Testing of Lithium Chloride Aversion to Mitigate Raccoon Depredation of Loggerhead Turtle Nests

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Abstract: Lithium chloride aversive conditioning to reduce raccoon (*Procyon lotor*) predation of loggerhead turtle (*Caretta caretta*) nests was tested under laboratory and field conditions. A total dosage of 1.0 g was determined to produce side effects (diarrhea and emesis) soon after ingestion, and the negative taste reaction to the drug was eliminated when a dosage level of 0.25 g/egg was administered. In separate phases of laboratory testing on 37 raccoons, an aversive conditioned response was observed in only a few individuals. During field testing, there was no significant difference ($t = 1.11$; $P > .05$) between the depredation rate on turtle nests before and after a 3-week period of LiCl treatment. Despite the administration of the drug at an undetectable dosage level with resultant physiological side effects, an effective psychological association of food with illness was not made by raccoons. The use of LiCl as a management technique to reduce raccoon depredation of sea turtle nests appears to have little utility.

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The Atlantic loggerhead turtle is listed as a threatened species under the federal Endangered Species Act of 1973 and there have been increased efforts to mitigate mortality affecting this sea turtle. The major predator on the nests of the loggerhead turtle in the southeastern United States is the raccoon (Holden 1964, Klukas 1967, Gallagher et al. 1972, Davis and Whiting 1977, and Hopkins et al. 1978). The purpose of this study was to determine if LiCl aversive conditioning could effectively reduce raccoon depredation of loggerhead turtle nests.

Lithium chloride has been tested on other predator species: coyote (*Canis latrans*) (Gustavson et al. 1974, Conover et al. 1977, Olsen and Lehner 1978), black bears (*Ursus americanus*) (Colvin 1975), wolves

which would not produce the negative taste reaction observed in earlier tests. The LiCl solution was injected uniformly into intact chicken eggs which were then buried in 40 liter galvanized tubs filled with sand. It was not feasible to inject the drug into intact chicken eggs if the corn syrup was added, therefore the dosage/egg was adjusted downward to eliminate the negative taste reaction. Although the dosage/egg varied in each test (0.5 g and 0.25 g), the total amount of LiCl given to each raccoon (1.0 g) was held constant by adjusting the number of eggs a raccoon received. These tests were conducted in the late afternoon or at night to coincide with typical activity patterns and the acclimation schedule was the same as Phase I. Seven raccoons were given 2 treated eggs/day (0.5 g LiCl/egg) for 20 consecutive days; 6 raccoons received 4 treated eggs (0.25 g LiCl/egg) and 2 untreated eggs/day for 20 consecutive days; and 5 raccoons received 4 eggs (0.25 g LiCl/egg) every fourth day for 5 trials per raccoon. The maintenance diet was fed on intervening days. Different raccoons were used for each test and 2 raccoons were maintained as controls during each test. These controls were fed on the same schedule and given the same number of eggs as the experimental animals, but were not exposed to LiCl.

Each time a raccoon was exposed to treated eggs was counted as one trial. If eggs were eaten or partially eaten, that trial was recorded as no aversion. If eggs were dug up but not broken open, that trial was recorded as an aversive response. The initial exposure to the treated eggs was not included in the total number of trials because raccoons were naive of the effects of LiCl during the first exposure.

Phase III: Field Testing

Field testing was conducted during the 1978 turtle nesting season on South Island in Georgetown County, South Carolina (see Hopkins et al. 1978). Fresh loggerhead turtle eggs were obtained from nests that were partially depredated by raccoons. Each egg was uniformly injected with 0.25 g of LiCl solution after which approximately 1 dozen eggs were placed in an imitation (dummy) nest cavity which was dug by hand at the apex of a turtle track. Only tracks of emergences that did not result in nesting were used. It was thought that the olfactory and visual cues of the turtle track could be associated with the induced illness. Dummy nests were spaced at approximately 0.4 km intervals, depending upon the location of recent non-nesting emergences. Twice weekly, 4 to 6 dummy nests were buried during late afternoon, marked with small stake-wire flags offset 1 m, and checked at dawn the following day to determine if they had been eaten. Dummy nests and natural turtle nests were marked in a like manner with flags. During the 3 week test period (26 June to 16 July), a total of 30 treated dummy nests were buried on the nesting beach. The rate of predation prior to the June treatment and

(*Canis lupus*) and cougars (*Felis concolor*) (Gustavson et al. 1976) with varying results. In theory, aversive conditioning occurs when the predator ingests the target prey item impregnated with a chemical emetic (LiCl). The LiCl causes an acute physiological reaction that creates an aversive response whereby the predator avoids eating that prey species in the future. If successful, aversive conditioning would provide a nonlethal method of reducing depredation of turtle nests.

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Methods

Phase I: Laboratory Testing for Dosage Determination

Raccoons were live-trapped in the lower coastal plain of South Carolina and held in 2 × 4 × 2-m pens, which were wire enclosures with concrete floors, for the duration of testing. Each pen contained a wooden hutch for cover and the study animals were acclimated to the facilities and to a feeding schedule for at least 1 week prior to testing. A maintenance ration of dry dog food was provided each morning and fresh water was given *ad libitum*. All animals were given untreated eggs during the acclimation period to insure that eggs were a recognized food item for the raccoons to be tested.

The first phase of laboratory testing in 1977 was designed to determine dosage level, reaction time, if an aversive response was produced, and the duration of this response. These tests were administered in the morning so that behavior and reaction time could be observed. To determine the dosage necessary to cause illness, 19 raccoons were fed between 0.5 and 2.0 g of LiCl solution (1.0 g LiCl/2.0 ml H_2O) mixed with broken chicken eggs in bowls. Other methods of administration with different food items proved less satisfactory because the exact amount of LiCl consumed could not be determined. Different raccoons were used for each test and reaction time and any aversive behavior were recorded.

Phase II: Multiple Exposure Testing

The second phase of testing in 1978 was designed to test the dosage level determined from the previous series on a larger number of individuals, to determnie the affects of multiple exposure, and to determine a dosage/egg

raccoons when checked the morning following their burial on the beach. The rate of predation during field testing was not included in the test for significance in order to compare the 2 most dissimilar values. There was no significant difference ($t = 1.11$; $P > .05$) in the predation rate before and after the LiCl treatment according to the test of equality for 2 percentages (Sokal and Rohlf 1969). The overall percentage of raccoon predation for the test year, 1978, was 87.2% compared to 86.2% in 1977 and 86.8% in 1979.

Discussion

An aversive conditioned response is the avoidance of certain prey or food items by an animal through learned behavior. In order to initiate an aversive conditioned response with a chemical emetic, 3 sequential events should occur: the administration of the drug, the physiological reaction producing unpleasant symptoms, and the psychological response by the animal resulting from associating the induced illness with the food or prey item. During the course of this research, numerous factors influenced the successful execution of these 3 events.

One factor that complicated the first event, administration of the emetic agent, was the detection of the agent. Taste detection was the major problem in successfully administering LiCl. Either the taste was so unacceptable that raccoons did not ingest enough to develop symptoms or they ingested the dosed food but associated the illness with the drug's taste and not the food item. The goal to obtain an aversion to eggs was not achieved so long as the aversion was to the taste of LiCl and not to the taste of eggs. Raccoons reacted to the taste of LiCl by shaking their heads and dropping treated eggs but consumed untreated eggs without hesitation. Conover et al. (1977) noted that coyotes avoided portions of chicken carcasses which contained LiCl. Similar taste rejection behavior was reported by Anderson (1980) and Burns (1980) for raccoons and coyotes, respectively. A dosage of 0.25 g/egg was determined to be the level at which there was no apparent discrimination between dosed and undosed eggs.

When non-detection is important in establishing the correct association between induced illness and the target food item, then some forms of administration (eg. coyote "getters," injection and encapsulated crystalline LiCl) may interfere with the establishment of the correct association.

The rapidness with which Li is absorbed from the intestine brings about the second event, the physiological side effects. Lithium ions separate from Cl anions in the stomach and gut where Li enters the bloodstream. Although the reaction time was variable among individuals, 1.0 g of LiCl produced an induced illness. The emesis and diarrhea appeared to lessen in severity with

the previous year's predation rate were used to evaluate the effectiveness of the field testing.

Results

Dosage Determination

A dosage of approximately 0.5 g LiCl given to 2 raccoons, produced emesis at 2 hours in 1 animal and no visible signs in another. Eight raccoons that consumed 1.0 g LiCl each had the onset of diarrhea from 8 to 60 min post-treatment. Some individuals continued to have diarrhea for several hours. A dosage of 2.0 g LiCl each produced severe emesis in 30 min and severe diarrhea in 40 min in 1 raccoon, but only thirstiness and lethargy in another. Although the onset of visual signs of illness varied widely among individuals, 1.0 g LiCl appeared to cause unpleasant symptoms in an acceptable time.

There was an obvious negative reaction to the taste of the chemical, therefore a small amount of white corn syrup was added to each bowl to mask the taste of LiCl when 7 raccoons were given 1.0 g/egg each. Every raccoon consumed the entire amount of the mixture and all exhibited diarrhea and emesis. Two of these raccoons refused eggs all 4 times they were offered during an 18-day period.

Multiple Exposure Tests

Of the 133 trials conducted during the first test (0.5 g LiCl/egg on 7 raccoons), 10 resulted in an aversive response. In 44 of the trials the eggs were partially eaten, indicating that the dosage/egg was still detectable. In a second test on 6 raccoons, the dosage was reduced to 0.25 g LiCl/egg and untreated eggs were also included. At least 2 eggs/trial were eaten by each raccoon in all 114 trials. Only 28 of 448 treated eggs were not eaten, and 27 of 228 untreated eggs were not eaten. The majority of the eggs were eaten in all trials, therefore discrimination due to the taste of the drug was not apparent, but no aversion was obtained. In the final test of 5 raccoons, administered every fourth day for a total of 25 trials, no aversive response resulted despite the induced illness. During these 3 tests on a total of 18 raccoons, 272 trials resulted in aversive behavior on only 10 occasions during the 20-day testing periods.

Field Tests

The predation rate on natural nests was 93.4% ($N = 61$), prior to field testing, 89.8% ($N = 49$) during the 3 weeks of field testing, and 87% ($N = 46$) following field testing. All dummy nests had been consumed by

ditions, other factors which could affect the proper psychological association may have been involved. The non-aversive behavior of raccoons could be explained by the "learned safety" mechanism described by Kalat and Rozin (1973) for rats. By this mechanism, pre-conditioning raccoons to eggs would interfere with an aversive conditioned response.

Because both laboratory and wild raccoons had experience with undosed eggs, "learned safety" may have influenced aversive conditioning. While short-term aversion may be produced in certain individuals, the use of LiCl appears to have little utility as a management technique for the protection of loggerhead turtle nests.

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repeated exposures in the 2 tests which were given for 20 consecutive days. Gattozzi (1970) said that the side effects in humans occurred when Li levels in the blood climbed above 1.3 – 1.5 meq/L, but abated within a few days or weeks, even though the absorptive peaks were the same, early and late in treatment. The lessening of the side effects might have had some bearing on the non-aversive responses of raccoons during repeated daily exposure. However, subsequent testing at 4-day intervals, while producing side effects, also failed to elicit an aversive response.

The psychological association (third event) between the illness and the food item must be made. Johnson (1970) reported that the food habits of raccoons seem to depend on availability, preference and learning, and that learning appears to be an important factor, especially where predation is concerned. Because of their ability to learn and their powers of memory (Kitzmiller 1934), raccoons would seem to be ideal subjects for aversive conditioning.

During Phase II, 939 of 1,015 eggs were consumed by 18 experimental raccoons (92.4%) compared to 330 of 344 eggs (96.0%) for 6 control raccoons. These data show that although successful administration of the emetic with the resultant physiological side effects was accomplished, the psychological association between the food item and the illness was not strong enough in most individuals to produce an aversive conditioned response.

Despite the predominately negative results in the laboratory, a field test was conducted because the laboratory trials had provided a means of administering the drug at an undetectable dosage which resulted in the unpleasant physiological side effects. The ineffective psychological association of illness to food item was questioned because it may have been an artifact of captivity. Field testing eliminated possible boredom and aberrant behavior due to confinement as well as the forced proximity to the test food. In addition it provided alternate food sources and a test on a population rather than on individuals.

The evaluation of the field testing was facilitated by characteristics peculiar to this predator-prey relationship. Loggerhead turtles leave distinct 1 m wide tracks in the sand, and nests are easily located at the apex of these tracks. Thus prey density and distribution is readily quantified. Previous research documented the predation level for the preceding year (Hopkins et al. 1978) and also prior to testing. The prey item (turtle nest) is also nonmobile, which preserves its spatial attributes and eliminates behavior associated with attack and escape (Lehner 1976).

Despite the suitability of this predator-prey relationship and the elimination of factors of captivity, no mitigation of predation could be documented. Since no useful aversive behavior was observed under laboratory or field con-

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