does. We estimate about $N = 2{,}000$ bucks and does in the herd. For 95% confidence, $z_{.05} = 1.96$ and from (9) the adequate sample size for precision of $\pm B = \pm 3$ bucks/100 does is

$$n = \frac{(1.96)^2(30)(2{,}000)}{\left(\frac{[\pm 3]^2 100[1{,}999]}{[100+30]^2} + (1.96)^2 30\right)}$$

$$= \frac{230{,}496}{[106.46 + 115.25]}$$

$$= 1{,}040 \text{ bucks and does.}$$

10. *Example for the use of equation (10).*

There are 109 bucks and 402 does observed in an unbiased, randomized preseason antelope classification. The herd ratio is 109:402 or 27.1 bucks/100 does. Therefore, $a = 27.1$, $n = 109 + 402 = 511$, and we estimate that about $N = 2{,}000$ bucks and does are in the preseason herd. If 90% confidence is desired, $z_{.1} = 1.645$ and from equation (10)

$$b = \frac{1.645(27.1 + 100)}{10} \sqrt{\frac{27.1(2{,}000 - 511)}{511(1{,}999)}}$$

$$= 20.9(0.1988)$$

$$= 4.2.$$

Therefore, there is (approximately) a 90% chance that the true herd ratio falls in the interval

$$(27.1 \pm 4.2 \text{ bucks})/100 \text{ does.}$$

COYOTE PREDATION AVERSION WITH LITHIUM CHLORIDE: MANAGEMENT IMPLICATIONS AND COMMENTS

RICHARD J. BURNS, ***U.S. Fish and Wildlife Service, Predator Ecology and Behavior Project, Utah State University, UMC 52, Logan, UT 84322***

Conditioned taste aversion has been proposed as a method to deter coyotes (*Canis latrans*) from preying on sheep. The method involves placing mutton baits laced with a strong emetic, lithium chloride (LiCl), on the range. Coyotes supposedly find and eat the baits, become ill, and subsequently avoid sheep because they associate the sheep with sickness (Gustavson et al. 1974, 1976, Ellins et al. 1977). Attempts also have been made to control coyote predation on turkeys (*Meleagris gallopavo*) using LiCl-laced turkey carcasses (Ellins and Catalano 1980).

Some investigations prior to 1978 cast doubt on the effectiveness of using LiCl baits to deter coyotes from killing (predation aversion) and, in a summary paper, Griffiths et al. (1978) concluded that no judgment could yet be made regarding the value of LiCl in preventing coyote predation. In this paper I synthesize the literature on the subject since 1978, discuss the most probable management implication (assuming LiCl produced predation aversion in coyotes), and point out some present information needs.

In defending an earlier publication, Conover et al. (1979) maintained that more research was needed on predation aversion with LiCl, whereas Gustavson (1979) felt that the existing studies demonstrated the success of the method. Cornell and Cornely (1979) believed that LiCl fed to coyotes in a variety of foods discouraged potentially dangerous coyotes from soliciting food at a campground. Burns (1980*b*) demonstrated that LiCl's salt flavor interfered with the ability of coyotes to form aversions to baits and prey killing. Burns and Connolly (1980) then produced a measurable black-tailed jack rabbit (*Lepus californicus*) bait aversion with low doses of LiCl that appeared not to provide flavor cues to coyotes. The bait aversion, however, was not transferred to predation aversion; coyotes continued to kill jack rabbits. Ellins and Martin (1981) later found that coyotes could detect LiCl and avoid baits at concentrations below

those used by Burns and Connolly (1980). Horn and Lehner (1981) examined the effects of administering LiCl during the approach, capture, and consumption parts of the predatory sequence. The longest predation aversion (20 days) occurred when LiCl was administered during consumption.

Bourne and Dorrance (1982) found no difference in coyote predation on sheep farms between groups of farms where LiCl baits and placebo baits (no LiCl) were used. However, Gustavson et al. (1982) and Ellins and Catalino (1980) continued to claim success with LiCl baits to control coyote predation on sheep and turkeys. Hence, experiments and field studies since 1978 continue to show inconsistent results, and the status of the control method is little improved.

LITHIUM CHLORIDE INFORMATION NEEDS

In most field studies, comparisons of predation on sheep have been made between a year in which LiCl baiting was used and a year or 2 before baiting. The year-to-year variations in coyote predation are thus not considered and can be considerable. These studies have usually not measured (or controlled) variables such as changes in coyote density or sheep management practices, alternate food available to coyotes, and coyotes killed for damage control, fur, or sport. Any combination of the above, and perhaps other, variables could produce great differences in coyote depredation on sheep from 1 year to the next, and these variables should be controlled in future studies.

A notable exception to the foregoing types of studies was conducted by Bourne and Dorrance (1982) who avoided year-to-year variation by conducting their study in 1 year on 8 farms with LiCl baits and 7 with placebo baits. The study design allowed statistical "balancing out" of uncontrolled variables. This type of study provides stronger scientific evidence, and more like it are needed to strengthen our understanding of how LiCl works in the field.

Additionally, future studies need to be aimed at providing sufficient experimental control and sample sizes to produce unequivocal results about the effectiveness of the LiCl control method, and about whether or not coyotes maintain their territories after being averted, thus influencing pup sheep-killing behavior. In conducting such studies one should consider the wariness of coyotes, e.g., apparently the increase in human activity associated with coyote studies can reduce coyote predation on sheep in the absence of study effects (Griffiths et al. 1978). Also, although LiCl is not considered a hazardous chemical, Rogers (1974) observed that 5 of 18 blackbirds (*Agelaius phoeniceus*) voluntarily consumed lethal amounts, and LiCl effects on nontarget animals need further investigation.

If LiCl predation (killing) aversion does not function in coyotes, taste aversion might still be useful in situations where coyote feeding (not killing) was undesirable. In Joshua Tree National Monument, coyotes developed the habit of accepting handouts at a camp site. The potentially dangerous situation was apparently alleviated by feeding the coyotes LiCl in a variety of foods (Cornell and Cornely 1979). In Kansas, Robert Henderson (pers. commun.) used LiCl to stop a coyote from stealing dog food by allowing the coyote to feed on the treated food. On wildlife refuges the use of LiCl baits might discourage predation by coyotes and other predators on waterfowl and crane eggs. These examples indicate the potentially wide range of application for taste aversion control of coyote problems, and this area shows potential that merits further exploration.

POTENTIAL MANAGEMENT ADVANTAGES

There are several attractive reasons why using LiCl baits to control coyote predation have

been advocated by conservation and protectionist groups, and why the U.S. Fish and Wildlife Service and others have spent much time and money studying the approach. Taste aversion, as widely demonstrated in rats, is usually learned quickly (after 1 illness experience), and retained well (Garcia et al. 1974). LiCl is a salt that is not poisonous as used in taste aversion, and its use is generally not associated with danger to nontarget animals or the environment.

Coyotes are appreciated aesthetically and fill an ecological niche. In control operations coyotes that were deterred from killing sheep by LiCl baits (instead of being killed by conventional control methods) would remain to be seen, heard, and photographed; and might exert some control on rodents and rabbits that compete for food with livestock and spread disease, and influence feeding of their pups so that pups would not kill the prey to which adults were averted (Gustavson and Garcia 1974, Gustavson et al. 1974). These coyotes also could remain on their territories and keep potential stock-killing coyotes away (Etter 1969).

POTENTIAL MANAGEMENT PROBLEMS

Baiting Considerations

Coyotes learn LiCl bait avoidance after feeding on 1–2 baits or carcasses, but they might not learn to avoid prey (Burns and Connolly 1980), and, when present, prey avoidance is probably short-lived (Lehner and Horn 1977). For LiCl baiting to be effective, it should produce predation aversion for those several months when lambs are most vulnerable to predation. A shorter time might be acceptable if coyotes could be easily rebaited with LiCl. However, rebaiting them would be difficult provided that coyotes retained a bait aversion longer than a killing aversion. In fact, the questions surrounding LiCl baiting, i.e., the amount of LiCl in baits, the effective duration of baits, the timing and dispersion of baiting, and the frequency of rebaiting are either not agreed upon or have not been dealt with experimentally.

Baiting strategies should be based upon knowledge of the biology of the coyote, and some aspects of coyote biology present questions about when to put out baits to effectively stop predation. Coyote populations probably include territorial pairs, dispersing pups in fall, and sometimes nomadic individuals moving among territories (Berg and Chesness 1978, Camenzind 1978). In order to use LiCl baits to teach members of each group of coyotes not to kill sheep, baiting probably should occur throughout the year. Moreover, exactly when and where coyote predation will occur is sometimes difficult to predict, which suggests the need for prophylactic baiting over widespread areas of coyote habitat.

Other questions concern the fate of coyotes that have eaten LiCl baits and whether or not pups learn prey avoidance from their parents. Gustavson et al. (1976) and Cornell and Cornely (1979) believed that coyotes left their study areas after eating LiCl baits. Coyotes that left an area after eating LiCl baits would neither defend the area against potential sheep-killing coyotes nor could they kill the rabbits and rodents there. Further, pups could learn a predation aversion after feeding on LiCl-treated material. However, in a pen study, LiCl provided (in regurgitate) to pups by their parents only temporarily interrupted pup feeding (40-day-old pups) and failed to influence pup food choice several months later (Burns 1980*a*).

In field tests to date, baits have been left on the range for periods of weeks to months (Gustavson et al. 1976, 1982, Ellins et al. 1977, 1980, Bourne and Dorrance 1982). How long such baits taste and smell like sheep to coyotes is unknown, yet this information is critical to predation aversion established with prey-flesh baits or carcasses, and to knowing how fre-

quently to change baits or add new ones. My own observations showed that coyotes changed their behavior towards LiCl baits that were offered to them for 4 hours/day for 3 days. The coyotes changed from bait avoidance to neck-shoulder rubbing or rolling on the old baits. Rubbing or rolling is a general canine response to rotting material, especially meat. The behavior change indicated that the coyotes no longer regarded the baits as something to be avoided but simply as any rotting meat, and suggested that baits in the warm sun smell like sheep for only about 0.5–3.0 days. To be effective, then, baits should probably be changed frequently.

Ellins and Catalano (1980) suggested that using LiCl whole-carcass baits might be more effective than LiCl prey-flesh baits. Obtaining sufficient lamb carcasses for a baiting program that required changing carcasses frequently over large areas for most of the year would be expensive. But, if LiCl bait aversion did prevent predation and the management advantages pointed out above resulted from the baiting, the control technique could justify a somewhat costly system of manufacturing and distributing LiCl baits or carcasses.

Linhart et al. (1968), in baiting studies over fairly large areas, were able to mark only 28–34% of the coyote population using 16 baits/square mile (2.59 km^2). At present, how many LiCl-laced carcasses or baits/km^2 would be necessary to reach most sheep-killing coyotes is unknown, although the information is essential to an effective baiting program.

Management of Averted Coyotes

Assuming that baiting problems can be overcome and coyotes could be averted to killing stock and, if averted coyotes did defend their territory, eat the rabbits and rodents there, and teach their pups not to kill sheep, these coyotes would become valuable assets to ranchers. The most striking management implication is that these valuable coyotes would need protection so they could continue to provide the expected benefits.

A management shift to protect coyotes would not be easy. Coyotes are killed for predator control, sport hunting, and fur; hence, coyote population turnover is generally high. The U.S. Fish and Wildlife Service (1978:71) reported adult coyote death rate at 38–56% and pup death rates even higher. The attitude of a large segment of rural residents and state and Federal laws would have to be changed to eliminate coyote killing for most reasons, particularly on or near livestock areas where most lethal control presently occurs. In order for public habits, attitudes, and laws to be changed not only LiCl predation control, but also the other benefits expected from the stock-averted coyotes, would have to be proven in the field.

On the other hand, coyotes that were protected could produce high populations and provoke a different set of problems. High coyote populations might, for example, impact populations of big game (Connolly 1978) or other desirable wildlife, such as other predators (Wagner 1972) and threatened or endangered species; they could, and in some places have, become a public nuisance (Starr and Huck 1981).

If aversion with LiCl baits is not strong enough to deter coyote predation, it might be possible to develop an alternate delivery system or some other aversive chemicals might be tested in baits. However, only the chemical or delivery system would have changed, and most of the management problems, questions, and lack of information mentioned above would still remain.

SUMMARY

Using LiCl baits to stop coyote predation on sheep is an attractive concept. Unfortunately, research pertinent to the approach has been

equivocal or inconsistent. The paper points out areas needing more research and pertinent areas that have not been investigated.

If LiCl baits were effective in teaching coyotes not to kill sheep and the suggested advantages for the technique were realized, the averted coyotes would become valuable assets. The most obvious implication would be a management shift to protect the valuable coyotes. Protecting coyotes would require changes in attitudes and in laws governing coyote killing. This shift would not likely come about unless it could be shown that predation aversion and its advantages were produced by the LiCl baits.

If predation aversion did not prove effective, taste aversion might produce control in situations where coyote feeding, not killing, was the problem to be alleviated. If LiCl in baits did not reduce coyote predation, other delivery systems or other chemicals might be tested.

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RELATIONSHIP BETWEEN HUSBANDRY PRACTICES AND COYOTE USE OF SWINE IN WEST CENTRAL ILLINOIS

JON M. JONES, ***Cooperative Wildlife Research Laboratory, Southern Illinois University, Carbondale, IL 62901***

ALAN WOOLF, ***Cooperative Wildlife Research Laboratory, Southern Illinois University, Carbondale, IL 62901***

Historically, the coyote (*Canis latrans*) has been the focus of controversy concerning the impact of predation on the livestock industry in the western United States. In recent times, the coyote has expanded its range; they are now abundant in Illinois in contrast to 40 years ago (Nixon 1979).

The purposes of this study were to: determine the food habits of west central Illinois coyotes to assess the importance of livestock, especially swine, in their diet; and to evaluate the relationships between husbandry practices and reported losses to coyotes.

STUDY AREA

In 1980, Adams and Pike counties, in west central Illinois, ranked second and third in the number of swine on Illinois farms. They ranked among the top 10 counties in cattle production, and Adams was highest in sheep production (Ill. Coop. Crop Rep. Serv. 1981). The counties are about 15% forested and 54% cultivated. They are among the leading Illinois counties in numbers of coyotes harvested, hence, populations are assumed to be abundant.

METHODS

Coyote stomachs ($n = 160$) and large intestines ($n = 11$) were collected bi-weekly during December 1979–March 1980 and November 1980–February 1981 to establish winter foods. Scats ($n = 69$) were collected monthly during July–August 1980 and May–August 1981 to evaluate summer food habits. Contents of gastrointestinal tracts and the scats were prepared and analyzed as outlined by Korschgen (1969). Occurrences of each food item were summed and expressed as a percentage of the total number of usable gastrointestinal tracts or scats.

A questionnaire was mailed to 673 swine producers. Questions addressed type and number of swine on the farm during 1980, farrowing operations, confinement practices and associated problems, monitoring schedules, carcass disposal methods, and numbers and causes of swine deaths (Jones 1982). Each reported husbandry technique was treated as a dichotomous variable for analysis. Reported combinations of husbandry techniques also were treated as exclusive dichotomous variables. Phi or point biserial correlation procedures (Roscoe 1975) were used to detect significant relationships ($P < 0.05$) between husbandry techniques and losses to coyotes. Chi-square tests were also used to include significance in losses to coyotes due to different management techniques.

RESULTS AND DISCUSSION

Food Habits

Four major food items were identified: plant material, cottontail rabbit (*Sylvilagus floridanus*), rodents, and swine. Plant material, especially grasses, was usually observed in small