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Procedures for Assessing Secondary Poisoning Hazards of Rodenticides to Owls

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ABSTRACT: Monitoring of owl populations can be used to assess secondary poisoning hazards to nontarget wildlife from rodenticide use. An indicator species is chosen based on its likelihood to intercept treated areas and target species as well as its sensitivity to the toxic compound. Hazard evaluation includes monitoring of rodenticide-use patterns, radiotelemetry to document nontarget survival or mortality posttreatment, and necropsy and residue analysis. Data on the natural history of the nontarget species (for example, habitat use, foraging behavior) are necessary to interpret the degree of hazard to individuals. When a hazard to individuals is found, data on population dynamics are critical for interpreting the hazard to nontarget populations.

KEY WORDS: secondary hazards, owls, radiotelemetry, rodenticide, poisoning

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) as amended requires the U.S. Environmental Protection Agency (EPA) to evaluate the hazards to nontarget wildlife as part of the process for rodenticide registration. Hazards can be separated into primary and secondary poisoning. Primary poisoning results when nontarget wildlife directly consume the rodenticide bait, while secondary poisoning results when nontarget wildlife (a predator or scavenger species) consume either target or nontarget species that have consumed the rodenticide bait.

Laboratory studies can be used to demonstrate the toxicity of compounds to various nontarget species [*1,2*], and such studies are valuable to understanding poisoning hazards [*3*]. However, field evaluations are necessary to determine the actual likelihood for a particular nontarget species to be affected by a particular toxic compound. Few field studies have been conducted to evaluate nontarget hazards from rodenticide use [*4–8*]; some studies have focused on secondary hazards to raptors, particularly owls [*9–11*].

In this paper, we will describe how to plan, conduct, and evaluate the results of field research to determine the potential for secondary poisoning of owls from rodenticide use.

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Choice of Species and Study Area

Choice of an indicator species is the critical first step of a field study of rodenticide secondary hazards. Generally, focus should be given to only one or two owl species. Attempting to evaluate hazards to several owl species simultaneously in the field is difficult and often inappropriate; it would require more personnel, greater diversity of capture techniques, and probably would reduce the opportunity for obtaining extensive data on any one species. Also, it should be possible, *a priori*, to distinguish between those owl species that might be at risk and those that likely will not be by: (1) determining the rodenticide use patterns (that is, crop, noncrop); (2) determining the geographical regions where the rodenticide would be used; and (3) reviewing natural history and ecological literature for information on owl species distribution as well as habitat use and prey.

Subsequently, it is important to consider: (1) the abundance of various owl species in and near the specific habitat types where the rodenticide would be used, so that an adequate number of individuals could be monitored; (2) the sensitivity of various owl species to the rodenticide based on laboratory toxicological data; (3) sedentary (nonmigratory) behavior during the treatment period, so that the exposed owl population can be defined and the outcome (survival, mortality) can be determined; and (4) species' life-history strategy [*12,13*], because loss of an individual belonging to a K-selected species (for example, long-lived, long maturation time, small brood size) would have greater population impact than loss of an individual belonging to an *r*-selected species (for example, short-lived, short maturation time, large brood size).

Study areas chosen for a hazard evaluation must meet three general requirements: (1) presence of a pest rodent population that justifies rodenticide treatment; (2) an owl population of adequate size; and (3) landowners that will agree to the treatment and monitoring activities. Size of a study area largely is dependent upon owl mobility and population density, as well as the distance between treated areas. Ideally, a study area should contain a resident owl population large enough to assure a reasonable sample size, yet be compact enough to simplify logistics. Monitoring a large number of individuals may be important because of variation in behavior among individuals (that is, home range size, habitat use, prey species) and thus also variation in poisoning hazard. We recommend sample sizes of 20 to 40 individuals. However, a sample this large may not be possible because of the difficulty of owl capture or the low density of owl populations resulting from habitat quality or territorial behavior. When the hazard is potentially high, large sample sizes will facilitate assessing the likelihood for population effects.

Capture Techniques

The difficulty of capturing owls can greatly limit the objective of evaluating secondary hazards. Some capture techniques for raptors can be used for several owl species, but techniques should be designed and implemented to maximize the opportunity to capture large numbers of the particular species being studied within a limited time period (usually less than one month) prior to rodenticide treatment.

Mist nets (10.2 cm mesh), placed in a variety of formations, can be used in owl flight paths near nest sites and in foraging areas. Owls can be lured to nets by using bait animals, such as rock doves *(Columbia livia)*, European starlings *(Sturnus vulgaris)*, Norway rats *(Rattus norvegicus)*, or house mice *(Mus musculus)*, tethered or placed in cages next to mist nets. Tape-recorded owl vocalizations can be used to lure territorial owls to a mist-net set. Tape-recorded distress calls of mice, rabbits, or birds also can be used to lure owls to a mist net.

Bait animals also can be used with Swedish goshawk and bal-chatri traps [*14,15*]. A dho-gaza trap can be used with a tethered great horned owl *(Bubo virginianus)* [*16*], and verbail traps [*17*] can be placed on perching locations such as fence posts. Noose carpets made from hardware cloth and with nooses made from monofilament fishing line [*18*] also can be placed at perching

locations or cavity entrances [*19*]. Hoop nets fitted with a bag of mist netting can be used at cavity (or building) exits [*9, 10*], and noose poles may assist in extracting an owl from a cavity.

Nest boxes provide specific locations to look for nesting or roosting owls, and thus they can be used to help locate and capture owls that use cavities. Nest boxes also can greatly facilitate monitoring of nesting success. Additionally, they help to assure and define the relationship between owl presence and rodenticide treatment, so that the potential for secondary poisoning can be tested. Installation of appropriately designed nest boxes often should precede the hazard evaluation, possibly by as much as one year. Use of nest boxes by owls, however, does not mean automatically that owls previously were not present or that their local numbers have been increased; boxes simply can provide a place for biologists to find them.

Radiotelemetry

Radiotelemetry is used to evaluate use of treated areas by nontarget species and, most importantly, to determine their survival or mortality posttreatment. When mortality occurs, radiotelemetry makes it possible to find and quickly retrieve carcasses for necropsy and residue analysis.

Owl body weight dictates the size of the radio transmitter chosen. The banding office of the U.S. Fish and Wildlife Service recommends a transmitter that is no more than 3% of a bird's body weight. Weight of the transmitter package is affected most by battery size, which in turn, depends upon the length of time the study will last and transmission power necessary to locate an owl within its home range. Battery life of two months should be a minimum. Radio transmitters generally have a single pulse rate, but transmitters with a mortality circuit (a different pulse rate if the transmitter remains motionless for about 45 min) can be used to help determine quickly if mortality has occurred [*10*].

Hand-held yagi antennas can be employed to obtain visual contact with owls in day roosts and also to find mortalities. However, for most owl species, vehicles equipped with roof-mounted antenna systems [*20*] (either single or double yagis) are essential to track efficiently many individuals over a large area, particularly at night. Multiple vehicles, with radio communication among them, allow bearings to be taken simultaneously and relayed to one vehicle where they can be plotted on aerial photographs and recorded as UTM coordinates (Universal Transverse Mercator system) [*21*].

The status of individual owls should be determined daily posttreatment; those with single pulse rate transmitters will have to be checked visually. Efforts should be made each night posttreatment to record several locations per owl. Radio-tracking at night can be done randomly (independent observations) for data indicating time spent in various habitats or continuously to determine the frequency that each habitat type is intercepted. All habitats within the home range of each owl should be cover-mapped and habitat type noted for each location recorded with radiotelemetry.

Rodenticide Treatment

Rodenticide treatment begins after an owl population is radio-equipped. Treatment must be conducted according to label instructions, particularly those pertaining to treatment rates (kg/ha). The specific rodenticide bait and use pattern may influence the duration of a hazard evaluation because some baits may not be consumed quickly by target species, may not degrade quickly, or may be applied at a rate that prolongs availability. The mode of action (for example, anticoagulant or acute toxicant) and half-life of the material (that is, persistence in tissue) also may necessitate a more prolonged posttreatment phase, possibly in excess of two months. Censusing of rodent populations pre- and posttreatment should be incorporated as part of the study

on it. This process will document that affected rodents were available to owls. Such censusing can be done with tracking tiles, trapping, bait consumption, or counts of active burrows [*22*].

Prey and Habitat Use

Beyond documenting owl survival or mortality, it is necessary to explain why the observed survival or mortality rate may have occurred. This involves assessment of owl diet and habitat use. Examining owl food habits is relatively simple for most species because of the availability of regurgitated pellets containing the remains (for example, bones, fur) of ingested prey [*23,24*]. However, when insects or birds comprise a portion of the diet, it is more difficult to quantify the frequency and biomass of prey in the diet.

Some data on owl food habits are available in the literature; however, pellet material should be collected if roost or nest sites are located. This material will be a source of information on owl diet in the study area, and the removal process makes subsequent collections of pellet material at that site time-specific. Pellet analysis will help to determine the occurrence of target species in the owl diet, and thus a possible food chain link to the toxicant. Because of seasonal changes in owl diet, pellets collected should be time-specific to relate owl food habits at the time of treatment to the outcome of the study.

A target species in an owl's diet posttreatment does not necessarily demonstrate consumption of prey captured in a treated area. For example, house mice found in common barn-owl *(Tyto alba)* diets in southwest New Jersey most often were taken from feral populations, not from farmsteads where rodenticides were used [*9*]. Marking of target rodents, such as with ear tags or a bone marker [*25*], in combination with owl pellet examination, has been used to document owl capture of a rodent from a treated area [*9*].

The relative abundance of various prey species in owl pellets can be compared to that found through extensive rodent censusing in the home ranges of owls. Prey species selected by owls, or prey size classes, can then be determined [*9*].

Owl habitat preferences should be evaluated statistically by comparing frequency of habitat use, as determined by radiotelemetry, to the availability of those habitats within a home range, such as with chi-square or a selection index [*26*]. Preference for or avoidance of treated habitats should be determined separately using each owl's day and night locations [*11*].

The percent of home range treated with rodenticide also should be calculated for each owl. The degree of exposure and risk of secondary poisoning for an individual owl may vary depending upon the amount of treated acreage within the home range, concentration of active ingredient in the bait, rodenticide application rates, density of target populations, amount of bait consumed by target animals, and availability of alternate prey and foraging habitat. If a treated area and a target species are intercepted frequently by the owl, then the poisoning hazard may be great.

Necropsy and Residue Analysis

When a dead owl is found, it should be placed in a plastic bag, labeled, and frozen as soon as possible. In addition to the specific nontarget species being studied, other nontarget species found dead during the hazard evaluation should be collected for necropsy and residue analysis. Not only is information on primary and secondary poisoning of other species important, but these species also may be consumed by raptors and thus may contribute to secondary poisoning. All mortalities subsequently can be assigned a random number and analyzed in the laboratory as unknowns.

Individuals knowledgeable in necropsy and residue chemistry should be consulted throughout the planning and completion of a secondary hazard study. Appropriate procedures for evaluating necropsy and residue chemistry results must be available prior to implementation of the

Prior to necropsy, knowledge of gross anatomical and physiological effects of rodenticide poisoning should be acquired from literature review or laboratory research. For example, hemorrhage in pleural and abdominal cavities, subcutaneous tissue, and visceral organs including heart, lungs, and intestine; massive blood loss; a pale-colored liver; and blood in the trachea can be found in animals dead from anticoagulant intoxication [*1,27*]. Necropsy must be conducted objectively and residue chemistry, radiotelemetry, and any other pertinent data fully evaluated before the most probable cause of death is stated. With some mortalities, for example, predation or car collision may be the proximate cause of death, while pesticide poisoning (causing a weakened condition) could be the ultimate cause.

Residue analysis should be conducted by a qualified laboratory using the most reliable technique available. In addition to mortalities found in the field, some birds found dead or collected away from treated areas should be included as controls in the sample of unknowns presented for residue chemistry. Additionally, owls treated with known dosages in laboratory studies also may be included. Analysis of these birds will provide a basis for assessing the quality of work done by the laboratory and the sensitivity of the residue chemistry procedure. They also will help in understanding the relationship between residue presence and mortality. With some rodenticides and analytical procedures, the lack of residue cannot be interpreted as evidence that secondary poisoning did not occur, particularly if the level of residue detection is too high. Residue analyses are performed on the most appropriate tissue for a particular rodenticide. For acute rodenticides, the stomach or intestinal contents usually are analyzed separately from the whole carcass [*8*], while with anticoagulants, the liver is analyzed separately from the whole carcass [*11,28*].

Control Area

In most cases, monitoring a large control population in addition to an experimental population is exceedingly difficult because of the time and effort required to capture and radio-track numerous owls. For a short-term study (for example, up to three months), a control population may not be needed, especially if diagnostic necropsy and residue chemistry criteria are available or when the outcome includes no or minimal observations of secondary poisoning. However, a control population may be needed if decisive and diagnostic necropsy criteria or residue chemistry are unavailable. Also, as the amount of mortality increases and approaches levels suggesting a population effect, it may be necessary to separate the number of deaths related to secondary poisoning from the number of deaths that would have occurred independent of rodenticide use, based on a control population. For example, during a study conducted in winter when natural mortality can be high, rodenticide-related mortality may not necessarily increase the net mortality seasonally observed in a population. A control population also may assist in distinguishing relationships between proximate and ultimate causes of death.

If a control population is not used, minimally or nonexposed individuals can be compared to individuals that frequently intercepted treated areas or to those with a larger portion of their home range treated [*11*]. If the rodenticide poses a hazard to a nontarget species, an increased rate of mortality would be expected with an increased rate of exposure.

This paper has dealt primarily with short-term studies of rodenticide hazard because, in most cases, rodenticides are used in a discrete rather than continuous manner. However, when mortality is observed and effects on population maintenance cannot be predicted, a long-term population study (up to five years or more) may be required. Such a study would require a control area with comparable owl density. It would focus on mark-recapture of owls on an annual or biannual basis to document differences in survival and recruitment rates between treated and control areas, as well as population censusing to determine if a reduction in the owl population near the treated area, in comparison to the control area, occurs through time.

Discussion

Ideally, several studies would precede initiation of field evaluations of secondary hazards. A stepwise approach includes: (1) a laboratory LD_{50} study with the target species; (2) determination of the lowest concentrations needed to provide acceptable mortality rates in target species; (3) determination of the lowest treatment rates needed to provide efficacious control of the target species in the field; (4) determination of the residue loadings of target species in the field, given the concentration and treatment rates chosen; and (5) determination of the susceptibility of nontarget species to the active ingredient by a laboratory LD_{50} study and also their susceptibility to the range of residue loadings observed in Step 4. If the information gathered in Steps 1-5 justifies a field study, better decisions can then be made on choice of indicator species, interpretation of necropsy and residue chemistry, and the length of time a study should last.

Any radiotelemetry study to evaluate hazards to wildlife from rodenticide use can be an expensive process, requiring specialized equipment and technical personnel. However, telemetry often is necessary to determine the actual fate of individuals posttreatment. Carcass counts and direct counts of wildlife pre- and posttreatment frequently are suggested for hazard evaluations, but these provide limited data. Infrequently is any wildlife carcass found in the wild, and predators/scavengers may quickly eliminate them [*11*]. Additionally, because of the delayed action of some rodenticides (for example, anticoagulants), mortality may occur after the nontarget animal has moved a considerable distance from the treated area. Direct counts only give numbers of individuals present, and when a species is capable of quickly filling a vacated territory, individual mortality may not be detected. Conversely, any reduction in the numbers of individuals posttreatment, such as from emigration, could be misinterpreted as a rodenticide effect. In particular, direct counts generally do not provide adequate information on rodenticide effects on predators (especially nocturnal predators) because of the difficulty in observing and detecting the presence of such individuals. However, monitoring of nest sites that can be located, before and after treatment, may provide some information on rodenticide effects [*8,10*].

Interpretation of field results includes integrating information on survivorship, necropsy, residue chemistry, habitat use, and prey. These components together, and when compared among owls, can substantiate whether or not secondary poisoning should be implicated in any observed mortalities, and thus to assess the risk to nontarget individuals and populations. Differences in habitat use or the percent of home range treated among owls can be powerful factors for explaining differential survival.

The most difficult issue following the completion of a secondary hazard study is defining the extent of acceptable impact by a particular toxic chemical on nontarget wildlife. Maintenance of nontarget populations, regardless of rodenticide use, may be used as the requirement for acceptable nontarget hazard. However, a population must be defined in both space and time. It could be defined as those individuals directly exposed to the toxicant (local population) or, in contrast, inclusive of individuals at increasing distances from the treated area (regional population). The percent of any population that experiences mortality can be highly biased, depending upon the number of owls sampled from the periphery of, versus close association with, treated areas. As the population is expanded to include a regional area, the proportion of individuals affected decreases, and any local population impact becomes deemphasized. Additionally, a population can be defined in a discrete time interval, such as one month posttreatment. However, when the population is defined over an extended time interval (for example, one year posttreatment), opportunities occur for recolonization, breeding, and thus local population recovery. We suggest focusing on local populations and, if a hazard occurs, population recovery (locally and regionally) within one breeding season posttreatment. Final interpretation and definition of population and hazard lies with regulatory agencies. The U.S. Environmental Protection Agency currently regulates based on the criteria: risk to endangered species and significant reduction in nontarget populations.

Because r-selected species have a high intrinsic rate of population increase (high productivity

short maturation time), loss of such an individual must be interpreted differently than loss of an individual belonging to a K-selected species (low productivity, long maturation time). Most raptors are relatively K-selected, and thus loss of such individuals would have a greater population effect than loss of, for example, most passerine birds. Additionally, agricultural needs and alternatives to the use of rodenticides with secondary hazards should be included in the decision to allow or reject use of a particular rodenticide.

A field study of secondary hazards can be separated into three distinct hierarchial levels: (1) hazard to individuals; (2) short-term population effects; and (3) long-term population effects. Results obtained on individual hazards determine whether or not the effects on populations need to be addressed. A telemetry secondary hazard study provides data on individual and short-term population effects (Levels 1 and 2).

On whatever level the secondary hazard evaluation is approached, and especially when hazard concerns are great, detailed data on species ecology may be essential in the final assessment and interpretation of hazard. Ecological information on many species of owls is limited, mainly because of their nocturnal habits; and researchers may find that a complex of ecological issues must be investigated simultaneously along with the hazard evaluation. By investigating owl ecology, factors affecting owl populations, independent of rodenticide use, can be recognized; data on rodenticide hazards then can be most credibly interpreted.

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