Overview of Controls: Why They Work and How They Function

Repellents

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Vertebrate repellents: Mechanisms, Practical Applications, Possibilities[1]

Background

Nonlethal approaches to the management of problem wildlife are increasingly popular, despite the absence of reliable tools and strategies needed to fully implement these schemes. Repellents are a case in point. Although aversive substances are frequently discussed as integral components in nonlethal approaches to wildlife damage management, few data are available that pertain to their relative effectiveness. Indeed, the marketing strategies for most commercial formulations emphasize anecdotes and testimonials rather that experiments and field evaluations. This remarkable lack of dependable information probably reflects the fact that the U.S. Environmental Protection Agency (EPA) does not require efficacy data for vertebrate repellents. Instead, the EPA requires the submission of evidence that putative repellents are environmentally benign and non-toxic. An unfortunate (albeit amusing) consequence of this regulatory strategy is that wildlife managers have access to an array of environmentally safe but potentially useless repellents to deploy for animal damage control.

The present discussion attempts to provide selection criteria, or at least a basic understanding, of how effective chemical repellents work. Visual and auditory repellents (e.g., hawk effigies, propane cannons) are not considered because they are expensive and, with few exceptions (e.g., Electronic Guard predator deterrents, flagging as a goose grazing deterrent), they confer little long-term protection. this is because visual and auditory strategies depend on startle responses and neophobia by target animals for their effects (e.g., Conover 1982, Dolbeer et al 1994). Such behaviors are not effective substrates for avoidance because they diminish rapidly when animals are exposed to the relevant stimuli more than a few times. Also, ordinances frequently ban noise and light pollution in urban and suburban settings, where the need for repellents is greatest. Ultrasound is not constrained by ordinances in the way that sonic repellents are, since humans are unable to detect ultrasonic frequencies. Unfortunately, most

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animals cannot detect them either (e.g., Summers-Smith 1963). regardless of the manufacturer or device, to date, no ultrasonic device has demonstrated significant effectiveness against any vertebrate or invertebrate species (Shumake 1997, Woronecki 1988).

Categories of Chemical Repellents

Vertebrate chemical repellents fall into three classes; those that cause **pain**, those that cause **fear**, and those that cause **sickness** (Mason 1997). Repellents are most effective when they are used to prevent the consumption of a treated item such as foods or electrical wiring. They seldom if ever prevent animals from entering areas containing treated items, i.e., there is little or no evidence for 'area' repellency associated with products available at the present time. To illustrate this point, napthelene (moth balls) is registered with the EPA as a bird repellent (to disperse roosts, Dolbeer et al. 1994). While there is no question that foods treated with naphthalene are avoided by birds, it is equally clear that napthelene is not always aversive. Moth balls spread in gardens for insect control are routinely picked up by a variety of avian species, who rub them on their feathers in order to kill arthropod ectoparasites (Clark et al. 1990).

Pain (Irritation)

Amongst the three types of chemical repellents, substances that cause sensory pain are most effective. This is because sensory pain elicits immediate avoidance independent of learning, and because repellency does not diminish for as long as the repellent chemical is present. Irritants are simply 'bad' tastes or smells; they stimulate specialized trigeminal pain receptors (so-called nociceptors; e.g., Silver 1990) present in the exposed mucous membranes of the eyes, mouth, nose, and gut lining. for mammals including humans, strong irritants include capsaicin and capsicum oleo resins (i.e., the active ingredients in 'hot sauce' preparations), and volatile chemicals such as mustard oil (allyl isothiocyanate) and ammonia (Budavari et al. 1989). Other effective irritants with potential practical applications include astringent tannins like quebracho and substances like agricultural lime. Quebracho is effective as a deterrent to gnawing by rodents (e.g., voles, Swihart 1990) and lime deters grazing by deer and geese (Belant et al 1997a,b).

Tastes, per se, are rarely (if ever) effective feeding deterrents. While bitter and acidic substances can reduce the consumption of treated materials slightly, intake typically returns to values close to baseline within a short period of time. Products that claim effectiveness solely because of a 'bad' taste are doing so largely (if not solely) in the absence of reliable evidence. In particular, products that contain denatonium derivatives (e.g., Bitrex, denatonium benzoate, denatonium saccharide) are ineffective repellents, regardless of the method of application (e.g., topical spray, translocated pellet delivered to the roots at planting). Most of these commercial preparations (e.g., Ropel, Tree Guard) are labelled for use against herbivores and carnivores. Both kinds of animals showed marked insensitivity to bitter compounds in experimental tests (Nolte et al. 1994b, Mason and McConnell 1997). New products containing denatonium benzoate appear with surprising frequency.

For birds, methyl anthranilate (a flavor compound in grapes and the active ingredients in

'ReJex-It' products [R.J. Advantage, Inc.]) is an effective irritant at concentrations that are inoffensive to most mammals. This differential effectiveness highlights a taxonomic difference between mammals and birds in irritant perception. Mammalian irritants are usually inoffensive to birds, and vice-versa. Capsaicin, for example, is an extremely effective irritant for mammals and it elicits avoidance at concentrations as low as 1-10 parts per million. Birds, on the other hand, tolerate capsaicin concentrations as high as 20,000 parts per million in drinking water. Likewise, mustard oil is a principle ingredient in riot control gases. For mammals, exposure to this substance provokes intense apnea and lacrimation. However, when open vials of mustard oil are placed in starling nest boxes, birds build more nests, lay more eggs, and hatch more nestlings. A plausible explanation is that this chemical acts as an insecticide and fungicide against pathogens and parasites present in the boxes but not as an avian repellent.

The greatest disadvantage to the use of irritants as wildlife repellents is that problem animals usually do not learn to avoid treated foods. For reasons that remain unclear, wildlife will continually 'test' materials, and reinfestation rapidly occurs once control measures are relaxed. For example, treating livestock feeds with methyl anthranilate will eliminate feed consumption by pest birds within 24-48 hours. However, if methyl anthranilate treatments are stopped, bird numbers return to pretreatment levels within two to three days (Mason et al. 1985).

Fear

Substances that induce what humans describe as 'fear' include sulfur compounds and volatile ammonium soaps of higher fatty acids (Milunas et al. 1994). Predator urines, and commercial preparations including Deer Away Big Game Repellent (IntAgra Corporation), Hinder (Uniroyal Inc.), and bone tar oil (e.g., Magic Circle Repellents) contain these substances. In genera, sulfur containing mixtures are effective against herbivores. Sulfurous compounds are not aversive to animals with other food habits, and they are usually attractive to carnivores. There are no data consistent with the belief that odors from one predator might be aversive to other predators, even though the latter might occasionally be eaten by the former.

Although sulfurous compounds are marketed exclusively as mammalian herbivore repellents, they may be offensive to avian herbivores as well. For example, both white-tailed deer and snow geese tend to avoid grazing in fields previously planted to cabbage (Mason and Clark 1996) and both avoid Big Game Repellent (Milunas et al. 1994, Mason Pers. Obs.). Two plausible explanations can be offered for this effect. First, the digestion of meat proteins produces sulfur compounds. For herbivores that are potential prey for meat-eating species, the presence of sulfur odors may signal that predators are somewhere nearby (Nolte et al 1994a). Second, forage plants that bioaccumulate sulfur also tend to bioaccumulate selenium (Mason et al. Unpubl. Ms.). Accordingly, sulfurous odors could be used as reliable cues for the avoidance of poisonous vegetation.

A disadvantage to the use of fear-inducing substances as repellents is that animals habituate to them. Repellency diminishes unless the presence of the cue is occasionally associated with the presence of a predator. Also, when a protected material is highly attractive, the aversiveness of fear-producing substances disappears. Under some conditions, these substances may even become attractive. for example, there are anecdotal reports that wolf urine applied as a repellent along roadways during winter can become a cue used by moose to identify locations spread with salt.

Sickness (Conditioned Avoidance)

Taste that are followed by sickness are avoided. This effect is variously called conditioned (or learned) taste avoidance, conditioned food avoidance or conditioned flavor avoidance. Learned avoidance can occur after a single aversive experience, particularly when sickness is great and the taste, food, or flavor is new to the animal. Avoidance is much harder to establish if target wildlife are already familiar with the sensory characteristics of the treated commodity.

Conditioned avoidance has been applied successfully to crop protection (e.g., Reidinger and mason 1983). It is the mechanism underlying the utility of methiocarb (mesurol) as a bird repellent, and disulfram (thiram) as a bird or mammal repellent. it also has been applied in attempts to control predation by coyotes and to encourage the avoidance of garbage dumps by bears. Neither of these attempts has been particularly successful. In the former case, conditioning failed to produce the desired result (avoidance of livestock) because learned avoidance applied to the **consumption** of prey, **not** the act of killing it. Predators readily learn to avoid consumption of a prey item after the prey is paired with sickness, but killing continues (i.e., killing and eating are separate motivational systems). Likewise, while it might be relatively easy to train bears to avoid a novel food paired with sickness, it is much more difficult to train animals to avoid a familiar place containing many familiar foods.

Combinations

The available evidence suggests that repellent combinations are more effective than repellents with single modes of action. For example, mixtures of capsaicin, thiram and Big Game Repellent may be considerably more effective deer repellents than any one of these substances used alone. Likewise, mixtures of mesurol and methyl anthranilate are more effective than either mesurol of methyl anthranilate alone. Cinmnamamide (e.g., Crocker and Perry 1990) d-pulegone (e.g., Mason 1990) and anthraquinone (Thomson 1989) are all broadly effective vertebrate (bird and small mammal) repellents that exert sensory (irritant) and post-ingestional effects. Intuitively, it is easy to believe that irritation and gastrointestinal malaise would provoke stronger avoidance than irritation or sickness alone.

Summary

Irritation is a more effective repellent principle than conditioned avoidance, and conditioned avoidance is probably a more effective repellent principle than fear. Regardless, the effectiveness of any repellent is affected by (a) the number and density of animals causing problems, (b) the number of alternative foods available in relation to the treated material, (c) the palatability of the treated commodity, and (d) weather conditions (Dolbeer et al. 1994). **Repellency is always relative and thus, always susceptible to failure**. Given sufficiently high numbers of animals and sufficiently few alternative foods, repellents will fail to confer protection. The clear implication is that repellents are not a stand-alone technology. The methods implemented alongside repellents may include harassment, sterilization, or the use of physical barriers. In some situations, it may be necessary to employ lethal methods of population reduction before nonlethal methods can be used. Ultimately, the development of selective, ecologically-sound and effective chemical repellents requires a knowledge of the chemosensory *Umwelt* of the species in question (von Uexkull 1934), and an understanding of the degree to which the species relies on chemical cues in the context of a particular problem.

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