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Experiments on Chemical Control of Behavior in Brown Tree Snakes

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ABSTRACT

The brown tree snake *(Boiga irregularis)*, accidentally introduced on Guam shortly after World War II, is the target of extensive efforts aimed at reducing populations and preventing their spread to other Pacific islands. Chemical attractants and repellents have been investigated, and this paper presents an overview of current knowledge. In particular, chemical cues that have strong effects in laboratory tests have had only modest (though significant) effects in field tests on Guam. Reasons for the different outcomes of laboratory and field studies are discussed along with recommendations for the redesign of laboratory experiments.

KEY WORDS

attractants, brown tree snakes (Boiga irregularis), captivity, field tests, foraging, Guam, habituation, laboratory tests, repellents, supersensitivity

INTRODUCTION

Brown tree snakes are rear-fanged colubrids, native to New Guinea and to nearby islands, as well as to northern Australia. This species was accidentally introduced on Guam shortly after World War II, with a variety of primary and secondary consequences unfolding during subsequent decades (Fritts 1988, Rodda and Conry 1992). Half of Guam's bird species are now extinct, and most remaining species are in precarious condition, as are several species of mammals and lizards (Savidge 1987, Rodda and Fritts 1992). The snake, being venomous, also presents a medical problem, although only very young humans appear to be at risk (Fritts and Haddock. 1990, Vest et al. 1991, Weinstein et al. 1991). Numerous electrical outages are caused by brown tree snakes as these arboreal snakes climb power poles in search of avian or saurian prey (Fritts et al. 1987). Efforts to control brown tree snakes on Guam have emphasized the need for attractants to enhance success of trapping programs and for repellents to drive snakes out of sensitive areas, including critical habitat for endangered species and cargo-holding facilities from which stowaway snakes could be transported to other islands.

We want to make three points during this presentation. The first is that we have data on attractants and repellents in brown tree snakes, so at least modest progress has been made in these directions. Second, our research paradigms have been borrowed, with only slight modification, from the basic, theoretically driven studies of chemical ecologists whose goal was to identify chemical cues (particularly those derived from prey) that are detected by snakes. Consequently, high sensitivity and ecological face validity are characteristic of these paradigms. At the same time they have another less desirable characteristic; they tend to focus on only the terminal aspects of feeding episodes, measuring the acts of attacking and devouring nearby prey rather than earlier components of feeding episodes such as foraging, stalking, or selecting locations where prey are likely to appear. This brings up our third point that attractants and repellents identified in standard laboratory tests have had smaller effects in the field than we had hoped, not because the laboratory tests were fallacious, but because chemical cues that determine terminal aspects of predation do not necessarily influence earlier components of predatory episodes. Implications of this point will be addressed in the discussion.

METHODS

Wilde (1938) introduced a technique for assessing snake response to chemical cues; and in recent years Arnold (1980, 1981), Burghardt (1970, 1980), Cooper (1989, 1990), and others have exploited this technique to study the effects of ontogenetic, genetic, and phylogenetic effects on chemoreception. In its simplest form, the method involves soaking cotton-tipped applicators with chemical extracts and then presenting the applicators to the lips of snakes for 60 sec, while tongue flicks and latency to bite the applicator are recorded. Cooper and Burghardt (1990) studied the efficiency of various dependent variables to compare snakes' responses to chemical cues derived from prey with other responses to various control solutions. The most recent review of the literature on reptile nasal and vomeronasal chemoreception was provided by Halpern (1992).

We have used a slight variation of the applicator technique to study response of brown tree snakes to chemical cues. Because the brown tree snake is a large and aggressive snake, it is not possible to suspend an applicator in front of the snake for 60 sec without risking either an escape or an attack aimed at the investigator. Consequently, we simply touch the snake gently on the lips with the applicator and then close the cage, recording tongue flicks during the next 10 min. Chemicals that stimulate more tongue flicking than does water are said to produce positive responses, whereas chemicals followed by fewer tongue flicks than occur after application of water are said to produce negative responses. Finally, chemicals associated with rates of tongue flicking not different from rates seen with water are said to evoke no response.

In our screening program, a positive response signals a potential attractant, provided that the same chemical applied to a euthanatized rodent either accelerates predatory attack or does not disrupt such an attack. A negative response signals a potential repellent, provided that the same chemical applied to a euthanatized rodent either disrupts predatory attack (usually by increasing its latency) or forestalls the attack entirely. Chemicals with these characteristics in laboratory tests are then subjected to field trials on Guam.

OVERVIEW OF RESULTS

Most chemicals tested in our laboratory have produced no response in brown tree snakes, but a few have been followed by significant positive responses. Examples of the latter include Russ Carmen's Triple Threat, Synthetic Fermented Egg, and Beaver Lure (Chiszar et al. 1996). These and numerous other lures for fur-bearing mammals are available from M & M Fur Company, Box 15, Bridgewater, SD 57319. During our studies we also tested whole blood using cotton-tipped applicators, with the result that brown tree snakes exhibited strong positive responses to blood from several mammals, including humans (Chiszar et al. 1991, 1993*a*). The substances that evoked positive responses in the applicator test also passed our second test in that their presence on mouse fur either accelerated predatory attacks or did not disrupt them. Consequently, these materials were tested as attractants in field trials on Guam. The result of the field tests was that significantly more brown tree snakes were trapped using these "attractive" materials as baits than when traps were unbaited or baited with odiferous but biologically irrelevant chemicals such as floral-based perfumes. Success was mitigated, however, by the fact that the trap grids also contained units baited with live mice, and these traps caught far more brown tree snakes than did any of the traps baited with chemical cues (Rodda and Chiszar 1993).

The only substance that we examined in the applicator tests that might have repellent effects is synthetic monkey pheromone (SMP), supplied to us by U.S. Department of Agriculture's Denver Wildlife Research Center. This material elicited vigorous jaw rubbing, as snakes attempted to remove the chemical from their lips; and, when SMP was applied to rodent fur, predatory episodes were disrupted, with most snakes refusing to attack (Byall et al. 1993, Chiszar et al. 1996). No field tests have yet been conducted to determine if brown tree snakes or any other species will avoid areas containing SMP. It is noteworthy that we initially tested SMP as a potential attractant because to humans its odor resembled those of some of the mammal lures that produced positive responses in applicator tests. Hence, our identification of SMP as a possible repellent was a surprise, similar to surprises encountered by Clark (this volume).

A product called Snake-a-Way® is currently marketed as a snake repellent. It had no effects in tests reported by McCoid et al. (1993)

DISCUSSION

While our laboratory experiments on attractants have produced insights into the chemical control of snake predatory behavior (e.g., Chiszar et al. 1993*b*), it is disturbing that substances eliciting strong positive responses in the laboratory had only modest effects in the field. Although we have not tested putative repellents in the field, Nishimura and Kamura (1993) did so with habu *(Trimeresurus flavoviridis)*. Substances that had repellent effects in laboratory tests had insignificant effects in the field in that snakes were not stimulated to leave their refugia (crevices in rock walls) when the areas were heavily sprayed with the presumed repellent. Accordingly, we urge that attention be given to the reasons why laboratory and field tests have produced such discrepant outcomes.

Two classes of phenomena are probably responsible for these differences:

(1) Because the generally impoverished and unstimulating nature of most captive environments cause normally important but episodic events, such as presentation of prey, to take on even greater significance than would be the case in nature, snakes and other animals long maintained in captivity become supersensitive or superresponsive to certain cues, especially those arising from prey (Hediger 1964, Sharpless 1975). Laboratory paradigms for study of responses to chemical cues have focused, perhaps inadvertently, on aspects of behavior that are strongly influenced by captivity-induced supersensitivity, especially the terminal aspects of predatory episodes. This focus on terminal aspects of predation has probably increased our estimates of the magnitude of response to chemical cues relative to estimates that would be obtained with wild snakes.

(2) Response of brown tree snakes to attractants and repellents in the field depend upon the ability of these stimuli to influence searching behaviors, precisely those aspects of predation that have been ignored in laboratory studies, which have measured only attacking and ingestive behaviors. If initial aspects of searching are not strongly influenced by the same stimuli that modulate terminal attack and swallowing components, then use of these stimuli to attract foragers to traps is not likely to be successful. For example, it appears that the brown tree snake relies heavily upon vision during initial searching behavior and that chemical senses become involved only later as predatory attack becomes imminent. Hence, a truly effective artificial attractant probably must have both visual and chemical elements.

Laboratory research on repellents is especially likely to be affected by the habituation effects that are inevitable aspects of captivity. While long-term captives become strongly responsive to prey-derived cues, the snakes become unresponsive to previously threatening stimuli associated with humans and with the laboratory environment (Chiszar et al. 1995). Hence, captive snakes might easily be induced to leave a refuge by a mildly noxious odor, whereas a wild snake would not do so because the countervailing forces keeping the animal in its refuge are stronger than are the mildly aversive ones added to the refuge by the investigator. Interactions of this sort are probably common, greatly complicating the task of discovering repellents that would be effective in the field.

Our view is that laboratory studies of attractants must be redesigned to measure initial, secondary, and other aspects of predation as well as its terminal components, attack and ingestion. We must create empirically verifiable models of the sequence in which sensory modalities participate in the guidance of foraging activities, and development of attractants must be informed by these models. Laboratory studies on repellents also must focus on searching snakes as well as hiding snakes. After all, even if we drive all resident snakes out of refugia in sensitive areas, this victory will remain incomplete if new foragers enter because cues which influence inactive, hiding snakes have little effect on actively foraging immigrants. At the same time, it is necessary to consider the habituated nature of long-term captive snakes when we evaluate repellent effects. Perhaps the best way to do this is to replicate studies of promising repellents with freshly caught snakes to verify that they behave as do long-term captives. Thus, while discrepancies between laboratory and field data have led to some disappointment in the study of snake attractants and repellents, we believe that the problems are not insurmountable and that they can be addressed by developing new, more complete experimental designs. In many respects, our ideas are convergent with those of Clark (this volume), who has developed new test procedures to measure movement patterns such as those that occur during foraging and refuge seeking.

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