An Evaluation of Conditioned Taste Aversion to Deter Nest Predators: A Non-lethal Approach

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Abstract: Traditionally, reducing game-bird nest depredation has involved lethal means of predator control. We evaluated a non-lethal alternative, conditioned taste aversion (CTA), in Tom Green County, Texas. Simulated nests were constructed and baited with 3 eggs injected with lithium chloride, an aversive chemical. Simulated nests were constructed along the perimeter of a 40-ha pasture. A 21-day treatment phase was conducted with depredated nests being rebaited daily with treated eggs. A 28-day post-treatment phase involved establishing 24 non-treated nests in both the treated pasture and a control pasture. The study was replicated over 2 sites: the Management, Instruction, and Research Center (MIRC) and Stone Ranch (SR). There was no difference in nest survival between treatment and control pastures at MIRC ($F = 5.0$; 1, 3 *df*; $P = 0.1$). At SR, nest survival was higher in the treated pasture ($F = 11.64$; 1, 3 *df*; $P = 0.03$). Principal nest predator species differed between sites and may have caused the variable results. Raccoons *(Procyon lotor)* accounted for 83% of the depredated nests at MIRC, while turkey vultures *(Carthartes aura)* accounted for 92% of the depredated nests at SR. These preliminary results suggest that CTA may be achieved for some predator communities. The feasibility of using CTA to deter nest predators may be affected by extent of area to be treated, chemical toxicity, and predator movements.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 51:276–284

Ground-nesting game birds sustain a high incidence of nest depredation, e.g., northern bobwhite *(Colinus virginianus)* (Stoddard 1931, Lehmann 1984), wild turkey *(Meleagris gallopavo)* (Schorger 1966, Vander Haegan et al. 1988), and ducks (Anatidae) (Klett et al. 1988). Reducing nest loss to predators is important when nest

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depredation is extensive or involves endangered species. Lethal means of predator control (i.e., toxicants, shooting, or trapping) have been used to increase nest success (Balser et al. 1968, Duebbert and Lokemoen 1980, Lehmann 1984, Lokemoen 1984). However, lethal control of predators usually affords only short-term relief, as the predators removed are replaced quickly by immigrants (Duebbert and Kantrud 1974, Lokemoen 1984, Greenwood 1986), Beauchamp et al. (1996) observed that nest success increased in areas where predators had been removed, although nest loss to predators did not appear to cause a long-term decline in nest success. Thus, reducing predators is often controversial, and their removal may cause other problems (Sargeant et al. 1984). For example, red foxes *(Vulpes vulpes)* are considered to pose a greater threat to duck nest success than coyotes (Sovada et al. 1995). Sovada et al. (1995) found an inverse relationship regarding coyote and red fox abundance, in areas where the species were sympatric. Thus, coyote control may be detrimental to duck nest success.

Non-lethal methods of predator management, such as predator-excluding barriers (Doty and Kruse 1972), improvements in nesting cover (Duebbert and Lokemoen 1976) and electric fences (Lokemoen et al. 1982) have been successful in protecting nests from predators, but not cost-effective. Although non-lethal approaches are desirable from several perspectives, few proven methods are available (Sargeant et al. 1984) or practical over large areas.

A non-lethal alternative for deterring nest depredation may be conditioned taste aversion (CTA). When animals consume a food flavor that is followed by a gastrointestinal illness, preference for that flavor is reduced, often in a single trial (Garcia and Koelling 1967). In theory, predators should develop a taste aversion to treated eggs, generalize aversion to all eggs, and discontinue depredation (Conover 1984). A successful CTA is dependent on 3 minimum requirements (Nicolaus and Nellis 1987, Conover 1990): predators need to be of relatively equal size; predators need to occupy small overlapping home ranges; and the area to be treated needs to be small and have a simple predator community.

Successful applications of CTA in wildlife management have been limited primarily to reducing avian damage to crops (Stickly and Guarino 1972, Guarino et al. 1974, Stone et al. 1974, Conover 1985*a, b*). However, studies have documented a reduction in nest loss following CTA (Nicolaus 1983, Nicolaus and Nellis 1987, Conover 1989, 1990). Emetine dihydrochloride appears to be a promising chemical for a CTA program designed to increase nest success (Conover 1989). However, toxic emetine is hazardous to use, thus its potential use in field situations is limited (M. Conover, Utah St. Univ., pers. commun.). Lithium chloride (LiCl) may be an effective option (Nicolaus and Nellis 1987, Conover 1989) and is considerably less hazardous to use than emetine. Properly applied taste aversion may provide wildlife managers with a non-lethal means of controlling nest depredation (Nicolaus 1983). Our objective was to evaluate the effectiveness of an aversive conditioning agent (LiCl) in deterring nest predators under field conditions.

Partial funding for this research was provided by Texas Parks and Wildlife Department's Turkey Stamp Fund. Additional funding was provided courtesy of Angelo

State University and Texas Agricultural Extension Service. We also thank Dr. E. Huston and Dr. C. Scott for statistical advice.

Methods

Study Area

This study was conducted in 1995 at 2 sites in west Texas: (1) the Angelo State University Management, Instruction, and Research Center (MIRC) and (2) the Stone Ranch (SR). The 2 study sites are located in Tom Green County, Texas, and are in ecotones of the southern Rolling Plains and the Edwards Plateau ecoregions (Hernandez 1995). Potential nest predators at these sites included raccoons *(Procyon lotor)*, striped skunks *(Mephitis mephitis)*, opossums *(Didelphis virginianus)*, red foxes *(Vulpes vulpes)*, gray foxes *(Urocyon cinereoargenteus)*, badgers *(Taxidea taxus)*, collared peccaries *(Tayassu tajacu)*, cotton rats *(Sigmodon hispidus)*, armadillos *(Dasypus novemcinctus)*, ravens *(Corvus corax)*, meadowlarks *(Sturnella magna* and *S. neglecta)*, greater roadrunners *(Geococcyx californianus)*, and various snakes.

The efficacy of CTA as a means of deterring nest depredation was evaluated by comparing nest survival between areas that had and had not been pre-treated with LiCl-injected eggs. The study consisted of treatment (4 June–25 Jun) and post-treatment (30 June–28 Jul) phases, both at MIRC and SR sites.

Treatment

A hypodermic needle was used to inject unwashed chicken eggs with 0.1 g LiCl/1 ml of distilled water. Because of consistent and high depredation rates during the treatment trial, on day 11 the concentration was increased to 0.4 g LiCl/1 ml of distilled water. Approximately 3 ml of yolk was removed and replaced with 3 ml of LiCl solution. A thin S-shaped wire attached to the end of a pencil was inserted into the egg and rotated rapidly by hand to blend the contents. The hole in the eggshell was covered with epoxy glue.

To allow comparisons with previous depredation studies in west Texas (Rollins, unpubl. data), simulated turkey nests were constructed and baited with 3 LiCl-treated eggs. Nests (N = 20) were distributed evenly along roads that encompassed the perimeter of a 40-ha pasture to "enclose" the treatment area with LiCl-treated nests. To make treated nests readily available to predators, we made no attempt to conceal them. At each site, 3 of these nests were monitored by TrailMaster® camera units. Nests were inspected daily during morning hours (0700–1200 hours), with depredated nests being replenished with additional LiCl-treated eggs.

Post-treatment

At each site, 2 transects (12 non-treated nests each) were established within each of the pre-treated pastures and a corresponding control pasture (i.e., not pre-treated with LiCl). Because of logistical constraints, the control and treatment pastures were about 1 km apart. A total of 48 nests was created at each site (24 in control pasture, 24 in treated pasture). Nests were monitored every 7 days over a 28-day period to determine the relative depredation rate. Depredated nests were not replenished with fresh eggs.

Statistical Analysis

Number of surviving nests (per transect) were calculated for control and treatment pastures for each week. These data were subjected to repeated measures analysis of variance with week of observation as the repeated measure (SAS Inc. 1989, Hicks 1993) to detect differences in nest survival. Transects (replications) were nested within treatments, with individual nests as observations. Nests were not considered independent.

Results

A site by treatment interaction was observed ($F = 11.44$; 1, 3, *df*; $P = 0.001$). Thus, we report results of sites separately, and the data will not be pooled across sites.

MIRC

The TrailMaster® camera units indicated nest predators at MIRC were predominantly raccoons (83%), with fewer skunks (10%) and foxes (7%, $N = 72$ incidents; Fig. 1). A total of 164 LiCl nests was depredated during the treatment phase. Most nests (57%) were partially depredated (i.e., eggs cracked with contents spilled on the ground; Table 1). There was no difference in nest survival between the control and treatment pastures ($F = 5.0$; 1, 3 *df*; $P = 0.1$; F. 2).

SR

TrailMaster® cameras indicated turkey vultures were the principal predators (92%) ($N = 64$ incidents), with raccoons accounting for the remaining depredation events (Fig. 1). A total of 281 nests was depredated during the treatment phase. Most depredated nests ($N = 230$, 82%) were completely eaten, or the eggshells could not be located and were assumed to have been eaten (Table 1). A difference in nest survival was observed between the control and treatment pastures ($F = 11.64$; 1, 3 *df*; $P = 0.03$; Fig. 2).

Table 1. Condition of depredated, simulated nests inoculated with LiCl during a 21-day trial, Tom Green County, Texas 1995.

	Study Area	
Condition of depredated nests	MIRC *N*	SR *N*
Completely depredated	59	12
Partially depredated	94	51
Eggshells missing	11	218
Total depredated nests	164	281
Total nests available	420	378

Figure 1. Raccoons (top) and turkey vultures (bottom) were the principal nest predators at MIRC and SR, respectively.

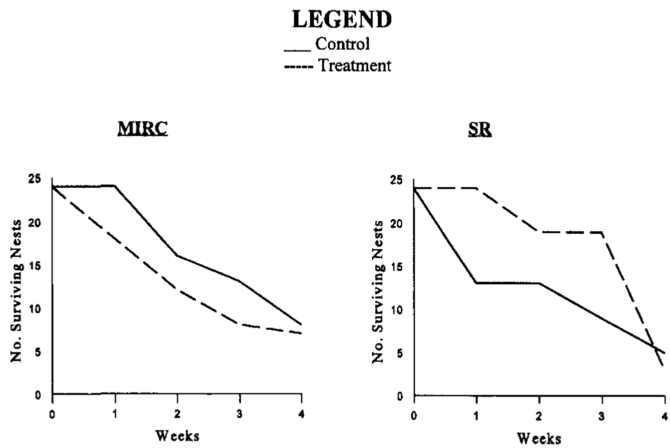

Figure 2. Survivorship of simulated nests following a 21-day CTA (LiCl) field trial, Tom Green County, Texas, 1995 (N = 24 nests/site).

Discussion

A difference in nest survival was observed for only 1 of 2 CTA trials (SR). Although this difference may only indicate a different pattern of nest survival (i.e., early mortality on control nests, late but equal mortality on treated nests), we believe nest survival differences were the result of CTA. A closer examination of the principal nest predators for the 2 sites may offer an explanation. A single dose of the aversive chemical may not have the same effect on a larger consumer as it does one of smaller mass (Nicolaus 1987). Raccoons, the predominant nest predator at MIRC, have a mean body mass of 6.8 kg (Lotze and Anderson 1979). Turkey vultures, the principal predators at SR, have a mean body mass of 1.8 kg. Therefore, the concentration administered may have caused an aversion to develop in turkey vultures while raccoons were unaffected. Further, a food cue that is salient for 1 predator may be ambiguous to another (Nicolaus 1987). At MIRC, 58% of the depredated nests during the treatment phase were only partially depredated, implying predators could distinguish LiCl. In such cases, predators may have received an insufficient and/or discontinuous dosage of LiCl and consequently never acquired a taste aversion. The continuous supply of treated eggs (i.e., 82% of depredated nests completely eaten) may have caused a CTA in turkey vultures.

Differences in foraging strategies could account for treated nests being partially or completely eaten by raccoons and turkey vultures, respectively. However, previous studies in west Texas showed raccoons completely depredated nontreated, simulated turkey nests (Rollins unpubl. data, Hernandez 1995, Slater 1996). To our knowledge, turkey vultures have never been documented as a nest predator, and thus we cannot comment on their foraging pattern of untreated nests. Nest depredation studies in the Prairie Pothole Region have made no mention of avian predators partially depredating natural duck nests (A. B. Sargeant, U.S. Geol. Surv., Biol. Resour, Div., unpubl. data). Thus, explaining nest condition based on foraging strategy may be speculative.

Phylogeny also may account for the observed results. Raccoons are omnivores and natural predators of gamebirds and their nests. Turkey vultures are scavengers, and thus we do not believe them to be common nest predators of natural quail or turkey nests. Familiarity with a food has been thought to weaken the establishment of CTA through a process known as "learned safety" (Kalat and Rozin 1973). While it is possible to develop CTA to a familiar food, taste aversion does take longer, especially if the food is nutritious (F. Provenza, Utah St. Univ., pers. commun.). Eggs may represent a familiar food to raccoons in nature, making them less vulnerable to CTA. Eggs may be a novel food source to turkey vultures, and vultures are thus more likely to acquire an aversion.

Several factors can determine the success of a CTA trial: size of treatment area, taste-aversive chemical concentration, and predator movements. The size of area to be treated may affect the success of a CTA study. A larger study site probably sustains a greater diversity and abundance of predators. The design of egg baits and their distribution in the field poses a simpler set of problems for 1 species of mammalian predator than if >1 species of predators is involved (Nicolaus and Nellis 1987). Using CTA to increase nest success is best suited for small areas that can be managed intensively (Conover 1990).

Toit et al. (1991) found that the degree of CTA was a function of the aversive chemical dosage administered to sheep. They reported a CTA was induced with 150 mg LiC1/kg body mass, which approximates the dosage required for a CTA in rats. In complex predator communities, obtaining a taste-aversion concentration appropriate to all predators is a rather difficult task. An inappropriate dosage may result in no taste aversion for large nest predators, such as coyotes or feral hogs. A more concentrated dose may provide predators with increased sensory cues resulting in avoidance of treated nests. For example, coyotes can detect LiCl by both olfactory (Ellins and Martin 1981) and gustatory cues (Burns and Conolly 1980). Consequently, predators may avoid or only partially depredate treated nests, resulting in no taste aversion.

Predator movements also may affect the success of CTA. For example, although capable of much farther travel, raccoons travel an average of 0.4 km (Lotze and Anderson 1979) and striped skunks generally restrict their activities to a 0.8-km radius (Wade-Smith and Verts 1982). However, red foxes travel extensively throughout their territory (Sargeant 1972), moving about 6 km (Cavallini 1992). Further, avian predators also are capable of extensive travel. Because of different predator movements, an area larger than the original site may need to be treated.

Studies have tried to reduce depredation on treated nests using CTA, but none has been completely successful in reducing depredation on untreated eggs (Conover 1989). During our CTA trials, we observed a difference in nest survival when turkey vultures were the principal nest predators. Although vultures are not natural turkey or quail nest predators, our data do not preclude the usefulness of CTA in wildlife management. The duration of CTA remains relatively unknown. If the food aversion lasts only for a few weeks (as our SR data indicated), maybe CTA is an option only for gamebirds with short incubation periods, e.g., northern bobwhite. Additional studies on the efficacy of CTA as a method for decreasing nest depredation are warranted. Our preliminary results suggest that CTA may be achieved, at least for some sites. Future studies should assess the interactions between available nesting cover, predator composition, distribution and movements, and various concentrations of LiCl or other chemicals that become available. With careful consideration and attention to these factors, CTA may be an effective management alternative for increasing nest success.

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