POSTER PRESENTATION

Investigating Methods to Control Piute Ground Squirrels in Irrigated Crop Ground

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ABSTRACT: Piute ground squirrels, a subspecies of Townsends ground squirrels, are adapted to the Great Basin, which is characterized by extreme seasonal temperatures and highly variable precipitation that concentrates plant growth between February and July. Current available methods to manage ground squirrel populations in southern Utah were ineffective. We tested spot treating ground squirrel burrows with either Ditrac or Rozol, spot treatment of Ditrac compared to Rozol via bait stations, treating cabbage with zinc phosphide and baiting in fallow corners of irrigated agriculture, and spot treating with Rozol in early spring as possible methods to manage this subspecies of ground squirrel. Spot treating ground squirrel burrows with Ditrac and Rozol in early spring resulted in a decrease in the number of squirrels and active burrows counted. Spot treating with Ditrac and using Rozol bait stations in mid-spring did not result in a decrease in the number of squirrels and active burrows counted. Finally, using a 2% zinc phosphide solution baited with cabbage during the early summer resulted in a decrease in both squirrel numbers and active burrows, with minimal above-ground carcasses. Although early spring is not a common time to use grain-based bait, this method is effective at reducing ground squirrel numbers in alfalfa fields in Utah. Furthermore, using zinc phosphide is a possible new control method for Utah. Future research with larger sample size, in additional areas with this species is recommended.

KEY WORDS: chlorophacinone, diphacinone, Piute ground squirrel, *Spermophilus townsendii mollis*, Utah, zinc phosphide

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INTRODUCTION

Townsend's ground squirrel and sub-species (*Spermophilus townsendii* spp.) are short-lived, with high reproductive rates; they have the second highest reproductive rate of 18 ground squirrel species (Van Horne et al. 1997). Their active season is concentrated to increase recruitment and survival during a short season of food availability. While each subspecies differs slightly, in general they emerge from their burrows in February and young are born in March. Immergence into aestivation is correlated to body condition, with larger, fatter males beginning aestivation as early as June. Piute ground squirrels (*S. t. mollis*), a subspecies of Townsend's ground squirrels, are adapted to the Great Basin in the western United States, which is characterized by extreme seasonal temperatures and highly variable precipitation that concentrates plant growth between February and July (Rickart 1982). As a result, this subspecies has lower body temperatures and is able to withstand higher ambient temperatures than other species within this genus. Female Piute ground squirrels have a more synchronized emergence and breeding season than their congenitors, although in general the subspecies' emergence from hibernation is related to soil temperatures (Rickart 1982). While Piute ground squirrels exist across the Great Basin, in areas with agricultural production its populations can become denser than would be found in natural settings because agricultural productions provide abundant resources that can help mitigate effects that drought or long winters might have on their survival (Van Horne et al. 1997). Piute ground squirrel populations in southern Utah are increasing, likely because of access to irrigated alfalfa production.

Managing Piute ground squirrel populations can be challenging because of a combination of climate, ground squirrel biology, and approved pesticides labeled for use in Utah. Additionally, while much is known about Townsend's ground squirrels, little research has been conducted on the subspecies Piute ground squirrel in particular. When managing vertebrate pest populations, ideally, control efforts target females to result in the greatest impact to the population size (Van Horne et al. 1997); however, if treatment cannot occur before females give birth, controlling all segments of the population during their short active season is necessary. Utah's current control programs for Townsend's ground squirrels target the animals when the adults first emerge from hibernation and begin to breed, usually starting in the middle of February and lasts until the alfalfa greens up around the middle of March. Because emergence is related to soil temperature, in some years Piute ground squirrels do not emerge until early March. Most lethal control methods, such a toxic bait, require bare ground before they can be applied, which can sometimes be as late as mid-March in southern Utah. As a result, in many years there is a span of 1-3 weeks in which female ground squirrels are still active above ground (i.e., they are still breeding) and the ground is suitable to apply licensed toxic bait to reduce ground squirrel populations.

If one cannot target the female Piute ground squirrels prior to their producing offspring, managing the population during the active season is problematic; once alfalfa

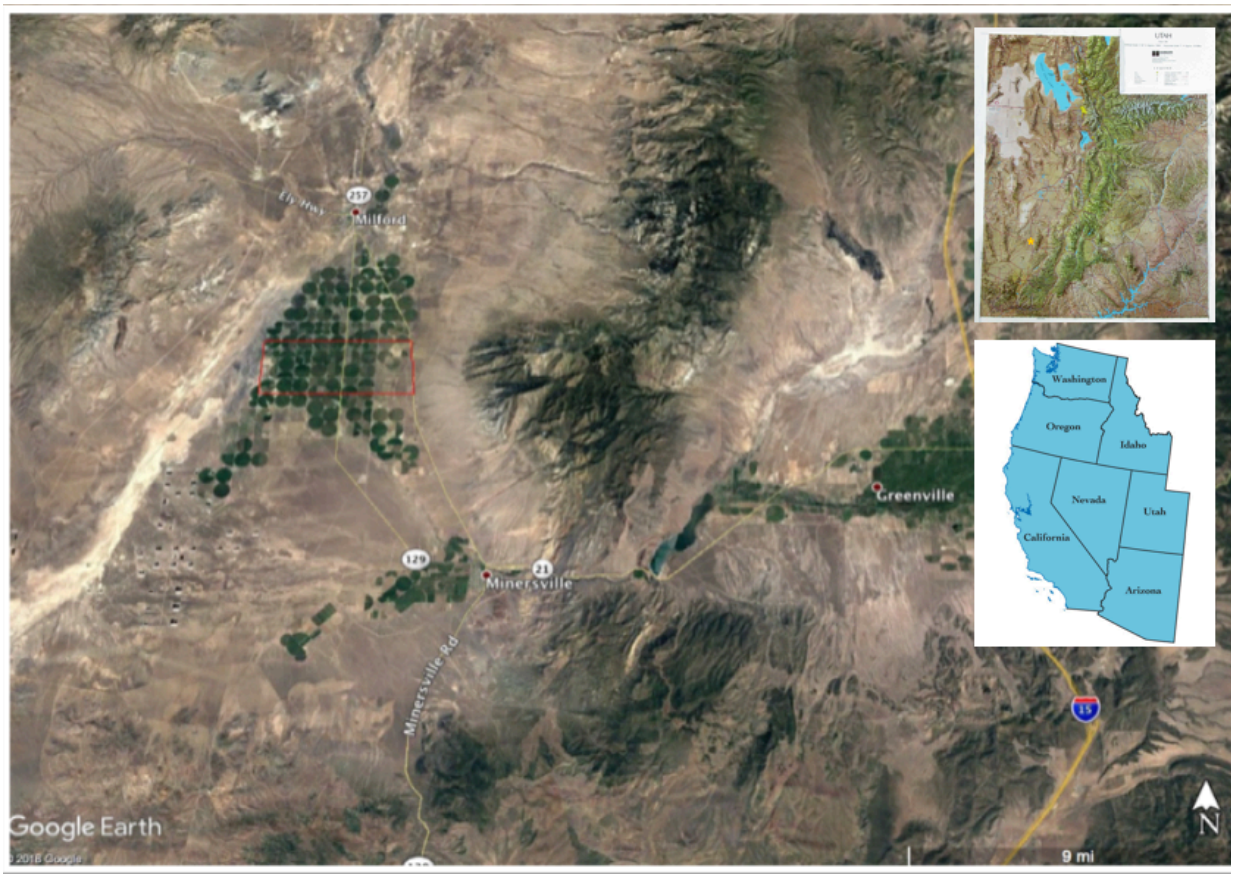

Figure 1. Location of the study site in Beaver County, Utah, 2016-2017

begins to grow, the toxic grain bait treatments have little effect. Ground squirrels select their forage based on water and protein content (Van Horne and Sharpe 1998), particularly as the season progresses into summer. While seeds and grains are important to their diet, consumption of seeds decreases in dry conditions. Consequently, once it begins to grow, alfalfa is more desirable than dried grain or even the surrounding native shrub habitat.

There are a couple registered pesticides and delivery mechanisms registered for use in Utah on ground squirrel species. Wilco (Wilco Distributors, Lompoc, CA) makes a pelletized bait with 0.005% diphacinone, registered to manage Townsend's ground squirrels in Utah. However past research has determined that Piute ground squirrels will not collect or consume this bait (M. Nelsen, pers. comm.). Since 2009, we have experimented with a population control program that consisted of using a grain bait impregnated with 2% zinc phosphide (e.g., Prozap, HACCO, Inc.; Randolph, WI). For the first several years this baiting program helped reduce the number of squirrels; however, in the past four years the squirrel numbers have significantly increased. Unfortunately, it appears our current method is either not appropriate for this species, or not flexible enough to coincide with the biological activity of ground squirrels each spring. We determined to study several different methods of controlling ground squirrels in irrigated pastures in southern Utah, to expand the window of opportunity for farmers to reduce squirrel numbers.

There are a few registered pesticides used to treat ground squirrel species in other states. Ditrac (Bell Laboratories, Madison, WI) is a grain bait with 0.005% diphacinone that was specifically designed to manage California ground squirrels (*Otospermophilus beecheyi*). Similarly, Rozol (Liphatech, Milwaukee, WI) is a grain bait with 0.005% chlorphacinone and is labeled for use on black-tailed prairie dogs (*Cymomys ludovicianus*). Finally, zinc phosphide, in forms other than pellets, has been used to successfully treat ground squirrels in the past. Matschke et al. (1983) reduced Richardson's ground squirrels (*Urocitellus richardsonii*) by broadcasting 2% zinc phosphide grain bait. The idea of using cabbage as a green bait was tested by White (1972), who reported its efficacy at delivering sodium monofluroacetate (1080) to ground squirrels. O'Brien (2002) determined that ground squirrels (including Townsend's ground squirrel) could be effectively treated using strychnine applied to cabbage as bait, placed just inside an open burrow. Oregon and Nevada have recently begun experimenting with using zinc phosphide (2% solution) on cabbage to control Townsend's ground squirrels, with success.

With several options for investigating a new pesticide and delivery method, we determined to test pesticides and delivery methods at different stages of squirrel activity. Should our initial study result in the successful reduction of ground squirrels by any of the unregistered uses, we intended to pursue our focus on these successes to conduct another study with a larger sample size for the

successful compound application within the regulations of a research permit, pursuant to the U.S. Environment Protection Agency's Section 24(c) and follow through with the registration of this product for an approved label of use for the compound, using the successful method.

METHODS

Study Area

Field trials were conducted in cooperation with local alfalfa producers in Beaver County, Utah (Figure 1). The natural landscape in Beaver County is considered high desert, part of the Great Basin ecosystem as defined by West and Young (2000). Shrubs are generally < 1m in height and sparsely spaced with loamy surface soils, and microphytic crusts. Grasses are also sparsely distributed. The elevation of the study area ranged from 1,493 m in Milford to 1,798 m in Beaver. The mean annual air temperature throughout the study area ranged from 7.2°-10°C, averaging 100-140 frost-free days annually. The average maximum temperature (1971-2000) occurred in July (31.3°C). The annual precipitation (1971-2000) ranged from 23-30.5 cm, presenting predominantly as snow in March and April and rain in August (Utah Climate Center 2016). The soils of the study area are considered a silty clay loam, of 0-2% slopes that the Natural Resource Conservation Service considers prime farmland if irrigated and a gravelly loam of similar slope that is not classified as prime farmland (NRCS 2016). The water table was a minimum of 2 m below the surface.

Beaver County ranks 10th in the state in the number of acres in hay, grass silage, and greenchop production (113.31 km^2; 28,000 acres), with another 20.24 km^2 (5,000 acres) in corn silage, corn for grain, and wheat (USDA 2012). Farm production is located around three municipalities: Beaver, Milford, and Minersville. The largest municipality in Beaver County is the town of Beaver, with roughly 2,500 residents and another 500 persons living outside the municipal boundary. Milford, to the west, has 1,400 residents within its municipality and the surrounding areas.

Survey Methods

Because we were using products in a way that is not currently registered in Utah, we consulted with the Utah Department of Agriculture and Food to determine our ability to research the use of these products as the first step in conducting research to change the product registration. As per our consultation, we limited each type of application to 1 acre per study. Field trials consisted of the following treatment types: a) spot treating ground squirrel burrows with either Ditrac or Rozol grain bait prior to alfalfa green-up; b) distributing Ditrac via spot treatment and Rozol via bait stations, prior to alfalfa green-up; c) treating cabbage with zinc phosphide and baiting in fallow corners of irrigated alfalfa, once alfalfa has begun to grow; and d) spot treating ground squirrel burrows with Rozol prior to alfalfa green-up. Control plots received no treatment.

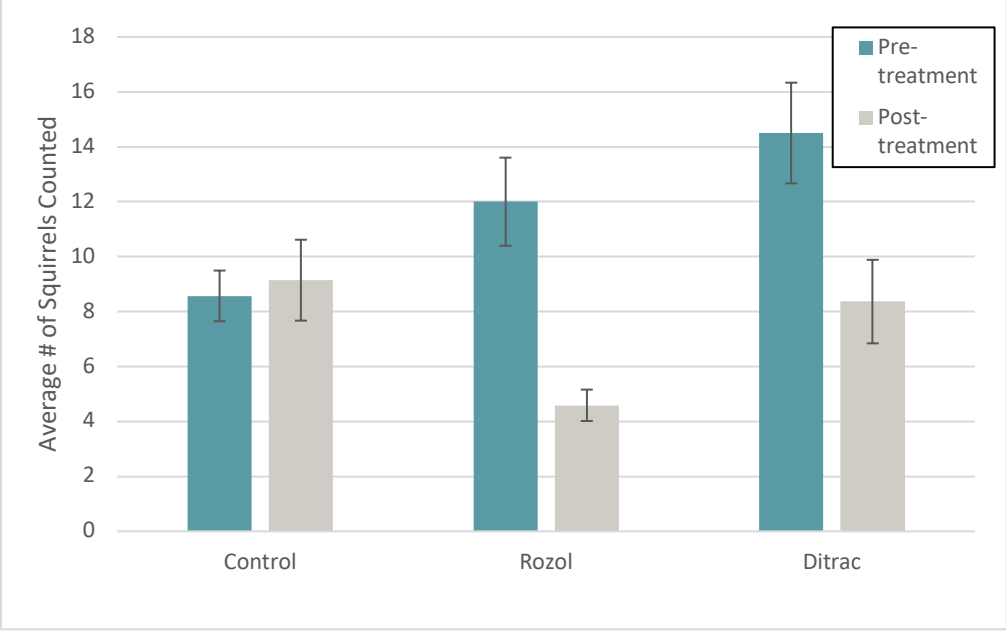

Figure 2. The average number of ground squirrels observed during repeated observations before and after spot treatment with Rozol and Ditrac, Beaver County, Utah, March 3-16, 2016.

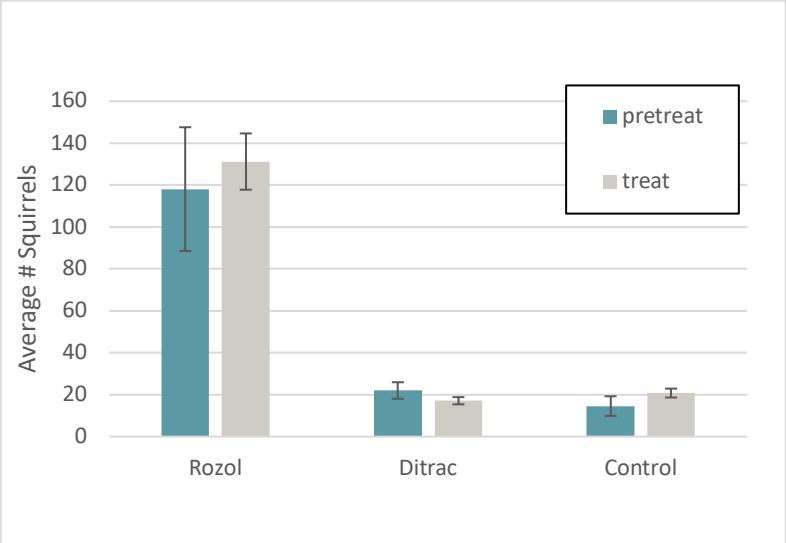

Figure 3. The average number of ground squirrels observed during repeated observations before and after spot treatment with Rozol bait stations and Ditrac, Beaver County, Utah, April 29 - May 14, 2016.

In 2016, we studied a method of spot-treating, which is directly treating only active burrows, prior to the alfalfa growing season. This method has been studied on California ground squirrels using diphacinone (Ditrac, 0.005% diphacinone), and resulted in high efficacy of the method (Baroch 1996). Concurrently, we tested this method using a Rozol 0.005% chlorophacinone bait (Liphatec, Inc., Milwaukee, WI) currently labeled to control voles in Utah via broadcast or spot treatment methods, although the product is registered for use on prairie dogs in other states. Next, we compared spot treating Ditrac to using Rozol in bait stations designed for ground squirrels. Finally, we investigated the use of zinc phosphide on green bait as a control agent. Nevada uses fresh cabbage treated a with zinc phosphide-oil mixture (2% zinc phosphide as active ingredient) to control ground squirrels (*Spermophilus* spp.), with documented success (Balliette et al. 2006). California is also investigating this method to control Belding's ground squirrels (R. Baldwin, pers. comm.). In 2017, using the same methods and study design, we studied the ability of spot treating with Rozol grain bait to reduce ground squirrel populations prior to alfalfa growth. The details of each method are as follows.

Ground Squirrel Surveys

Survey methods were the same for each part of the study. These surveys were repeated in entirety for each part of the study (spot treatments, bait stations, and cabbage). We conducted two indices to measure a change in ground squirrel populations: visual counts and active burrow indices.

Visual counts were conducted on days with <50% cloud cover and sustained winds <20 mph, to reduce the influence of weather on monitoring ground squirrel activity. Pre-treatment visual surveys were conducted on each study plot for a total of three days, 1-3 days prior to the beginning of the baiting. We attempted to make them three consecutive days, and we randomly assigned the order in which study plots were surveyed. Post-baiting surveys began seven days after the initial application of bait and continued for three days.

Visual counts were conducted from within a truck, roughly 300 ft from the study plots. Upon arrival to a study plot, the observer waited five minutes before starting the survey, to minimize the effects of human disturbance on squirrel activity. We determined five minutes was adequate because after that amount of time, squirrels near the truck resumed their activity. Using binoculars, the observer began to count squirrels on one side of the field, excluding the buffer, and slowly panned across the field for two minutes. The observer recorded the number of ground squirrels counted. The observer then waited five minutes and repeated the process two more times, for a total of three surveys. The highest number of squirrels counted per 2-min scan was recorded as the official count.

Active burrow indices were conducted pre- and post-treatment. Three days before the beginning of the trials, all burrows were covered in each treatment plot and in the control plot. Active burrows, indicated by fresh excavated soil, were flagged. After 48 hrs, we resurveyed the plots, checking each flagged burrow and looking for any fresh new burrows. If any had been opened, we considered these active burrows. After the post-treatment visual count surveys were completed, we repeated the active burrow count indices.

***Spot Treating with Ditrac or Rozol*:**

This portion of our study was conducted March 3-March 16, 2016. For each compound, we used a 1-ac field. Additionally, we had one 1-ac field as a control, which had no pesticides applied; for a total of three acres in this study. Each plot was selected such that there was a minimum of 20 ground squirrels visibly present in the survey area. The perimeter of the plots (209 × 209 ft) was

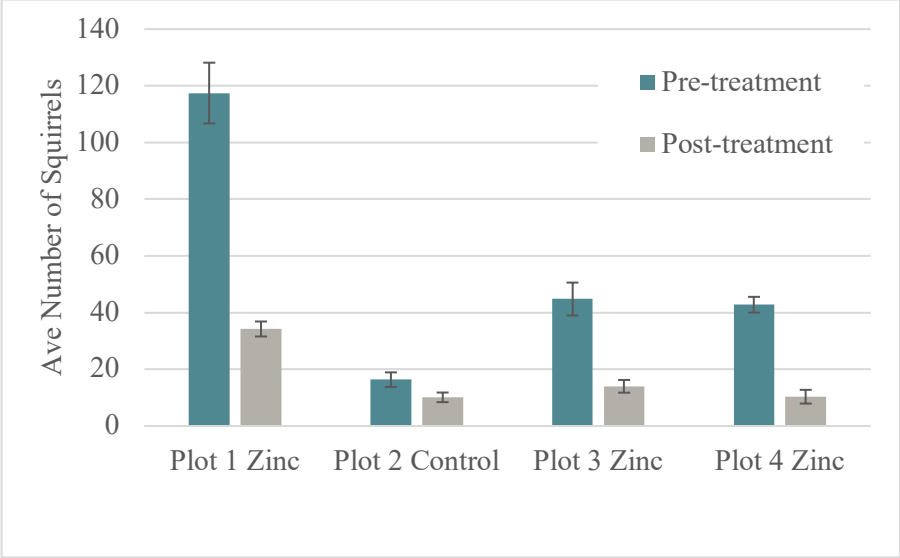

Figure 4. The average number of ground squirrels observed during repeated observations before and after treatment with Zinc, Beaver County, May 17 - June 1, Utah 2016.

mark with colored flagging. Around each acre a 200-ft buffer was also marked with flagging (of an opposing color). The buffer zone was included in the pesticide application but not in the surveys for squirrel activity. Each study area (and buffer) was separated from the next study area by 300 ft.

To apply the Ditrac, we used label instructions as approved for California ground squirrels to determine the amount of pesticide to use. This was similar to methods used in California from which we derived our study methods. We used a standard ¼-cup measuring cup to calculate the appropriate amount of pesticide to distribute, and spread the pesticide near each active squirrel burrow hole. To apply Rozol, we referred to label instructions for pocket gopher control and prairie dog control. Using ≤¼ cup per burrow hole, we applied the bait directly at the ground squirrel hole.

Both pesticides were applied on the same day or within 24 hrs. The control field was visited in a similar manner to the treated fields, but without any application of poison or placebo bait. We treated all burrow openings that appeared to be active in the pre-treatment survey conducted just prior to the baiting, applying the bait to the study area as well as the buffer zones.

Ditrac Spot Treatment vs. Rozol in Bait Stations

To conduct our next trial, we used the same study plots used in the spot treatment studies. We conducted this study April 29 - May 14, 2016. While they were the same plots, squirrels had one month to recolonize the area, and therefore we assumed the results would be independent of the previous study. During this time period, juveniles had left their burrows and were active above ground. We distributed Ditrac using the spot treatment method used in the first study period; bait stations were used to deploy Rozol. Bait stations were distributed at 50-ft intervals across the plot and the buffer zone. Bait stations were checked every 2-3 days to ensure that bait was consistently available to ground squirrels. Bait stations were active for seven days; at the end of seven days, we conduct post-treatment ground squirrel surveys and burrow surveys in all three fields.

Zinc Phosphide on Green Bait

The last portion of our study in 2016, to determine if zinc phosphide could be an effective tool, was conducted May 17 - June 1. We used two of the same plots used in the first two trials, and two new plots for this portion of the study. The first of these two plots had been used as a control in the first trial and had seen little effect in the second trial. The second of these two plots had been the control in the second trial, and therefore there were many squirrels on this plot. One of the four plots was randomly selected to be the control plot. Once we had conducted ground squirrel surveys, and two days before the trials began, we pre-baited the study fields with cabbage that had no pesticide. We followed the process of preparing cabbage for zinc phosphide bait, cutting the cabbage and placing 1-2 oz at each active burrow. A group of burrows was treated as one burrow if they were less than three inches apart. After the pre-bait period, we applied zinc phosphide using the label instructions for use in California, at a rate of ¼ cup (2 oz) of zinc phosphide concentrate (63.2% a.i., Pocatello Supply Depot, Pocatello, ID) and 24 oz of food-grade canola oil per 20 lbs of cabbage. We distributed 1-2 oz of baited cabbage at each active burrow, similar to O'Brien (2002).

Zinc phosphide is a fast-acting chemical; animals may die above ground, becoming accessible to scavengers. In an abundance of caution, we conducted carcasses searches for ground squirrels within 36 hrs after the application of zinc phosphide, concurrent the to ground squirrel surveys previously described.

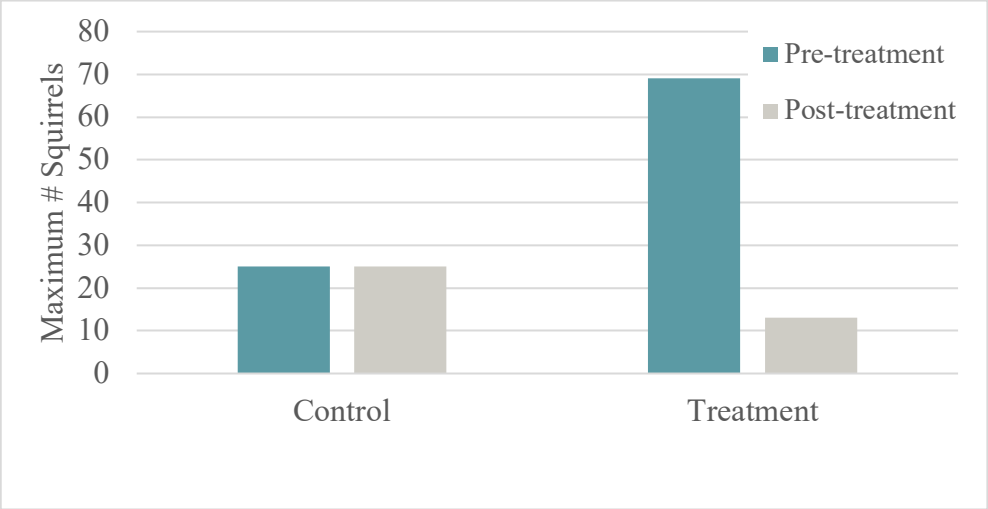

Figure 5. The maximum number of ground squirrels counted pre- and post- Rozol spot treatment, Beaver County, Utah March 3-22, 2017.

Rozol Spot Treatment

In 2017, we repeated the Rozol study, because of the interference we had experienced with this portion of the study in 2016, and to move forward with obtaining a registration for Rozol for Townsend's ground squirrels in Utah. From March 3 - March 21, 2017, we repeated our Rozol study to determine if using a spot treatment of Rozol would reduce ground squirrel numbers during their breeding season. For this study, we had one control site and one treatment site. Initially, each site was intended to be 1 ac to compare to other portions of our study. However, squirrel density was lower in 2017 than 2016, and we increased the size of each site to 2 ac to obtain a high enough squirrel count (20 individuals) to conduct the study. We collaborated directly with Liphatech to administer this study according to their protocols so that we could move forward toward obtaining a registration for this product's use on Piute ground squirrels in Utah. We used the same methods to set up, administer Rozol, and measure squirrel activity as those used for spot treatment using Rozol in 2016.

Statistical Analyses

For each trial of the study, we used the average number of ground squirrels observed during the visual scans and active burrow counts as indexes of the population density in each plot for the day counted. We calculated the average number of squirrels recorded for the pre-treatment and post-treatment count period for each plot. We also recorded the number of active burrows per study area in the pre- and post-treatment periods. We used the Kruskal-Wallace nonparametric rank sum test to compare the number of ground squirrels recorded in pre- and post-treatment periods (this method reports a χ^2 test statistic). We also used Tukey multiple range tests to compare results from pre- and post-treatment counts. The measure of the success was a statistically significant ($P \leq 0.05$) reduction in the numbers squirrels counted.

RESULTS

Spot Treatment of Ditrac and Rozol

A Kruskal-Wallace rank sum test determined the average number of squirrels counted on plots treated with Rozol decreased after treatment ($\chi^2 = 12.5$, df = 1, $P < 0.001$), as did those treated with Ditrac ($\chi^2 = 3.8$, df = 1, $P = 0.05$; Figure 2). Because of the small sample size, statistical analyses were not conducted on the number of open burrows counted before and after treatment. However, we observed a 46% reduction in the number of open burrows after treatment with Ditrac. In the field treated with Rozol, we observed an 81% reduction; however, the farmer disked his field during the second day after treatment, and therefore we cannot determine if the reduction is due to the destruction of burrows or the reduction in the population. In our control field, we observed an 87% increase in the number of open burrows observed during the post-treatment observation period.

Ditrac Spot Treatment Compared to Rozol Bait Stations

A Kruskal-Wallace rank sum test found no significant differences in the number of squirrels counted before and after treatment with Rozol bait stations ($\chi^2 = 0.095$, df = 1, $P = 0.76$) or when treated with Ditrac ($\chi^2 = 0.95$, df = 1, $P = 0.33$; Figure 3). Because of the small sample size, statistical analyses were not conducted on the number of open burrows counted before and after treatment. The number of open burrows counted on plots treated with Rozol decreased by 54%, those treated with Ditrac had a 56% reduction in the number of open burrows. However, the number of open burrows in the control plot decreased by 54% during this time; therefore, we do not find this reduction in the number of active burrows significant.

Zinc Phosphide on Green Bait

A Kruskal-Wallace rank sum test determined that there was a significant decrease in the number of

squirrels counted on plots treated with zinc phosphide (χ^2 = 12.552, df = 1, P < 0.001; Figure 4). There was a 52% reduction in the number of open burrows counted after the plots were treated with zinc phosphide. During the post-treatment surveys, there was a 24% reduction in the number of open burrows counted on the control plot. Our carcass search found one dead ground squirrel at each of the plots; two were adults and one was a juvenile. Two carcasses were intact and one was scavenged; two were in the treated area and one was in the buffer area.

Spot Treatment of Rozol (2017)

This portion of the study was statistically analyzed by Liphatech. Due to contraints with their confidentiality during their labeling process, we were unable to publish the statistical results of this data analysis. However, we present the figures for exploration. In 2017, Rozol spot treatment resulted in an 81% reduction in squirrel numbers, while there was no reduction in squirrel numbers in the control plot (Figure 5). During this time, there was a 91% reduction in active burrow counts in the treated plot; there was a 51% reduction in active burrow counts concurrently in the control plot.

DISCUSSION

Spot Treatment of Rozol and Ditrac

Our results supported previous studies conducted on California ground squirrels that indicated Ditrac and Rozol can be used as a spot treatment to reduce ground squirrel numbers (Baroch 1996). In contrast to Baroch (1996), who used spot treatment of diphacinone when native grasses were producing seed and juvenile squirrels would be actively foraging above ground, we conducted our study in early spring, when adults first emerge and there is very little green vegetation. We presume that even though squirrels may not be actively seeking seed at this time, they are most likely going to be attracted to any food source upon emergence. Therefore, grain was still attractive as a food source. Our active burrow counts were confounded for our Rozol study site. In 2016, our study plot for Rozol was disced by the landowner in a misguided attempt to reduce ground squirrel numbers during our post-treatment phase, which eliminated our ability to determine if there was a true reduction in the number of open burrows during this phase. However, active burrow numbers declined in our Ditrac study plot. When we repeated the Rozol spot treatment in 2017, we saw a reduction in ground squirrel numbers as well as active burrows. However, the control site also experienced a reduction in active burrow counts at this time; therefore it is difficult to determine if this reduction in burrows was a result of the Rozol treatment.

Ditrac Spot Treatment and Rozol Stations (mid-Spring)

The second stage of our study involved spot treating plots with using Rozol or Ditrac in bait stations designed to dispense bait to ground squirrels. One reason that Rozol isn't often used for non-burrowing animals is that it can be lethal to a wide range of mammalian and avian species. Using a bait station would reduce this availability to avian species, which are particularly attracted to the grain bait and are present in southern Utah during this time of year. This study was conducted in April-May, when alfalfa had begun to grow and there was green forage available. Usually grain bait stations are used when native grasses have started producing seed (Hazen and Poché 1992); however, in Utah, sometimes weather or professional time constraints prohibit producers from treating for ground squirrels in March, and therefore they try to find other options later in the spring. During 2016, juvenile ground squirrels were not above ground during this time, but would begin to emerge within a week or two after the treatment. In other years, juveniles may be seen during the first week of May, but the majority of the juvenile population usually emerges from their burrows in mid-May. We did not detect any reduction in ground squirrel population as a result of either spot-treating with Ditrac or Rozol bait stations. While the plots using Ditrac did experience a decrease in ground squirrel numbers and open burrows, this decrease was not large enough to be significant.

Zinc on Cabbage to Control Ground Squirrels

White (1972) reported successfully using cabbage as a delivery mechanism for sodium monofluoroacetate (1080) to control ground squirrels. Currently, there is no registered agricultural application for 1080 in Utah. Recently, California, Nevada, and Oregon have begun to use the fresh cabbage bait delivery method with zinc phosphide as the active ingredient. Zinc phosphide grain bait is a registered use in Utah and has been proven effective on other ground squirrel species (Matschke et al. 1983). Our study to test the possibility of using zinc phosphide applied to fresh cabbage in Utah supported past results of control efforts in Nevada, Oregon, and Montana (White 1972, Albert and Record 1981, O'Brien 2002). Our test resulted in a significant reduction in the number of ground squirrels and open (active) burrows.

We have been testing methods to control ground squirrels in late spring, to assist in squirrel control should we miss the window of time to apply bait in early spring. What is significant about this test is that it was initiated one week after the test comparing Rozol bait stations and Ditrac spot treatments to control ground squirrels, when we did not find a significant reduction in the number of squirrels or open burrows. Therefore, using zinc phosphide applied to cabbage and delivered to the open burrows could be a tool for reducing ground squirrels during a time of year when other methods fail. While the bait is delivered above ground, the quick uptake of the cabbage by squirrels minimizes any direct ingestion by non-target wildlife, as does the delivery of the cabbage directly to open burrows. We observed adult and juvenile ground squirrels retrieving and consuming the cabbage within minutes of its delivery.

Non-target safety is a concern when using zinc phosphide, a broad-spectrum rodenticide. We surveyed the area for carcasses 36 hours after bait delivery and found only a few carcasses above ground. Similarly, Albert and Record (1981) found 0.43 carcasses per 100 holes and determined that 75% of these carcasses were found within 48 hours of bait delivery. In a future test, we would recommend conducting multiple carcass surveys

within 96 hours after application if one desires to collect and dispose of carcasses off-site to reduce not target hazards. However, zinc phosphide detoxifies in a carcass over time, and does not accumulate in animal tissues (i.e., does not lead to bioaccumulation; Marsh 1987). Therefore, there is a low risk to those animals that do scavenge ground squirrel carcasses.

CONCLUSION

Our study was able to determine initial success in the use of Ditrac and Rozol in the early growing season (March, in Utah) to reduced Piute ground squirrel numbers. Reducing the adult breeding population before it begins reproduction is the most effective method to reduce damage due to ground squirrels throughout the alfalfa growing season. The use of zinc phosphide on fresh cabbage was also successful at reducing adult and juvenile ground squirrel populations. This is the first test in Utah of zinc phosphide on green bait, and also the first documentation of a pesticide application that can be used to reduce ground squirrel when alfalfa is green. Further research should be conducted with larger sample sizes to gather more evidence to support these methods for Piute ground squirrel control in Utah. These efforts should be conducted so as to provide support for a labeled use of these pesticide applications in Utah.

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