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Richard J. Burns
U.S. Fish and Wildlife Research Service, Denver Wildlife Research Center

Guy E. Connolly
U.S. Fish and Wildlife Research Service, Denver Wildlife Research Center

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RICHARD J. BURNS[1] **and GUY E. CONNOLLY,** U.S. Fish and Wildlife Research Service, Denver Wildlife Research Center

ABSTRACT: Conditioned food or flavor aversion has been proposed as a method to stop coyote predation on sheep. The method entails treating sheep carcasses or meat baits with an emetic, lithium chloride (LiCl), and scattering them on sheep ranges. Theoretically, coyotes eat the baits, become ill, and subsequently desist from killing and eating sheep because they associate sheep flavor with sickness. In recent studies, coyotes have not formed prey aversions. Coyotes avoided baits because of LiCl flavor rather than prey flavor and prey-killing aversions were not found. We conducted a study designed to find the best LiCl-prey flesh concentration to produce bait aversion in coyotes, and to test the transfer of bait aversion to a prey-killing aversion. Baits with 1 g LiCl per 500 g prey flesh produced the strongest aversion to untreated baits, but coyotes conditioned to avoid prey baits made at this concentration killed and ate live test prey as frequently as coyotes with no conditioning. The lack of transfer from bait aversion to prey-killing aversion suggests that LiCl bait aversion will not prevent coyote predation on livestock.

INTRODUCTION

Predation aversion, instilled in coyotes (*Canis latrans*) by conditioning with a strong emetic, lithium chloride (LiCl), has been proposed as a method to reduce coyote predation on sheep (*Ovis aries*) (Gustavson et al. 1974, 1976, Ellins et al. 1977). The method entails treating sheep-flesh baits or sheep carcasses with LiCl and scattering them on sheep ranges. Theoretically, coyotes in the area will consume the treated flesh, become ill, and subsequently desist from killing and eating sheep because they associate sheep flavor with illness. In more recent investigations, coyotes have not exhibited LiCl-conditioned predation aversion and the usefulness of the method has become controversial. Griffiths et al. (1978) summarized the evidence on both sides of the controversy and concluded that no valid judgment could yet be made regarding the value of LiCl in preventing coyote predation on sheep. More recently, Conover et al. (1979) maintained that more research was needed, whereas Gustavson (1979) suggested that the studies to date have sufficiently demonstrated the success of the method. Cornell and Comely (1979) believed that LiCl fed to coyotes in a variety of foods discouraged potentially dangerous coyotes from soliciting food at a campground. But, Bourne and Dorrance (1980) found no difference in coyote predation on sheep between 12 ranches where **LiCl** baits were used and 13 ranches where placebo baits (no LiCl) were used. Of field tests with LiCl, only the work by Bourne and Dorrance (1980) has incorporated experimental controls. Burns (1980) demonstrated that salt flavor interfered with the ability of coyotes to form aversions to baits and to prey killing.

The results indicating failure of coyotes to form prey-killing aversion has suggested further investigation to develop effective baits, test the transfer from bait aversion to prey-killing aversion, and investigate the possible influence of prior killing experience on the formation of prey-killing aversion (Conover et al. 1977, Griffiths et al. 1978; Burns 1980). Here, we report on two experiments: (1) to determine the LiCl concentration in prey-flesh baits that produced the best aversion to untreated baits, and (2) to test the transfer from bait aversion to prey-killing aversion using baits developed in experiment 1. In experiment 2, only coyotes that had not killed jackrabbits, chickens, or larger prey were used.

METHODS

General

If conditioned prey-aversion is to be effective in the field, it should function without injections and within the established home ranges of resident coyotes. In our study therefore, we used LiCl baits to establish prey aversions and tested coyotes in pens familiar to them. Baits were used in preference to LiCl-injected carcasses because "hot spots" of LiCl flavor might occur at injection sites and interfere with flavor aversion. Additionally, coyotes were not required to make left- or right-hand choices, or to enter goal pens to get prey, as had been done in a previous study (Gustavson et al. 1976). Directional choices and goal pens could have provided coyotes with numerous stimuli (visual, tactile, sequential, locational) that might have been associated with sickness and influenced prey killing and feeding.

The investigation was conducted at the U.S. Fish and Wildlife Service predator research station near Logan, Utah. Coyotes were fed 500 g mink food per 10 k body weight daily, except on days when they ate baits or live prey. Jackrabbits (*Lepus californicus*) were used to make baits. Jackrabbits and chickens (*Gallus gallus*), respectively, were used as the test and alternate live prey in experiment 2. For bait preparation, jackrabbits were field dressed and skinned, and the remaining carcass was ground in an industrial meat grinder. Ground prey was mixed with powdered LiCl and was sewed into a jackrabbit hide. In experiment 2 the intact head and forefeet were left on the hide, so that the

[1]Current address is U.S. Fish and Wildlife Service, Predator Ecology and Behavior Project, Utah State University UMC 52, Logan, Utah 84322.

completed bait resembled a jackrabbit carcass. Gustayson et al. (1975) reported that, in rats, gustatory cues were more important than visual or auditory cues in aversion formations; however, Olsen and Lehner (1978) suggested that visual cues were more important for aversion formation in coyotes. Therefore, we attempted to have baits that resembled the live jackrabbits as closely as possible.

Experiment 1

In experiment 1, we tested baits containing 1, 2, and 4 g LiCl per 500 g of ground prey flesh. Baits were offered to coyotes at 500 g of treated flesh per 10 k of body weight. Three coyotes were used at each treatment level. Coyotes were held in kennels made of chain link measuring 1.4 m wide, 1.8 m high, and 2.5 m long. All coyotes were about 10 months old and had been raised by their natural parents in field pens in our captive colony.

Before being tested with LiCl baits, coyotes were fed mink food daily at about 8:00AM by the observer driving a specific truck. Daily feeding behavior was then recorded by the observer from the same truck parked in the same location each day. All observation periods lasted 4 hours. Tests with LiCl-treated baits were conducted in the same manner, and began the day after coyotes ate their mink food within 10 minutes on 3 consecutive days. During tests with treated baits, coyotes were offered one treated bait per day until a bait was refused (bait aversion established). Beginning the day after a treated bait was refused, coyotes were offered one untreated bait per day until an untreated bait was consumed (extinction to bait aversion established). Untreated baits continued to be offered until a coyote ate one untreated bait on each of 3 consecutive days.

Five factors were used to determine which treatment level produced the best bait aversion: (a) number of baits eaten; (b) frequency of vomiting; (c) extinction time; (d) time taken by coyotes to consume untreated baits, once extinction had occurred; and (e) frequency with which parts of the untreated baits, hide and fur or flesh, remained uneaten at the end of the observation period. The LiCl-bait concentration that provided the best conditioned aversion in experiment 1 was then used in experiment 2 to test the transfer of bait aversion to prey-killing aversion.

Experiment 2

In experiment 2, a control group and a treatment group, of four coyotes each, were used. All eight coyotes were approximately 1 year of age, and had been raised by their natural parents in field pens in our captive colony. No coyotes from experiment 1 were used. The coyotes were held in kennels, as described above, that adjoined 250-m^2 pens. Coyote movement between the kennels and pens was controlled by a sliding door operated from an observation building situated above the kennels. Coyotes were observed through a glass window from the building. The observer was screened from the coyotes' view by a curtain. Coyotes were observed individually and each had a pen adjustment period and a test period before the next coyote in the sequence.

During the pen adjustment period, mink food was placed at varying locations in a pen at 8:00AM each day. One coyote was immediately released from its kennel and allowed to feed and roam freely in the pen for 4 hours. At the end of the 4-hour observation period, the coyote was chased back into its kennel and the door was closed. Testing began on the day after a coyote fed on its mink food within 10 minutes on 3 consecutive days.

During testing, each control-group coyote was allowed to enter the pen and feed on one untreated jackrabbit bait (with head and forefeet attached), until one had been eaten each day for 3 consecutive days. On the following day a live jackrabbit and a live chicken were placed in the pen and the coyote was released into the pen to kill and feed. The prey-choice tests were continued for a minimum of 4 days, and until each coyote had killed and fed on three jackrabbits.

Following the pen-adjustment period, each treatment-group coyote was allowed to enter the pen and feed on one treated jackrabbit bait per day (4-hour period) until one or more baits were eaten, followed by one day in which a bait was refused (bait aversion established). On the day following establishment of bait aversion, the coyote was released into the pen which contained a jackrabbit bait, a live jackrabbit, and a live chicken. The test situation was repeated daily until each coyote had killed and fed on three or more jackrabbits and one or more chickens. The strength of the transfer from bait aversion to prey-killing aversion was assessed by comparing numbers of prey killed and fed on between the treatment and control groups.

RESULTS

Experiment 1

Of the three LiCl concentrations tested, 1 g LiCl per 500 g prey-flesh bait (1-g level) was the most effective in establishing aversion to untreated baits (Table 1). Coyotes at the 1-g level, compared to coyotes at the other 2 levels: (a) ate twice as many baits; (b) vomited less (only one vomited and the vomitus was re-eaten); (c) exhibited longer extinction times; (d) took longer to consume untreated baits when feeding on untreated baits began; and (e) more frequently left some hide, fur, or flesh uneaten at the end of the observation period. Results (d) and (e) involved feeding behavior and suggested that, after coyotes began consuming untreated baits, they did not like the taste. Based on these results, the baits used in experiment 2 were made with 1 g LiCl per 500 g prey flesh.

Table 1. Results of testing different treatment levels of lithium chloride to produce conditioned bait aversion in coyotes (averages of three coyotes per treatment level). Extinction time is given in days, with hours of observation shown in parentheses.

LiCl treatment level	Treated baits eaten	Emesis observed or vomitus found in kennel	Extinction time in days (hours)	Feeding[1/] time in minutes	Feeding behavior
1 g	2	1 of 3	4.33[2/] (17.23)	79 (n=24)	Some hide and fur left frequently (22 of 24 obs)
2 g	1	2 of 3	2.67 (10.68)	52 (n=25)	Some hide and fur left less frequently (3 of 25 obs)
4 g	1	3 of 3	2.67 (10.68)	13[3/] (n=16)	Some hide and fur left least frequently (1 of 16 obs)

[1/]Time taken to feed on untreated baits after extinction had occurred and feeding on untreated baits had begun.

[2/]Not statistically significant (P>.05). Analysis of variance showed 68% probability of a difference among extinction times.

[3/]Significantly (P<.05) faster feeding than the 1-g and 2-g concentrations.

Experiment 2

Three coyotes did not kill on the first day, and one coyote did not kill on the second day, that prey were offered. Thereafter, coyotes killed and fed on one or both prey each day. The results showed no significant differences in numbers of jackrabbits or chickens killed and eaten by control-and treatment-group coyotes (Table 2), and indicated no effect on prey killing that could be attributed to bait treatment with. LiCl. Two of four coyotes in the treatment group fed selectively, avoiding treated flesh to feed on untreated heads and hide. Even at the 1-g level, these coyotes were able to use LiCl flavor to avoid treated flesh.

Table 2. The numbers of jackrabbits and chickens killed and fed on by 4 coyotes in a control group without LiCl bait aversion and 4 coyotes in a treatment group with LiCl bait aversion.

	Jackrabbits killed and fed on	Chickens killed and fed on
Control group	12	9
Treatment group[1/]	14	10

[1/]Chi-square analysis showed no significant differences (P>.05) in the number of jackrabbits or chickens killed and fed upon between the two groups.

Bait aversion among the treatment-group coyotes, however, appeared to be stable when live prey was present as an alternate food. Extinction of bait aversion was not measured, but none of the coyotes showed interest in the baits during an average of 4.5 days (18 hours of observation) of simultaneous exposure to baits and live prey. Whenever live prey was available, coyotes ignored the baits.

DISCUSSION

In our experiment 1, the LiCl bait concentration (1-g level) that produced the strongest bait aversion was lower than concentrations of LiCl used by earlier workers. Griffiths et al. (1978) pointed out that the amount of LiCl used in baits and carcasses, though difficult to determine in some publications, varied from about 3 to 15 g per bait in studies with captive coyotes. In field studies or attempted control operations, the amount of LiCl has varied even more widely, and has been recommended and used at concentrations as high as 60-80 g LiCl per kilo (30-40 g LiCl per 500 g) of bait flesh(Burns 1980).

We believe that the 1-g level produced the strongest bait aversion because, at this level, coyotes ingested more baits and vomited less frequently than coyotes offered higher levels. Thus, coyotes at the 1-g level probably ingested and retained the most LiCl, which presumably caused a prolonged and more severe illness. This interpretation is consistent with the premise that animals usually form stronger aversions after more severe illnesses (Garcia et al. 1974). Additionally, baits at the 1-g level had the least salt flavor, increasing the likelihood that coyotes would form aversion to prey-flesh flavor rather than to salty flavor. We suggest that the highest LiCl concentration that coyotes will ingest without vomiting or avoiding baits because of salt flavor is likely to produce the best bait aversion. The intraperitoneal injections used in an earlier study (Gustavson et al. 1974), forced coyotes to "suffer the illness" because the LiCl could not be eliminated by vomiting. Those injections may have been important in establishing the bait aversion not only because of the stimuli surrounding the injections, as suggested by Bekoff (1975), but also because the coyotes were unable to expel the injected LiCl.

In experiment 2, aversion to LiCl baits did not prevent coyotes inexperienced with the test prey from killing or eating them. We think that LiCl would be even less effective on coyotes already experienced in killing, particularly if prior killing experience interferes with forming prey-killing aversion in the same way that prior experience with a flavor can interfere with forming flavor aversion. Kalat (1977) pointed out that the more experience rats had with a flavor before the flavor-sickness pairing, the more difficult it was to establish flavor aversion. The failure of our coyotes to transfer from bait aversion to prey-killing aversion might be related to the senses used by coyotes in capturing and killing, and to the ability of coyotes in discriminating between a killed prey and a bait. Wells and Lehner (1978) reported that coyotes are primarily visual predators. It follows that bait aversion, based on taste cues, would have little influence on killing. After the prey was killed, it did not sufficiently resemble a bait to prevent feeding or to cause coyotes to associate the live prey with a sickness-producing bait; i.e., warm, freshly-killed prey does not look, feel, taste, or smell the same to a coyote as cold, old, and perhaps slightly salty, bait. Coyotes apparently, can easily distinguish between treated baits and killed prey.

To stop coyotes from killing, it might be necessary to apply aversive stimuli during the attack, kill, or both, instead of before the attack. Olsen and Lehner (1978) suggested that a prominent visual stimulus was the most important of those tested in establishing a conditioned avoidance in coyotes. Milgram et al. (1977) reported that, in mouse-killing rats, mouse feeding but not mouse-killing was suppressed if the rats were allowed to feed on the mice before LiCl injections. LiCl did suppress mouse killing if LiCl administration followed the killing behavior. The administration of LiCl to coyotes during the attack or kill under field conditions, however, would seem to be infeasible.

Most studies of conditioned food and flavor aversion have been conducted with rats, and as Gustavson and Garcia (.1974) so aptly stated, "... the rat cannot vomit to get rid of poison in the stomach, so nature seems to have designed the rat to be an expert at avoiding the taste of poisonous foods." Rats evolved feeding mainly on plants, some of which are poisonous. Coyotes, on the other hand, can vomit if they ingest poisonous plant material; furthermore, coyotes usually prey on mammals, birds, and some invertebrates, that are generally not poisonous. Hence, the coyote probably has had little selective pressure to evolve a prey-killing aversion mechanism similar to food aversion in rats.

Flavor aversions in rats are well known, and supported by a large volume of literature. However, the concept of using aversive baits to prevent prey killing by coyotes is relatively new, little tested, and has shown contradictory results in various studies. In this study, we produced measurable bait aversion in coyotes, but the bait aversion had no influence on prey-killing or on feeding after the kill. Therefore, we question the efficacy of LiCl-treated baits in reducing coyote predation on domestic animals.

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