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Repellents: Integrating Sensory Modalities

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ABSTRACT

Recommendations for managing wildlife damage situations often involve application of multiple methods or techniques. The basis for such recommendations is unclear as there is little evidence that such combinations of methods work more effectively than the individual methods alone. In order to improve beyond hit or miss repellent applications, we should adopt principles exhibited in nature and develop repellent treatments based on the design of signals used in animal communications. In particular, characteristics that increase detectability, discriminability, and memorability should be identified and incorporated into repellent design. To do so, the sensory capabilities of the target species need to be more completely understood.

KEY WORDS

communication, repellents, signal design

INTRODUCTION

In wildlife damage management, it is common to recommend that more than one type of management method be used to protect a resource from depredating wildlife. A recent situation at the Kennedy Space Center illustrates this approach. A pair of northern flickers *(Colaptes auratus)* had pecked >100 holes in the insulation of the fuel tank of the space shuttle Discovery; in response, NASA officials deployed an array of techniques including "tape-recorded predator screeches, plastic owl decoys, streamers, human sentinels with horns and balloons with menacing eyes to keep the woodpeckers away." (Gainesville [FL] Sun, 14 July 1995). Essentially, NASA officials tried everything that was practical and reasonable in the hope that something would work.

Such an approach is often given legitimacy by being termed integrated pest management "whereby several control methods are combined and coordinated with other management practices in use at that time" (Dolbeer et al. 1994*b*). Generally, however, support for the effectiveness of such a management strategy is lacking. There are little or no data showing that combinations of methods offer better protection than the individual methods applied singly.

Obviously there is no lack of tools that could be incorporated into an integrated pest management plan, but what is the basis for believing that combinations of tactics are effective? Where did such a notion originate? To a great extent, it probably relates to our observations of the natural world. There are many examples of chemically defended, bad-tasting, smelly, brightly colored prey items (e.g., Wiklund and Jarvi 1982, Marples et al. 1994). Presumably, such multiple defense systems evolved because they more effectively protect the prey than do single modes of defense. There are, however, several possible explanations for the existence of multiple component predator defenses (Pearson 1989). For example, many prey species require protection from a variety of predators, and the separate individual defense components may each be targeting different predators. Alternatively, defense components may have developed in response to the needs of the prey species at different stages of their life history.

In support of the concept of multiple defensive tactics against predation, there are data from laboratory studies showing that combining sensory stimuli can increase repellent responses over those obtained with stimuli presented singly (e.g., Inglis et al. 1983, Mason 1989). Although suggestive and stimulating, the relationship of such laboratory studies to behavior of depredating animals in the wild remains to be demonstrated.

In nature, combinations of sensory stimuli have evolved through interactions among predators and prey. As a result, effective combinations of stimuli have been created that protect prey and inform predators that prey are not palatable. Is the natural model a good one for wildlife managers to follow? For now, it is, but successful management will depend on the degree to which we simulate stimuli that animals respond to in the natural environment. We are attempting to alter behavior that has been selected over long time spans by applying recently derived and newly developed techniques.

The challenge is one of communication. We want to deliver, without ambiguity, messages such as, "Stay away from this place!" or "Do not eat this food item!" to animals with diverse sensory capabilities, motivations, and individual histories. How can this be done most effectively?

To devise ways of improving communication, it is necessary to focus on the communication process itself. By examining how communication has evolved in nature, we may gain insights that will increase the effective application of repellents to a diversity of wildlife management problems.

COMMUNICATION PROCESS

Guilford and Dawkins (1991) emphasize three attributes of signals that affect the communication process: detectability, discriminability, and memorability. Each of these is important to effective repellent application.

Detectability

If the receiver does not detect the signal, then communication fails. To a great extent, detectability is determined by the sensory capability of the receiver. It is futile to present an ultrasonic signal to a bird because birds cannot detect such frequencies. Nevertheless, ultrasonic bird repellent devices are marketed. The sensory capabilities of many species are still being defined by researchers, particularly in the area of avian olfaction. Only recently have we begun to appreciate the sensitivity of passerine birds to volatile stimuli (Clark et al. 1993) and to recognize the possible influence of olfaction on birds' behavior (e.g., Clark and Mason 1987, 1988; Avery and Nelms 1990). A more complete understanding of a given species' ability to detect chemical, visual, and auditory stimuli is requisite for the design of improved repellent methods.

Discriminability

This refers to the ability of the receiver of a signal to recognize that the signal belongs to some discrete category (Guilford and Dawkins 1991). Fr example, in nature, warning c9lors, particularly red, orange, and yellow, make discrimination of unpalatable from palatable prey relatively easy because most palatable prey are inconspicuously colored. There is ample evidence from feeding trials with captive birds that discrimination between palatable and unpalatable food can be enhanced by the addition of a prominent sensory cue to the unpalatable items (e.g., Bullard et al. 1983). In such feeding trials, the aversive agent most frequently used is methiocarb, a carbamate compound that produces postingestional illness (Rogers 1974). There is doubt, however, that methiocarb will continue to be available to wildlife managers as a crop protection tool (e.g., Dolbeer et al. 1994*a*). In light of this, additional studies are needed to examine whether enhanced discriminability applies to contact irritants such as methyl anthranilate in the same way that it does to postingestional repellents such as methiocarb (Mason 1989).

Memorability

Like other predators, crop depredating species must learn the association between unpalatability and appearance (Guilford and Dawkins 1991). Obviously, it is advantageous if the learning process is rapid. The depredating individual gains by not being exposed unnecessarily to a potentially harmful chemical, and the manager or producer gains because the losses incurred while educating the depredator are minimized. Even though responses to food items treated with a contact irritant such as methyl anthranilate are unlearned, repeated exposure to the treated food may be necessary for the animal to associate a given site with the presence of unpalatable food. Subsequent avoidance of the site will presumably follow provided the treatment is sufficiently noxious and discriminable. Research and management objectives should include minimizing the time between the animal's initial contact with the treatment and its avoidance of the site.

An important question then is what makes a signal memorable and easy to learn? Numerous factors affect an animal's ability to associate events (e.g., eating a particular food and becoming ill) and to retain the association once it is learned. These factors include the intensity of the punishment, the consistency of the association, and the animal's prior experience (Guilford and Dawkins 1991). While it is not possible to take all of these factors into account, it may be possible to improve memorability of a signal by incorporating findings from animal learning experiments.

Contrast

Learned avoidance of unpalatable prey occurs more quickly if the prey items contrast with their background (Gittleman and Harvey 1980, Roper and Redston 1987). The effect of contrast might apply not only to colors but to patterns as well (Mason 1988, Guilford 1990). These findings imply that research into means of increasing the contrast between repellent-treated food and natural backgrounds would lead to improvements in repellent efficacy. We currently know relatively little about how animals perceive their foraging environment. This is particularly relevant to birds because vision dominates their feeding behavior (e.g., Gillette et al. 1983, Avery 1984), and visual capacities of birds are still being defined (Parrish et al. 1984).

Novelty

Familiarity or preexposure can retard the associative learning process (e.g., Mason and Reidinger 1983). In the environment, therefore, conspicuous colors positively affect the learning process because they have no prior associations with palatable prey that must be unlearned (Guilford and Dawkins 1991). It stands to reason then that incorporation of aposematic colors or odors (Eisner and Grant 1980) in a repellent treatment will enhance novelty and so increase the memorability of the signal. Managers can also exploit the novelty effect by applying repellents to the crop before damage begins. By so doing, there will be no need to overcome positive associations and established patterns of feeding behavior, and repellents should be more effective.

Potentiation

An animal's association of two stimuli, such as the taste of a food item and subsequent postingestional illness, can be enhanced by the presence of a third stimulus, such as a novel odor, that by itself is not aversive. In birds, novel tastes can potentiate associations between color and unpalatability (Clarke et al. 1979, Lett 1980). Pyrazine odors may potentiate learned avoidance of colored food (Guilford et al. 1987, Avery and Nelms 1990). Thus, multisensory repellent applications may be substantially improved by including biologically relevant, but nonaversive, stimuli. Additional research is needed to identify the most promising prospects for potentiation.

CONCLUSIONS

It is clear that combining stimuli can enhance repellent effects. Results from experimental studies as well as field observations are consistent with this view. Combining sensory stimuli has often been a matter of expedience and intuition, however, and a more systematic basis for the design and testing of such multisensory combinations is needed. In particular, we should return to basics and delve into the sensory world of the animals we most want to affect. Without understanding the sensory world, or Umvelt (Lorenz 1937), of the organism, the study of behavior is incomplete. There are still many unknown aspects of sensory capacity and behavior in even the most well-studied species. Studies emphasizing basic perceptual capabilities and how these influence the animal's behavior are needed. Such knowledge will aid in the efficient development of useful, effective repellent treatments.

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