-only baiting is unlikely to fully control rats because they do not typically nest indoors (Shore and Coeurdassier 2018), and presents a non-target exposure pathway as they move outdoors. As with mechanical trapping, bait station placement to ensure rodents encounter, enter and feed on the bait is key to a successful baiting program (Mallis 1990).

Resistance to FGARs has been well documented and emerging resistance to SGARs is a concern in some areas. Historical patterns in anticoagulant rodenticide resistance show occurrences in areas of poor sanitation, where rodents have been exposed for many generations. Resistance does not arise from exposure to sublethal doses of bait; rather, is selected for in resistant individuals existing normally in a population (usually in less than 5% of individuals), that survive rodenticide exposure and build in population over the next generations, with a larger proportion surviving subsequent treatments. Once a population reaches 20% resistance, effective control with anticoagulant rodenticides will no longer be possible (Mallis 1990). Therefore, permanent, ongoing use of anticoagulant rodenticides in the same area against the same rodent population may increase the risk of selecting for a local resistant population.

An optimal baiting strategy will use anticoagulant rodenticides judiciously, and when baiting, will alternate classes of rodenticides (e.g. non-anticoagulants with anticoagulants, and possibly FGARs with

SGARs). Indiscriminate and continual use of rodenticide baits should be avoided. When using FGARs, bait must be frequently checked and replenished as necessary in order to deliver a toxic dose through multiple feedings. When using SGARs, “pulsed” baiting is the recommended strategy: bait at limited intervals rather than continuously, then switch to alternate treatment strategies if necessary to control remaining rodents (Mallis 1990; Corrigan 2001).

6.3 Area-wide management approaches

Rodent-related issues are expected to increase with the development and densification of urban areas, as well as with climate change (Meyer 2003). Urban rodent management is more difficult than in less populated, rural areas, due to the difficulties in coordinating the efforts of more people as well as the increased harbourage opportunities available to rodents in urban environments (Meyer 2003). With the ubiquitous, mobile and adaptive nature of commensal rodents, there is a need for comprehensive, large-scale rodent management strategies for effective area-wide and long-term control of rodent pests. There is also a need to shift the measure of success away from complete rodent elimination from our environment. Within an IPM context, this may mean re-visiting the threshold for rodents and establishing more of a tolerance in certain settings where elimination is not possible. Municipal rodent control programs are most effective with the collaboration and cooperation of governments, community members, and pest management professionals (Colvin and Jackson 1999; Corrigan 2001).

Researchers recently completed an extensive literature review to understand large-scale municipal rodent management programs and frameworks, common in the United States but less so in Canada. They concluded that 1) very few, if any, of the programs had clear evidence of success; 2) the public and stakeholders were generally unsatisfied with current programs; and 3) rodenticide baiting programs are ineffective in the long-term (Lee et al. 2022). Meyer (2003) compared different types of large-scale rodent management strategies, and highlighted the advantages of proactive rodent control measures for overall infestation reductions in comparison to reactive programs. However, because the overall costs of heavy urban rodent infestations are not well known, the lack of a comprehensive cost-benefit analysis to support proactive programs has largely resulted in a move to more complaint-driven reactive programs. Colvin and Jackson (1999) also emphasized the importance of ongoing, proactive rodent management programs for long-term success.

Large-scale programs must focus on environmental changes, such as sanitation efforts, rather than depend on any one control tool for lasting success. Early research in Baltimore in the 1940s demonstrated that by implementing sanitation improvements and thus reducing the rodent population carrying capacity, lasting rat population reductions were achieved. Previous rodenticide baiting efforts alone had initially knocked down rat numbers, only to be followed by a quick rebound in the population (Jackson 1998). In the 1990 "Boston Model", a comprehensive IPM approach covering an 18 km^2 area in Boston, Massachusetts was implemented. The program was a partnership between various city departments, community members, and professional pest management companies. The combination of sanitation efforts, public outreach, control measures (trapping and poisoning), and bylaw enforcement was successful in achieving an 87% reduction in rat control referrals on private properties, and a >99% reduction in rat observations within the project area (Colin and Jackson 1999).

Despite this, there are few examples of successful, long-term, city-wide rodent management programs. Of these, cities achieved "success" of extirpating rats mainly by applying huge amounts of rodenticides across the landscape, which have known environmental impacts and potentially could contribute to resistant rodent populations (Lee et al. 2022). For the vast majority of municipal rodent management programs, results have traditionally been inadequate and/or unsustainable, or unable to be properly determined due to the lack of evaluation or benchmarks for success. The literature suggests that this is largely due to the failure of programs to consistently adhere to IPM principles. This may be attributed to relatively low public or political interest, inability to address rodent issues in a comprehensive manner due to differences in jurisdiction (i.e. public vs. private spaces), a lack of information on rodent IPM, and difficulties in changing residents’ behaviour (Lee et al. 2022).

As a result of their comprehensive analysis, Himsworth (2020) recommended a paradigm shift away from the goal of rodent elimination in urban landscapes. Instead, communities should aim to share the urban ecosystem with this wild animal while identifying, preventing, and mitigating the associated impacts. This ecologically-based strategy prioritizes environmental management and monitoring, rather than an ultimately ineffective and reactive approach of isolated control measures, such as piecemeal baiting programs (Colin and Jackson 1999).

Chapter 7: Findings

The aim of this review was to better understand current rodent management practices in B.C., including the use of SGARs, as well as the risks these products may present to non-target wildlife. Information was gathered through a literature review (with particular focus on B.C. data), and with a targeted engagement strategy with a broad range of sources. The information heard was used to verify learnings from the literature as well as to include other perspectives that may not have already been captured through other aspects of the review.

From this, general findings were synthesized to inform recommendations for future policy options on the sale and use of SGARs in B.C. under the *Integrated Pest Management Act*. The scope of this review was to analyze the impacts to wildlife from the use of rodenticides. Analyses of human health risks, business or economic impacts, or social impacts from rodent pests and/or SGAR use were out of scope for this report.

The general findings below flow from the properties and general use patterns of anticoagulant rodenticides, to potential pathways for environmental exposure, to the actual observed impacts on wildlife in B.C. today and where data gaps exist for this analysis.

Anticoagulant Rodenticides: Properties and Use Patterns

- Anticoagulant rodenticides are critical control tools to manage rodents in certain use scenarios, such as extreme rodent population outbreaks or for conservation purposes.
- Second-generation anticoagulant rodenticides (SGARs) are highly toxic, persistent, and bioaccumulative substances with established pathways for environmental exposure and significant potential to impact non-target wildlife.
- Anticoagulant rodenticide baiting programs are abundant in urban environments, frequently deployed and re-filled on a regular basis at numerous locations, and most often use SGARs.
- Permanent, preventative SGAR-baiting programs are also common in agricultural operations, especially in food storage, processing, or transport facilities. These facilities are often mandated by audit programs to implement rodent-control programs to meet health and safety standards, with zero tolerance for contamination.

- SGARs continue to be registered by regulatory authorities worldwide and remain the dominant rodent control method. This is often attributed to 1) the high demand for control products to protect human health, structural integrity, the food supply chain, and biodiversity; and 2) the lack of effective (and cost-effective) alternatives.

- Rodent management programs that combine exclusion efforts with ongoing environmental sanitation programs provide the most cost-effective and long-term infestation control, and some pest management professionals have shifted to this model.

- In some current use scenarios, the principles of Integrated Pest Management (IPM) are not being applied adequately. Relying on rodenticide baiting without addressing exclusion and sanitation deficiencies will not result in long-term rodent control.

- To be successful, large-scale rodent management programs require ongoing, proactive measures including environmental management (e.g. addressing sanitation deficiencies), with collaboration among municipal agencies, community members, and pest management professionals.
    - Relying on a single control method (e.g. rodenticide baiting) or a complaint-based reactive model will not provide effective or long-term rodent management.

Pathways for Environmental Exposure

- Both intended and non-compliant uses of anticoagulant rodenticides can potentially provide exposure pathways to the environment.

- Non-target wildlife exposure is occurring via secondary poisoning, as well as primary poisoning and possibly tertiary poisoning. Exposure is likely occurring through a combination of pathways, and more information is needed to understand the extent to which these occur for a given species and how anticoagulant rodenticide residues may spread through the food chain.

- Frequent and ongoing baiting programs in both urban and agricultural areas provide the potential for a constant stream of anticoagulant rodenticides into the environment through both target and non-target animal exposure.
    - Providing a continuous source of anticoagulant rodenticides to a rodent population in the same area also increases the likelihood of resistance development.

- Sensitivity to anticoagulant rodenticides appears to be interspecific and intraspecific. There is no consistent concentration of detected residues known to result in a lethal dose in non-target wildlife, and estimates range over orders of magnitude.

- The proportion of mortalities attributed to anticoagulant rodenticide toxicity, as determined by necropsy of submitted wildlife specimens, are much lower than detected exposure rates. A relatively low number of tested carcasses are determined to have died from rodenticide toxicity, even if rodenticide residues are detected in the animal.

- Many researchers suggest that sublethal effects from anticoagulant rodenticide exposure can contribute to other causes of mortality, and this requires further investigation.

- Effects to non-target wildlife from cumulative exposures to rodenticides or from ingesting combinations of different types of SGARs could have outcomes beyond simple additive effects.

Observed Impacts

- People in B.C. are concerned about the potential impacts of rodenticides to wildlife. This was heard almost universally through engagement with pest management professionals, agricultural operators, technical experts, research scientists, Indigenous peoples, non-governmental organizations, and community members.
- There are significant and increasing levels (both in frequency and concentration) of anticoagulant rodenticide residues being detected in non-target wildlife in B.C., across Canada, and around the world.
- Of the anticoagulant rodenticides, SGAR residues are most frequently detected, and often more than one type of SGAR is detected in a single individual.
- There is no background population monitoring of wildlife rodenticide exposure in B.C.; therefore, the magnitude of exposure in a natural population of any species is unknown.
- Data should be carefully considered within the context and limitations from which it is collected (i.e. opportunistic collection of dead or moribund animals, typically in regions with higher populations and higher rodenticide use). This results in a non-random population sampling and data bias.
- Current research does not show significant temporal or landscape trends in non-target exposure, which may be skewed by the sample collection methods.
- While individual non-target wildlife mortalities due to rodenticide toxicity have been documented in B.C., whether there are any population-level effects remains unclear. However, for vulnerable populations (for example, species at risk or isolated populations), individual effects must be carefully considered.
- B.C. data compiled by provincial and federal wildlife agencies over a five-year period showed the most frequent causes of death for submitted owls and raptors were physical trauma (e.g. collisions, electrocutions) or physiological (e.g. starvation, stress hemorrhage).
- Due to the sampling bias and potential for sublethal effects contributing to the ultimate cause of death, more research is needed to quantify the actual proportion of rodenticide-exposed non-target wildlife that die from rodenticide toxicity.
- The next federal re-evaluation of SGARs is scheduled to begin in 2022. The most current data on risks to wildlife from SGARs will be included in Health Canada’s extensive risk assessment processes and any new mitigation measures will be proposed for public consultation.
    - A large dataset of non-target wildlife exposure from western Canada is expected to be published by Environment and Climate Change Canada in the near future.

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