WITHIN-BURROW AND SURFACE FEEDING OF OAT GRAIN BY CALIFORNIA GROUND SQUIRRELS

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Abstract: Because the response of California ground squirrels to different baits varies with changes in the location, time, and mode of bait application, a solid understanding of ground squirrel foraging behavior is necessary for the development of effective, reduced risk baiting strategies. It has been assumed that ground squirrels will not consume bait placed in their burrows and that they may scatter it on the surface while clearing out their burrows. To determine how placing grain within the burrow affects the level of bait consumption by ground squirrels, we compared bait consumption when grain was applied within the burrow versus when grain was applied on the ground near the burrow entrance. Baiting was performed twice daily so that potential for consumption by squirrels during the day, and by non-target species at night could be evaluated. The level of daytime consumption for in-burrow baited burrows was lower than when bait was applied above ground. For both daytime and nighttime baiting periods, grain consumption was significantly higher for surface baited burrows. This indicates that surface-baiting results in a higher level of bait acceptance by ground squirrels but in-burrow baiting does provide some bait acceptance.

Key words: anticoagulant, bait acceptance, baiting, ground squirrel, non-target species, *Spermophilus beecheyi,* zinc phosphide

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INTRODUCTION

California ground squirrels (*Spermophilus beecheyi)* are one of the most serious agricultural and rangeland pests in California, causing damage estimated at $30-40 million annually (Marsh 1994). Ground squirrels may compete with livestock for forage, degrade rangeland, and damage crops, equipment, and structures. Rodenticide treated baits are the most economical of all approaches to squirrel population reduction and have traditionally been the mainstay of ground squirrel control (Whisson et al. 2000). However, the growing concern about the hazards that rodenticide use may pose to non-target species has created pressure to integrate an understanding of these risks into the development an effective control program. While some research has been done on the hazards that various toxicants may pose to non-target species, little research has been done to evaluate how baiting strategies may reduce or increase these risks (Colvin et al. 1988). Changing the mode of bait application also changes the effectiveness of the control. Sterner (1994) found in an analysis of spot baiting versus broadcast baiting that altering baiting strategy had different impacts on the

control of mice, voles, and prairie dogs because their biology and foraging behaviors differ. He found that while broadcast baiting provided effective control of mice and voles, using broadcast baiting rather than spot baiting reduced control of prairie dogs because they developed bait-shyness. In order to develop effective forms of control for California ground squirrels that minimize risk to non-target species, it is necessary to have a comprehensive understanding of their foraging behavior and to consider how using different baiting strategies with different types of toxicants affects control (Timm and Salmon 1988).

Regardless of toxicity, if squirrels do not consume enough bait within the required period of time the rodenticide will not provide effective control. Therefore, a baiting strategy must first be evaluated in relation to foraging behaviors. Variations in quantity of bait used, and the timing and location of bait placement will affect both probability that a squirrel will discover the bait and the subsequent rate of consumption. The closer grain can be placed to the burrow, the greater the probability that it will be discovered and consumed before the normal food source is reached (Lund 1988a).

Although the development of control strategies is based upon the predicted response of ground squirrels to control techniques, much of our understanding of their foraging behavior is primarily anecdotal. It has been noted that California ground squirrels will feed on grain bait between late March and early November, after the natural vegetation has dried but before they begin to hibernate. It has been observed that during these months, squirrels will find bait and consume it on site or take it back to the burrow to consume it (Clark 1994). Current baiting techniques are based on the belief that scattering grain appeals to the squirrel's foraging tendency and is therefore the most effective mode of bait distribution. Ground squirrel feeding behavior in their burrow is relatively unknown. A qualitative study of California ground squirrel biology reported that ground squirrels most often forage before 1000 hr or after 1700 hr and that they will feed for about 30 min. at a particular location (Lindsdale 1946). Lindsdale also found that they will carry food stored in cheek-pouches to mounds outside of their burrows for consumption and stated that they will cache food within and near the burrow exit, but made no reference about eating within the burrow.

Some forms of in-burrow baiting have been used for California ground squirrels but little is known about their effectiveness and there is a general assumption that ground squirrels will not readily consume grain that is piled within their burrows. However, a literature review provided no recent evidence to support this assumption, and some research has suggested otherwise. For example, in a study on the efficacy of Lufenuron to control fleas (vector of plague), the Lufenuron was administered using feed cubes that were placed in the burrows and subsequently fed on by the ground squirrels (Davis 1999). It has also been stated that squirrels will scatter grain placed within their burrows when cleaning the burrow (Quayle 1912) but a review of the literature produced no evidence suggesting that this observation can be applied to the species as a whole.

When developing a control program, it is important to consider the mode of action of the toxicant that will be used since this impacts how the material must be consumed. For example, zinc phosphide requires a relatively large feeding over a short period of time (Sterner 1994). Anticoagulants require small feedings over a long period of time (Whisson and Salmon

2002). Clearly, a baiting strategy must accommodate the consumption requirements of the particular bait.

The rodenticides currently registered for control of California ground squirrels are diphacinone, chlorophacinone, and zinc phosphide. Of these, the anticoagulants, diphacinone and chlorophacinone are the rodenticides most commonly used for control of ground squirrels because of their general safety and low probability of causing bait shyness (Whisson et al. 2000). Anticoagulants act as chronic toxicants, and are most effective when animals are exposed to them multiple times over the course of a few days (Hadler and Buckle 1992). Current anticoagulant baiting methods aim to provide excess bait so that all individuals in a treatment area will be likely to consume several doses. These application methods may increase the potential for exposure of bait to non-target species (Whisson et al. 2002). Consequently, if anticoagulants are used, a baiting method that would result in slower consumption, increase probability of squirrels finding the bait, and limited access to the bait by other species would be ideal. When developing a control program, it is also important to consider that anticoagulants pose both a primary risk through bait exposure and a secondary risk to non-target species through the carcasses of poisoned squirrels.

Zinc phosphide is used less frequently for ground squirrel control, and it has been reported that its effectiveness in the control of California ground squirrels is inconsistent (Marsh 1987). However, recent studies suggest that the baiting method may be a contributing factor in the effectiveness of zinc phosphide, and that this rodenticide may result in 96% population reduction when used in some situations (Salmon et al. 2000). Zinc phosphide is a fast acting acute toxicant with a single feeding required (Lund 1988b). This toxicant poses some primary non-target threat but a much lower secondary hazard. Consequently, if a baiting strategy such as in-burrow baiting were employed, the hazards associated with bait exposure to non-target species could be reduced.

This study will determine whether California ground squirrels consume sufficient grain within their burrows to justify further testing of this application method as a baiting strategy, and test the null hypothesis that there is no difference in bait consumption between above in-burrow surface baiting strategies.

METHODS

In order to determine whether ground squirrels will consume bait placed within the burrow, we performed a paired burrow study comparing grain consumption from in-burrow baiting versus surface baiting. Field studies were conducted in the Experimental Ecosystem on the University of California Davis campus in Yolo County, California, between 28 May 2002 and 10 June 2002. This time period was during the summer months when squirrels actively forage on seeds and grain. The ecosystem is a 40-ha area with a relatively flat topography. The vegetation is primarily grasses and forbs such as brome (*Bromus spp.),* wild oats *(Avena spp.),* milk thistle *(Silybum marianum),* mustard *(Brassica spp.),* and yellow star thistle *(Centaurea solsticialis).* The vegetation dries and goes to seed in the summer, as is normal for the Mediterranean climate that characterizes this area. The entire area is considered good ground squirrel habitat (Salmon et al. 1987). We selected a recently mowed area within the ecosystem in which burrows of an active ground squirrel colony were relatively visible. The study site itself had a relatively uniform distribution of grasses and forbs.

For the purposes of the study, we considered each burrow entrance a

"burrow." We surveyed all visible ground squirrel burrows within our study site. Of approximately 130 burrows surveyed, 60 were selected on the basis of visibility of the burrow entrance, apparent ground squirrel activity, and proximity to one another. So that grain could easily be distributed and recollected from within the burrow, we considered only burrows with an entrance slope of less than 60% for in-burrow baiting. A nearby burrow was then selected for surface baiting. Initially, activity was ascertained by a lack of cobwebs and debris within the burrow entrance, and a presence of feces, seedpods, and/or tracks surrounding the burrow. We used a paired design in order to reduce variation in grain reduction that might be due to either variation in ground squirrel activity or variation in environmental factors at different areas in our study site. The 2 burrow entrances in each pair were within 1.5 m of each other. The area surrounding each burrow was raked free of debris and the burrows were marked with numbered flags.

We placed 20 g of grain in a pile within the burrow entrance using a bait spoon. The pile of grain was deposited as deep within the burrow as was possible but still allowing observation. Before each application, we scooped out any bait remaining from the previous application using a spoon. The area surrounding the burrow was also surveyed for bait that may have been pushed out of the burrows by the squirrels. We scored the amount of grain consumed by measuring grain remaining and assigning it to one of 4 classes.

For comparison, we used spot baiting to distribute grain to the burrows selected for surface baiting. For this treatment, an approximately 25 cm^2 area within 10 cm of the burrow entrance was cleared of grass and debris so that the bait applied would be visible. We scattered 20 g of clean oat grain bait using a bait spoon. This resulted in a bait distribution of approximately 0.8 g/cm^2. Before each application, bait remaining from previous applications was removed from the site and the amount of grain remaining was measured.

We monitored burrows during 2 consecutive 5-day periods with 15 burrow pairs monitored during each period. We were not able to monitor all burrows within a single baiting period because of time constraints. The weather was relatively uniform (warm and sunny with low winds) over the course of the study.

We applied bait and collected data twice daily, once at approximately 0730 hrs (within 1-2 hr after dawn) and once at approximately 1730 hrs (within 1-2 hr before dusk). We extended the nighttime baiting period beyond the dark hours to decrease the probability that feeding by nocturnal species would occur during the daytime baiting period. We assumed that any reduction of grain between morning baiting and evening data collection was due to consumption by ground squirrels. Reduction in grain that occurred over-night, when squirrels are typically inactive, was assumed to be primarily the result of consumption by nocturnal, non-target species.

We rated bait consumption using a scale of 0 - 3: 0 = bait untouched or very little consumed (0 - 25%); 1 = a low level consumed (>25 - 50%); 2 = a moderate to high level of consumption (>50 - 75%); and 3 = all or almost all of the bait was consumed (>75 - 100%). We determined the consumption rating for each burrow by averaging the daily consumption levels. We then compared the consumption for all burrows resulting from in-burrow versus surface baiting using a paired t-test with the means procedure.

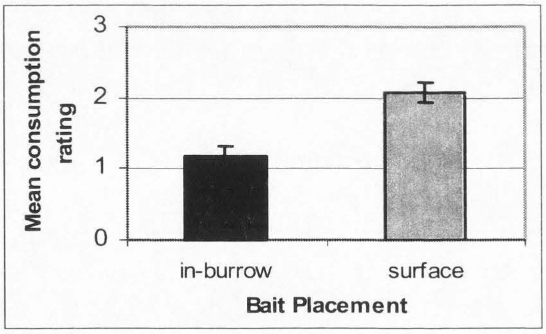
Bait acceptance on some burrows was also monitored qualitatively with an infrared video unit with 4 cameras that were

mounted on metal stakes outside selected burrows 3 days prior to the beginning of the study. This was done to verify the time and species involved in the bait reduction. We assessed foraging activity by the number of feeding events occurring during each baiting period. We defined feeding events as times that an animal fed for longer than 15 seconds in a particular location. The burrows used for video monitoring were selected based on constraints of the camera equipment, such as cord length relative to distance between pairs, but were representative of the sample.

RESULTS

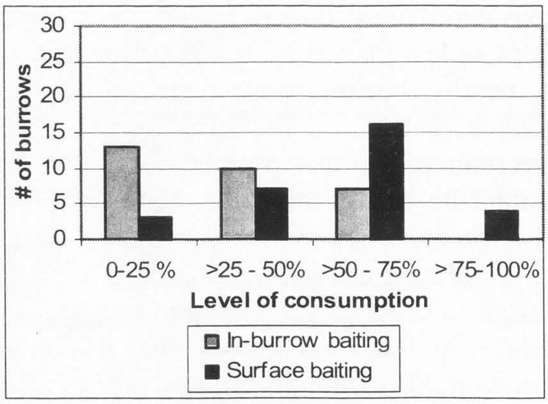
Daytime bait consumption occurred in at least one burrow within every pair. The mean consumption rating for in-burrow baiting averaged 1.187 ± 0.752se. The mean consumption rating for surface baiting averaged 2.080 ± 0.780se (Figure 1). The difference between these means was significant ($P < 0.0001$; $t = 5.58$).

Figure 1. Mean diurnal grain consumption ratings for ground squirrels for in-burrow vs. surface baited burrows. (0 = 0 – 25%, 1 = >25 – 50%, 2 = >50 – 75%, 3 = 75 – 100%).



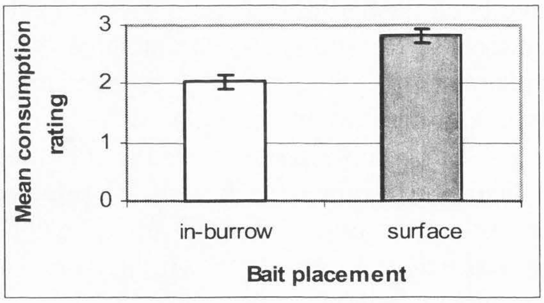
Though the average consumption rating was >0 for all but 2 of the in-burrow baited burrows, a relatively high proportion (43%) of the in-burrow baited burrows had a consumption rating of <25% and none had a rating >75%. The consumption ratings for surface-baited burrows were more normally distributed about the mean, 53% having consumption rating between 50 – 75% (Figure 2).

Figure 2. Diurnal consumption ratings for in-burrow-baited burrows. (Daytime baiting period = 0730 – 1730 hr).



Nighttime bait consumption occurred in at least one burrow within every pair. The mean consumption rating for in-burrow baiting averaged 2.047 ± 0.752se. The mean consumption rating for surface baiting averaged 2.820 ± 0.780se (Figure 3). The difference between these means was significant ($P < 0.0001$; $t = 7.21$)

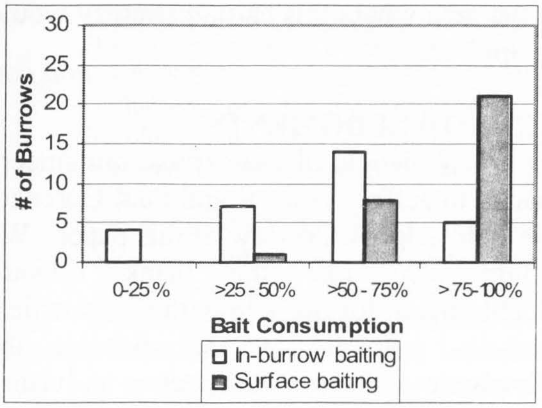
Figure 3. Mean nocturnal grain consumption ratings for nocturnal rabbits for in-burrow vs. surface baited burrows. (0 = 0 – 25%, 1 = >25 – 50%, 2 = >50 – 75%, 3 = 75 – 100%).



The surface bating treatment had a higher proportion of burrows with a consumption rating of >75% than the in-

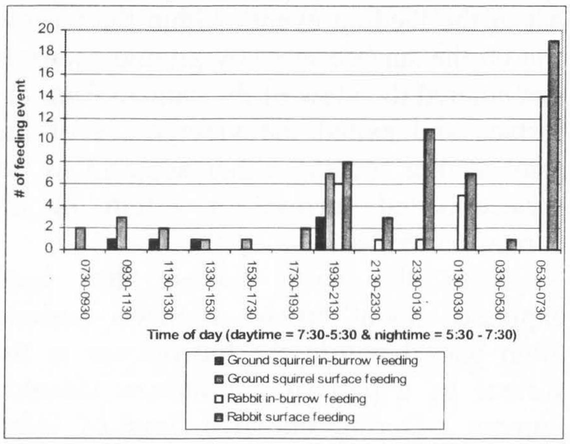
burrow baiting treatment. The distribution for in-burrow baited burrows was relatively normal, 46% of the burrows having consumption between 50 – 75%. The majority of the surface baited burrows had 100% consumption (Figure 4).

Figure 4. Nocturnal consumption ratings for surface-baited burrows. (Nighttime baiting period = 1730 hr – 0730 hr.



The 120 hours (5 consecutive days) of video observation confirmed that grain consumption during the day could be attributed to foraging by ground squirrels. Ground squirrels were recorded entering the feeding area from beyond the camera view, feeding on surface baited grain or entering the burrow entrance to feed, and leaving the burrow area after feeding. Surface feeding events occurred 14 times and in-burrow feeding events occurred 6 times. During the baiting periods in which there was no ground squirrel activity observed bait consumption was zero for the video-monitored burrows. Furthermore, except for 1 morning on which a yellow-billed magpie was recorded in the feeding area, no species other than ground squirrels were observed during the daytime baiting period. The magpie did not feed on the grain. The video data also indicated that nighttime consumption was the result of feeding by desert cottontail rabbits (*Sylvilagus audubonii*). Rabbits fed regularly during the nighttime baiting period, being most active close to dawn, between 0530 – 0700 hr, with feeding occurring as late as 0715 during one baiting period. At least 2 ground squirrels were also observed foraging during 1 nighttime baiting period at 2130 hr (Figure 5).

Figure 5. Feeding activity by ground squirrels and rabbits at video-monitored burrows. (Daytime baiting period = 0730 – 1730 hr nighttime baiting period = 1730 hr – 0730 hr).



DISCUSSION

This study demonstrates that California ground squirrels will feed on grain placed inside their burrows. However, in-burrow baiting resulted in significantly less overall grain consumption than surface baiting, suggesting that this baiting strategy would likely result in either a lower overall quantity of bait consumption or a slower rate of consumption. Average daily consumption rating for most of the in-burrow baited burrows was less than 25%, further supporting this conclusion. This reduced consumption might result in reduced efficacy for some rodenticides, particularly the acute materials. However, if in-burrow baiting resulted in a reduced rate of consumption continuing over the course of a few days, it might be an effective method of applying anticoagulant baits.

Tests that measure both the effectiveness of control and risk to non-target species should be conducted to determine whether this might be a feasible alternative to spot baiting.

The video data support the assumption that daytime reduction in grain is caused by ground squirrels, both inside and outside of the burrow. A squirrel was observed exiting a video-monitored burrow only once during the study period. Otherwise, the cameras recorded no activity by squirrels emerging from the burrows. All of the feeding events within the burrow and on the surface were by ground squirrels that entered the view of the camera from the surface and exited the view range of the camera after feeding either adjacent to the surface baited burrows or within the in-burrow baited burrows.

In the past, concern has been expressed about ground squirrels pushing grain placed within the burrow out to the surface as a part of the burrow cleaning process. During our five days of video recording, we never observed ground squirrels scattering grain from within their burrows, and we never found scattered grain outside of in-burrow baited burrows. One morning we observed extensive burrow cleaning behavior for 1 in-burrow-baited burrow but there was no grain scattered from within the burrow along with the dirt and debris that were cleared out.

We have established that California ground squirrels will eat grain placed within their burrows, but we need to do further tests to evaluate the effectiveness of in-burrow baiting as a method of applying anticoagulant baits. We also need to determine whether there will be changes in bait consumption if grain is applied deep within the burrow rather than near the surface where there is a relatively high amount of ambient light. If either deep in-burrow baiting or in-burrow baiting near the surface results in substantial reductions in ground squirrel population, further tests could be done to determine whether this is an effective strategy for reducing risk. Whether in-burrow baiting should ultimately be used as an alternative method for application of anticoagulant or other toxic baits depends on whether the potential reduction of risk to non-targets outweighs the potential costs (labor or reduced control) in the area where this baiting strategy would be applied.

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