RODENTICIDE SELECTION AND BAIT COMPOSITION TO MINIMIZE POTENTIAL PRIMARY HAZARD TO NONTARGET SPECIES WHEN BAITING FIELD RODENTS

Rex E. Marsh, Wildlife and Fisheries Biology, University of California, Davis, California 95616

INTRODUCTION

A wide variety of methods is used to reduce potential hazards to nontarget species when baiting out-of-doors for rodents. The principles involved in making rodent baits highly selective hinge on the biology, particularly the feeding habits and food preferences of the target species. The differences or uniqueness of both the at-risk nontarget animals and the target animals should be assessed and then capitalized upon where possible in terms of susceptibility to toxicant, kind, size and shape of bait, etc. Generally only a few nontarget species are at risk in any particular situation, and the degree of this risk also varies. For example, strictly insectivorous birds are not at risk when rodent baits made of cereals are used. Predatory or carnivorous mammals and birds also are not at risk since they, too, are not likely to consume cereal baits. However, predatory and scavenger species, may be at some potential risk from secondary poisoning, depending on the toxicant used and other considerations. But techniques used to mitigate secondary hazards are a subject unto themselves and are not included in this paper.

The emphasis of this paper is placed on rodenticide selection and the composition and formulation of baits that contribute in safeguarding nontarget species. This, however, is only 1 important aspect concerning potential safeguards. Others include various methods of applying or offering baits, the rate and pattern in which baits are applied, the timing of baiting, how baits are destroyed or removed, and various diversion tactics which will mitigate potential hazards to nontarget species.

RODENTICIDE SELECTION

When considering safeguards, the choice of toxicant to use is of foremost importance because other factors such as concentration in bait, rate of application, and the method and timing of application are often dictated by the kind of rodenticide selected and species to be controlled. If there is a choice, the toxicant is selected on the basis of high susceptibility of the pest and low susceptibility of the nontarget species at risk. If the options available concerning rodenticide selection are limited because of efficacy and lack of registered materials, safeguards must be achieved by other means.

With a selection of rodenticides to choose from, it may be possible to provide safeguards to certain species of wildlife which otherwise would be at special risk in a baiting program. For example, in the Central Valley of California, both strychnine and 1080 are good choices for ground squirrel control where pheasants may be of concern. Although strychnine is toxic to birds, pheasants—like a number of gallinaceous birds—are comparatively much less susceptible than ground squirrels. Likewise, birds are much less susceptible to sodium fluoroacetate (1080) than are ground squirrels; hence these 2 baits are effective for ground squirrels, yet present little potential hazard to birds.

The lower the number of rodenticides available for the control of pest species, the more limited will be the options for special safeguards, a point which the U.S. Environmental Protection Agency (EPA) has ignored in its arbitrary decisions for cancelling registration or greatly restricting uses of strychnine for such species as prairie dogs, deer mice, meadow mice, chipmunks, marmots, cotton rats, and kangaroo rats, and proposed cancellations of 1080 for certain field rodents, with little or no data whatsoever that these uses were hazardous to any nontarget species (U.S. EPA Strychnine RPAR Position Document No. 4, 1983; U.S. EPA Sodium Monofluoroacetate RPAR Position Document No. 2/3, 1983).

The concentration of the rodenticide used on bait should be optimum for effective control of the target species, and the best concentration often depends upon the method of application and application rate. For example, 1 percent zinc phosphide bait is used for spot broadcast baiting of ground squirrels; however, 2 percent zinc phosphide bait, with an application rate of about 6 pounds per swath acre, should be used when broadcasting the baits mechanically.

Rodenticides that cause bait or toxicant aversion or serve as emetics to some species are discussed later.

BAIT SELECTION

Maximum efficacy in rodent control relies on the selection of baits that are highly preferred by the target rodent species. When several different grains are highly acceptable, other considerations can be made. For example, whole grains of oats, barley, and wheat may be nearly equally accepted by certain ground squirrel populations; however, since wheat is much more apt to be consumed by certain larger seed-eating birds than either barley or oats, it is not a good choice of bait. For this reason the California Department of Food and Agriculture does not recommend wheat for ground squirrel control. Wheat, oat groats, and milo are all quite well accepted by pocket gophers (*Thomomys* sp.); and although pocket gopher baits are placed below the ground, should any spillage occur above ground, milo would present the greatest potential for hazard to ground-feeding seed-eating birds because it is much more acceptable to birds than oats or wheat. For this reason milo is rarely the bait of choice prepared and distributed to the growers by the agricultural commissioners of California (Clark 1975).

Whole grains are often selected as baits for field rodents. In some instances the hulls are removed from oats and barley; in other instances the grain is rolled. Hulled grain is consumed at a faster rate by some rodents and thus considered desirable for use with certain rodenticides. The rolling or crimping of some kinds of whole unhulled grain has a similar effect on consumption. Steam rolling also increases the surface area of kernels of grain and makes it easier to uniformly adhere the rodenticide by slurry treatment methods. Rolled grain deteriorates more rapidly under moist or wet conditions, which can be an added advantage in eliminating residue bait following control.

Rolling or crimping creates flattened kernels that when dyed are thought to appear larger and less attractive to birds than nonrolled kernels of the same grain. However, to what degree rolling aids in repelling birds is unknown. Hulling and rolling both add to the cost of the bait, and their advantages in safeguarding nontarget birds are not all positive. If the rolling process creates a high percentage (over about 5 percent) of small particles of broken kernels that are not removed by screening, these small particles may be of a size acceptable to small seed-eating birds. For the same reason, cracked, broken, or coarse ground grains are avoided as field rodent bait for spot-baiting or broadcast-baiting where potential hazards to seed-eating birds may exist.

The pelletization of field rodent baits for broadcast purposes offers many opportunities to safeguard nontarget species since size, shape, and hardness can be controlled with precision. Pellets can also be designed to degrade rapidly by adding hygroscopic ingredients and withholding insecticides and fungicices. If composed of flour-size particles, decomposed pellets will disintegrate into minute particles and become an intrinsic part of the soil and duff substrate.

Paraffin rodent bait blocks (i.e., cereal baits embedded in melted paraffin and solidified into a block), although originally developed for use in high humidity or high-moisture situations, have proven very effective in increasing bait selectivity for gnawing rodents (Marsh and Plesse 1960). Paraffin bait blocks are used effectively for controlling both muskrats and Norway rats along agricultural irrigation and drainage water systems in California (Clark 1975). They offer good selectivity against birds of all sizes. Rarely are any of the local birds interested in such baits.

Mouse tubes were another innovative bait formulation development which not only was effective in the control of meadow voles, *Microtus* sp., but also protected the bait from most nonrodent species (Libby and Abrams 1966). The treated grain bait was adhered to the inner surface of a hollow cardboard tube (1.75 inches in diameter and 5 inches long) with an edible glue. In essence, the mouse bait tube was a bait-loaded miniature bait station which was formulated as a single unit designed for field use (Marsh et al. 1967). The mouse-tube approach never progressed much further than the experimental stage.

Rodent bait formulators should be given greater encouragement for the development of innovative techniques and procedures for safeguarding nontarget species. While research and years of experience in baiting field rodents have provided much information on how to safeguard nontarget species, more could be accomplished to further our objectives by developing improved formulations.

ARTIFICIALLY COLORED BAITS

The value of artificially colored (i.e., dyed) field rodent baits to assist in protecting seed-eating birds was advanced by Kalmbach (1943). The research of Kalmbach (1943) and Kalmbach and Welch (1946) was most convincing, as was a color movie entitled "Birds, Beasts and the Rainbow" produced and filmed by Kalmbach and used by the U.S. Fish and Wildlife Service during the late 1940s and early 1950s as an educational and training film.

Kalmbach and Welch experimented with green and yellow-colored grains containing the rodenticide strychnine and discovered that the dyed baits were rejected by birds to a much greater degree than undyed baits. Considerably fewer bird fatalities resulted from dyed baits. Current evidence suggests that the dye may not have been alone in producing the desired repelling response from birds, and that a taste-conditioned aversion to strychnine may also have been implicated with the color serving as a visual cue. This in no way diminishes the value of colored bait and, in fact, is an added value. It does, however, suggest that studies of the repellent effects of dyed baits should be conducted in the presence of the toxicant intended to be used. The testing of dyed placebo (nontoxic) baits may not present the full picture of their potential value (Wilcoxon et al. 1971, Czaplicki et al. 1976, Wilcoxon 1977, Martin et al. 1977).

The artificial coloring of field rodent baits has been a common practice in California and elsewhere ever since the late 1940s (Dana, personal communication; Hayne 1950). More recent studies of artificial coloring to repel birds were conducted by Caithness and Williams (1971) and Brunner and Coman (1983). Pank (1976) found that certain dyes and coloring agents were of value in protecting conifer seeds from bird consumption.

The effectiveness of dyed or colored bait relies on the fact that birds perceive color and use color in selecting or rejecting food items. The evidence suggests that birds will avoid foods dyed with certain colors, specifically bright greens and yellows, when placed in certain environments. Rodents, on the other hand, lack true color vision and perceive colors as shades of black and white, and, if the dye is tasteless and odorless, the colors do not influence bait consumption. Gray and black dyes and pigments have also been found to repel birds.

A variety of dyes and pigments have been used to color baits. Monastral green, alkali fast green, auramine O yellow, DuPont oil blue, nigrosene black, and lampblack are coloring agents commonly used for field rodent baits in California (Clark 1975). Coloring agents must be compatible with the other bait ingredients and should be tested for their acceptability to rodents prior to use.

Coloring agents in baits also help identify toxic baits from food or feed and thus prevent accidents caused by human error.

CONDITIONED AVERSION

The dying of baits is not foolproof. There are incidents where birds consume lethal quantities of dyed bait but significant losses are relatively rare, especially with currently used acute rodenticides, because other factors are also playing a role in protecting nontarget birds and mammals. The concentration of the rodenticide may be such that few birds will receive a lethal dose even if they consume some bait. Sublethal symptoms from the rodenticide often occur which cause nontarget animals to stop feeding. This aversion reaction to a bait can be more than a response of the moment and may lead to lasting aversive conditioning. Aversive conditioning is a phenomenon which is synonymous with bait or toxic-shyness in the target species. Bait aversion results from becoming ill as a result of feeding on a sublethal dose of a toxic bait. The aversion is often linked to the carrier, i.e., the food on which the toxicant is applied (Barnett 1975, Bhardwaj and Khan 1977). If this occurs, the animals so influenced will for a time reject that food, even if it contains no toxicant. In other situations, the aversion is associated with both the food item and the toxicant. A substantial amount of research has been conducted on the subject of aversion (Riley and Baril 1976), and evidence suggests that a number of different cues (i.e., vision, taste, texture and odor) may be implicated in food aversions (Mason and Reidinger 1982, Wilcoxon et al. 1971, Fuller and Hay 1983).

Learned aversion is thought to be one of several ways animals determine what foods are edible and can be consumed safely. Most vertebrates live in an environment filled with plants, fungi or other potential food items, many of which are highly toxic if consumed. Animals have evolved in their presence and thus have evolved mechanisms by which they are protected.

Many plants produce defensive chemicals (so-called secondary compounds), and these chemicals—some of which are highly toxic—and the mechanisms by which animals avoid serious physiological consequences vary greatly (Freeland and Janzen 1974). Strychnine, red squill, and sodium flouroacetate (1080), in fact, are defensive secondary compounds found in plants. It is hypothesized that the phenomenon of conditioned aversion or, more specifically, taste aversion exists because it helps the animal species survive in nature.

The feeding behaviors which tend to characterize generalist herbivores and are thought to be most important in the animals' ability to detect and reject lethal quantities of toxic bait are as follows: 1) New or novel foods are sampled or consumed with caution; 2) Animals are capable of quickly learning to reject toxic foods after ingesting minute quantities; and 3) They prefer to feed on foods with which they are familiar. Not only do these factors safeguard nontarget species, but they present many challenges in attempting to achieve control in the pest species and are 1 of the reasons why control efforts generally fall short of ideal objectives.

The length or duration of time that learned aversion to baits lasts varies. Howard et al. (1977) found that in deer mice, *Peromyscus maniculatus*, aversion to 1080-treated oats lasted for as long as 8 months or nearly their usual lifespan. It may relate to the initial exposure and how ill the animal becomes; it may also depend on the nature of the toxicant itself (Nachman and Hartley 1975). The aversion may be magnified or prolonged if the animals ingest even a very small amount in 1 or more subsequent trials.

There is some evidence that social transmission of conditioned aversions exists at least in some species (Galef 1977, Galef and Clark 1971). Lavin et al. (1980) provide evidence that a sick rat is an aversive unconditioned stimulus. Thus, in the presence of a sick rat, a healthy rat may be averted from novel foods or tastes without actually experiencing an ill feeling. If this social transmission extends to other species, it adds an important dimension to learned aversion theories.

Food (i.e., bait) associated aversions resulting from initial sublethal ingestions must be considered an important factor in safeguarding nontarget species. The ability of lethal rodenticides to cause aversion varies with the toxicant. Strychnine, sodium fluoroacetate, zinc phosphide, phosphorous, red squill, arsenic, endrin and ANTU are all known to produce significant aversions.

Taste aversion or aversive conditioning, as presented in this paper, is, for brevity, a simplification of a complex and not totally understood phenomenon in animal behavior.

EMETICS AND NEUTRALIZING CHEMICALS

The idea of the use of emetics in toxic bait formulation was advanced by F.E. Garlough of the U.S. Biological Survey (Spencer 1938). Tartar (antimony potassium tartrate) emetic was subsequently used in a number of bait formulations, particularly in commensal rodent baits, primarily for the protection of pets, domestic livestock and humans. Tartar emetic unfortunately reduced bait acceptance for the target species and fell into disuse in the last 2 decades. There was no way its use could be continued and pass the efficacy test formerly required by EPA. Although tartar emetic has a taste factor and reduces bait acceptance, rodents cannot vomit and hence emetics have little effect on them from the standpoint of eliminating poisonous bait from their stomachs.

Advancements have been made in emetics for humans and pets since tartar emetic was used, and these should be reviewed and scrutinized for their effective use in current rodent baits. We have greater options for their use now than in the past. For example, many rodent baits are now pelletized, which makes it possible to formulate and blend 2 or more kinds of pellets of different composition, yet of similar appearance. Hence pellets containing essentially only an emetic could be blended with the rodenticide pellets in an effective ratio. The rodents have the ability to select out the edible pellets, leaving emetic pellets. However, since dogs tend to gulp their food, they would ingest the emetic along with the bait, should they gain access to a bait station. The same approach might also be effective to safeguard children. The blending of pellets made up of some very bitter but nontoxic substances could effectively cause a child to spit out the bait.

There are several rodenticides which also act as emetics. Red squill is 1 such rodenticide, and that is 1 reason it is considered so safe. It triggers vomiting in cats, dogs and humans when ingested, and thus the stomach is emptied or partly emptied of the toxicant. Rodents are not alone in not being able to vomit; horses and cattle also fall into this category. Red squill is so emetic to humans that some individuals cannot work where bait is being formulated, for even the volatiles or a very minute amount of inhaled dust causes vomiting.

Zinc phosphide also triggers an emetic action in cats and dogs and thus provides some safeguards to pets and related wild carnivores. Although zinc phosphide is somewhat emetic, this should not be relied on as a totally effective action because dogs and cats are occasionally killed accidentally with this rodenticide.

Another approach that has been discussed but inadequately explored is the use of activated charcoal pellets or particles in baits. Since activated charcoal is known to have an effinity for some chemicals, if ingested in a rodent bait by a dog it would help tie up the rodenticides, thus reducing absorption. For example, the center core of a paraffin rodent bait block could be solid activated charcoal, which should reduce rodenticide hazards should a dog chew up the entire block. Rodents, on the other hand, would carefully gnaw away the bait and reject the charcoal core.

In a similar way, vitamin K_1 might be included in bait to counteract anticoagulants. Such inclusion of neutralizing agents must be formulated in a way that part of the bait would be rejected by the rodents and yet be available in effective amounts for certain nontarget species, especially dogs and domestic livestock.

INCREASED SELECTIVITY THROUGH SPECIAL CHEMICALS

The use of avian-specific repellents theoretically may play an important role in the future to safeguarding birds from rodent baits. One such potential compound is dimethyl anthranilate (DMA), which has recently been studied by Mason et al. (in press). DMA is a common food flavoring which is repellent to birds but not to mammals.

SUMMARY

Potential primary hazard to nontarget species can be minimized through the proper selection of rodenticides and through bait composition techniques. Bait composition includes the selection of grain or grains used as bait and the way that these grains are processed and formulated into a finished product. Size, shape, texture and hardness are bait characteristics which can make them both effective and selective for the target species.

The value of artificially colored baits in repelling birds has been proven for over 30 years. The phenomenon of aversive conditioning associated with many rodenticides provides an added safety measure to nontarget species.

The usefulness of emetics and neutralizing and special chemicals as bait adjuncts has been discussed as past and future possibilities of increasing the safety of rodent baits.

Concern over the protection of nontarget species is of long-standing in field rodent control. While much progress has been made, there remains substantial room for new approaches and innovations in formulating baits to further minimize potential hazard to nontarget species, without significantly jeopardizing effective control of the pest species.

LITERATURE CITED

Barnett, S.A. 1975. The Rat: A study in behavior. University of Chicago Press, Chicago. 318 pp.

Bhardwaj, D. and J.A. Khan. 1979. Effect of texture of food on bait-shy behaviour in wild rats *(Rattus rattus)*. Applied Animal Ethology 5:361-67.

Brunner, H. and B.J. Coman. 1983. The ingestion of artificially coloured grain by birds, and its relevance to vertebrate pest control. Australian Wildlife Research 10:303-310.

Caithness, T.A. and G.R. Williams. 1971. Protecting birds from poisoned baits. New Zealand Department of Internal Affairs, Wildlife Publication No. 129. 4 pp.

Clark, D.O. 1975. Vertebrate Pest Control Handbook. State of California, Department of Food and Agriculture. 180 pp.

Czaplicki, J.A., D.E. Borrebach and H.C. Wilcoxon. 1976. Stimulus generalization of an illness-induced aversion to different intensities of colored water in Japanese quail. Animal Learning and Behavior 4:45-58.

Freeland, W.J. and D.H. Janzen. 1974. Strategies in herbivory by mammals: The role of plant secondary compounds. American Naturalist 108(961):269-89.

Fuller, P.J. and M.E. Hay. 1983. Is glue production by seeds of *Salvia columbariae* a deterrent to desert granivores? Ecology 64(4):960-63.

Galef, B.G., Jr. 1977. Mechanizm for the social transmission of acquired food preferences from adult to weanling rats. In: Learning Mechanisms in Food Selection (L.M. Barker, M.R. Best and M. Domjan, Eds.). Baylor University Press, Waco, Texas. 632 pp.

Galef, B.G., Jr., and M.M. Clark. 1971. Social factors in the poison avoidance and feeding behavior of wild and domesticated rat pups. J. Comparative and Physiological Psychology 75(3):341-57.

Hayne, D.W. 1950. Mouse populations in orchards and a new method of control. Michigan Agricultural Experiment Station Quarterly Bulletin 33(2):160-68.

Howard, W.E., R.E. Marsh and R.E. Cole. 1977. Duration of associative memory to toxic bait in deer mice. Journal of Wildlife Management 41(3):484-86.

Kalmbach, E.R. 1943. Birds, rodents and colored lethal baits. Transactions North American Wildlife Conference 8:408-416.

Kalmbach, E.R. and J.F. Welch. 1946. Colored rodent baits and their value in safeguarding birds. Journal of Wildlife Management 10(4):353-60.

Lavin, M.J., B. Freise and S. Coombes. 1980. Transferred flavor aversions in adult rats. Behavioral and Neural Biology 28(1):15-33.

Libby, J.L. and J. Abrams. 1966. Anticoagulant rodenticide in paper tubes for control of meadow mice. J. of Wildlife Management 30(3):512-18.

Marsh, R.E., R.E. Cole and W.E. Howard. 1967. Laboratory tests on the effectiveness of Prolin mouse tubes. J. of Wildlife Mgt. 31(2):342-44.

Marsh, R.E. and L.F. Plesse. 1960. Semipermanent anticoagulant baits. State of California, Department of Agriculture Bulletin 49(3):195-97.

Martin, G.M., W.P. Bellingham and L.H. Storlien. 1977. The effects of varied color experience on chickens' formation of color and texture aversions. Physiology and Behavior 18:415-20.

Mason, J.R., A.H. Arzt and R.F. Reidinger, Jr. Evaluation of dimethyl anthranilate as a nontoxic starling repellent for feedlot settings. Proceedings First Eastern Wildlife Damage Control Conference. September 27-30, 1983. Cornell Univ., Ithaca, N.Y. (in press).

Mason, J.R. and R.F. Reidinger. 1982. Observational learning of food aversions in red-winged blackbirds *(Agelaius phoeniceus)*. Auk 99:548-54.

Nachman, N. and P.L. Hartley. 1975. Role of illness in producing learned taste aversions in rats: A comparison of several rodenticides. J. of Comparative and Physiological Psychology 89(9):1010-18.

Riley, A.L. and L.L. Baril. 1976. Conditioned taste aversion: A bibliography. Animal Learning and Behavior 4(1B):1S-13S.

Pank, L.F. 1976. Effects of seed and background colors on seed acceptance by birds. Journal of Wildlife Management 40(4):769-74.

Spencer, D.A. 1938. Cultural and other methods for the control of injurious wildlife. USDA Bureau of Biological Survey. Wildlife Research and Management Leaflet BS-115. 6 pp.

U.S. Environmental Protection Agency. 1983. Sodium monofluoroacetate (Compound 1080). Position Document No. 2/3. 103 pp.

——— 1983. Strychnine Position Doc. No. 4. 57 pp.

Wilcoxon, H.S. 1977. Learning of ingestive aversions in avian species. In: Learning Mechanisms in Food Selection (L.M. Barker, M.R. Best and M. Domjan, Eds.), Baylor University Press, Waco, Texas. 632 pp.

Wilcoxon, H.C., W.B. Dragoin and P.A. Kral. 1971. Illness-induced aversions in rat and quail: Relative salience of visual and gustatory cues. Science 171(3937):826-28.