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Efficacy of BurrowRx® Fumigation for Control of Richardson's (*Urocitellus richardsonii*) and Columbian Ground Squirrels (*Urocitellus columbianus*) in Montana: Two Pilot Studies

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ABSTRACT: In recent years, landowners and pest management professionals have expressed increasing interest in methods that can control burrowing rodents without the residual and secondary poisoning risk characteristic of many rodenticides. Carbon monoxide injectors constitute one method that meets those requirements. The author tested the BurrowRx® to determine the injection time needed to successfully fumigate burrows occupied by Richardson's and Columbian ground squirrels in Montana. Efficacy for control of Richardson's ground squirrels on combined locations was 80% with a 60-second injection time and 44% with a 180-second injection time for Columbian ground squirrels. Average number of burrows and relative size for both species was collected also.

KEY WORDS: burrow fumigation, carbon monoxide, Columbian ground squirrel, Richardson's ground squirrel, rodent control, unregulated, *Urocitellus columbianus*, *Urocitellus richardsonii*, wildlife damage management

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INTRODUCTION

The burrowing and foraging by Columbian (*Urocitellus columbianus*) and Richardson's ground squirrels (*U. richardsonii*) can cause significant damage to crops, pastures, and lawns (Baril 1983, Johnson-Nistler et al. 2005). Although effective rodenticides and fumigants are available to manage ground squirrel numbers, many people choose to avoid pesticides on account of safety concerns, regulations, or a belief that they are not effective. While shooting and trapping are alternative control methods, their use can require significant time investments to obtain desired results.

The development of carbon-monoxide injectors introduced a new tool for the management of burrowing rodents. These devices, of which there are several models (PERC®, H&M Gopher Control Manufacturing & Sales, Tulelake, CA; Gopher X/BurrowRx®, Quality Manufacturing, El Cajon, CA; Cheetah, Cheetah Industries, Paso Robles, CA; and CO-Jack, Jack Rabbit Equipment, Ripon, CA), use the exhaust from a gasoline-powered engine to fumigate burrowing animals. Unfortunately, published research on the effectiveness of carbon-monoxide injectors is limited (Orloff 2012, Baldwin et al. 2016, Baldwin et al. 2017, Meinerz et al. 2018, Vantassel 2022) and none of the literature pertains to the control of ground squirrels native to Montana. [A search was performed via the Montana State University Library using the key words "carbon monoxide" + fumigant + rodent on August 10, 2023].

The researcher had little doubt that carbon-monoxide injectors could kill ground squirrels. It was perfectly reasonable to conclude that if carbon monoxide from ignitable gas cartridges could control ground squirrels, so could carbon-monoxide injectors (Dolbeer et al. 1991). Additionally, the researcher had received anecdotal reports from various sources that the devices were effective. What was unknown was how long a burrow needed to be treated to obtain lethal control of Columbian and Richardson's ground squirrels respectively. The answer to that question would likely be device, species, and soil specific.

The Montana Department of Agriculture's Vertebrate Pest Specialist decided to test the BurrowRx on Columbian and Richardson's ground squirrels as Quality Manufacturing donated the device several years earlier. The study sought to achieve two specific goals. First, determine the needed injection time to control Columbian and Richardson's ground squirrels, respectively. Although BurrowRx recommended an injection time of three minutes (BurrowRx No Date; BurrowRx 2018), we needed to determine what time was necessary for our species and soils. Second, we sought to obtain a better understanding of the burrow structure of Columbian and Richardson's ground squirrels as revealed through use of the BurrowRx's "smoke oil."

STUDY SITES

Columbian Ground Squirrel

The study site was a 37-acre pivot irrigated field located in northeast of Helena, MT in an area just north of Lake Helena consisting of residential homes with acreage characteristic of exurban landscapes (Google Earth Pro 2022; Newburn and Berk 2011). Soil was classified as Musselshell-Crago Complex with 2 to 8% slopes. (USDA-Natural Resources Conservation Service 2022). Approximately the northern ⅔ of the field was plowed and essentially barren of plants. The remaining southern portion was uneven with scattered grassy plants. The study period occurred between June 6-10, 2022. Weather conditions were warm with low/highs over the five days as follows 52/68, 47/71, 45/68, 53/82, and 58°/79°F. Rain was minimal during the study with 0.01 inches on June 6 and trace on June 8. However, almost ½ inch of rain fell two days before the study began (National Weather Service 2022).

Richardson's Ground Squirrel

The study site was located in a small residential subdivision of small acreage owners (approximately 20-acre lots) northwest of Lewistown, MT. Treatment occurred in three areas where Richardson's ground squirrels were

present: two pastures, a northern pasture approximately 4.7 acres and a southeastern pasture about 3 acres in size, and a horse pen of about 1 acre in size (Google Earth Pro. 2022). The pastures were used to feed several horses which were maintained by the landowner whose residence was on the property. Soil type for the entire area was described as Danvers-Tamaneen clay loams, with 0 to 2% slopes (USDA-Natural Resources Conservation Service 2022).

The first part of the study occurred between April 26-29, 2022 on the southeast field. Research began on the 26th during warm weather (low/highs of 33°/66°F) which was 6.2°F higher than normal. Weather conditions tended to cool, trending below the average monthly temperature of 40.9°F with temperatures ranging from 31/61, 28/55 and 31°/43°F (National Weather Service 2022). Rainfall consisted of 0.14 inches occurring on April 27, trace on the April 28, and 0.7 inches falling on April 29.

The second part of the study occurred during May 5-8, 2022 and focused on the northern pasture and the horse pen. The initial research day was warm with a low/high range of 38°/75°F which was 10.3°F above average. The remainder of the study period temperature ranges were 44/70 and 35°/56°F respectively (National Weather Service 2022). Temperatures following the study were trending down and were almost 6°F cooler than the daily average on the last day of the study and following. Average monthly temperature on a historical basis was 50°F. Rainfall on the four days prior to the study amounted to 0.09 inches and during the study was 0.01, Trace, and 0.36 inches respectively, likely helping the study's conclusion.

STUDY METHOD

The BurrowRx machine consists of a Briggs & Stratton (Wauwatosa, WI) Vanguard 203cc Horizontal 6.5 HP four-cycle engine built in 2016. The engine exhaust is connected to a chamber for application of the smoke oil which in turn is connected to a high temperature flexible hose. The engine is housed on a two-wheel cart with a handle capable of holding the accompanying 10-foot hose and a pint bottle of smoke oil. Having used the device in a previous study (Vantassel 2022), the equipment was already unboxed and assembled. Super grade gasoline was used according to manufacturer recommendations. The device can be used with a short hose (10 feet) or a long hose (24 feet) or both. The 34-foot hose was used during both studies. While it is doubtful that the hose length noticeably affected control, it is possible that the use of a longer hose, coupled with the shorter injection time, reduced the amount of carbon monoxide entering the burrow.

Because the goal of the study was to determine an effective injection time, burrows were only treated when a ground squirrel was observed entering or occupying the hole. Upon arrival, the hose was inserted into the burrow with some shaking and wiggling to ensure the hose entered at a sufficient distance to ensure the gas entered the burrow. Soil was then shoveled around the hose to ensure exhaust remained in the burrow. Smoke oil was then added in an amount based on injection time. For example, for a one-minute injection time, the smoke oil cup would be filled to approximately ½ to ⅔ of the cup's volume. For a three-minute injection time, the cup would be filled near to the brim (approx. ¼ inch from rim). The engine was started and run for the specified period (i.e., 1:00, 2:00 or 3:00 minutes) at full throttle. The applicator monitored the area for smoke emerging from connected holes, sealing them with soil as quickly as possible. Treated burrows were flagged with a number corresponding to the treatment and lettered to signify the holes connected to the treatment burrow. For example, if a burrow had two additional holes connected to the injection hole, and it was the first burrow treated, three flags would be labeled 1A, 1B, and 1C, respectively. Burrows with two or more connected holes, as revealed by escaping smoke, had the distances from the treated hole to the furthest connected hole measured with a Keson® Measuring Wheel MP401 (Keson LLC, Aurora, IL). Burrow closures were monitored for up to three days to determine if they remained closed.

The study process was essentially the same for both species of ground squirrels, except that the Richardson's study was performed in two stages and only tested one-minute injection times as testing of longer injection times was not deemed necessary due to the success of one-minute treatments. Treatment success was defined as follows: 1) treated burrows remained unopened for the entire follow up period, and 2) if a burrow system had holes opened twice and/or a ground squirrel was seen entering the system, the treatment was considered ineffective. Since burrows usually had more than one opening, and in the case of Columbian ground squirrels, significantly more openings, opened holes would be refilled and monitoring continued provided it was not the final day of follow up. This flexibility was given as hole closures reopen as soil sinks into the hole and/or ground squirrels may reopen closed burrows of fellow ground squirrels. Both study areas had ground squirrels present in areas adjacent to the treatment sites. In general, however, the evaluation of success was biased towards considering a treatment as a failure.

RESULTS

Columbian Ground Squirrels

The size of the field and the abundance of ground squirrels, likely an artifact of being past the birth pulse (i.e., the time when young emerge from the burrow), allowed for three different time treatments at this location. Use of the BurrowRx revealed the complexity and size of the Columbian ground squirrels' burrow system as shown in Table 1.

Richardson's Ground Squirrel

The Richardson's ground squirrel study was performed on three different fields over two different time periods. A summary of the results is provided in Table 2. A treatment was considered successful if the holes were not opened twice and/or the hole was not opened on the last day of inspection. This decision was made because some of the treatments could only be monitored for two days. This resulted in a total of 59 treated burrows included in the study.

DISCUSSION

The pilot studies suffered from the same challenges incumbent with all field research endeavors. Sometimes errors stemmed from operator error, such as timers were not started properly, or smoke oil was not added. Other errors were caused by the constraints of working alone.

Table 1. Efficacy of BurrowRx treatment of Columbian ground squirrels based on 1, 2, & 3-minute injection times with burrow length by surface measurement of connected burrows per treatment.

Treatment Dates	Treatment Time (minutes)	Ratio Opened/ Treated	% Control	Avg Burrow Length ft; 2+holes	Ratio Holes/Burrow	Avg # of holes per burrow
June 6-9, 2022	1:00	17/20	15%	11.30	98/20	4.9
June 6-9, 2022	2:00	19/20	5%	10.8	97/20	5.0
June 7-10, 2022	3:00	11/25	44%	13.04	107/25	4.28

Table 2. BurrowRx Treatment of Richardson's ground squirrels with 1-minute injection time with burrow length by surface measurement and number of connected burrows per treatment.

Treatment Dates	Field	Ratio Opened/ Treated	% Control	Avg Burrow Length ft; 2+holes	Ratio Holes/Burrow	Avg # of holes per burrow
April 26-29, 2022	SE	4/12	75%	6.375	17/12	1.42
May 5-8, 2022	North	3/22	86%	8.1	36/22	1.64
May 5-8, 2022	Horse Pen	1/7	86%	6.75	11/7	1.57

Recall that holes would be closed when escaping smoke revealed them. When several holes were revealed near the end of the treatment period, it was challenging to close them and return before the time expired. While these difficulties were annoying, it is not believed that they substantively affected the results. For example, in situations where smoke oil was not added, there was usually enough oil residue in the system (i.e., smoke chamber and hose) to create visible smoke.

High soil moisture improves fumigation effectiveness (Baldwin and Holtz 2010). While rainfall and time of year provided more favorable soil moisture conditions for the Richardson's ground squirrel test than the Columbian, the author does not believe the moisture difference significantly impacted results. Though moisture levels were not tested as part of this study, conditions were cool enough and the ½-inch rainfall prior to the Columbian ground squirrel test to believe that soil moisture conditions were high enough to mitigate the negative impacts of dry soils characteristic of the Helena Valley during the summer months.

The Columbian ground squirrel treatments demonstrated that even a 180-second treatment period was not sufficient to obtain control. While control was minimal, the gas had an impact as on at least two occasions, the applicator saw ground squirrels poking their head out of a hole, presumably to find clean air, or on the ground outside the burrow system.

The device's lack of high levels of control on Columbian ground squirrels is likely due to the size of the species' burrow system as compared to that of the Richardson's. It could be suggested that the failure to treat at the 4-minute level prevented a complete determination of the true size of Columbian ground squirrel burrows. While that is a possibility, this author believes that view is unlikely. A careful look at Table 1 shows that the 2-minute injection time revealed more openings per burrow than during the 3-minute treatment. While it is possible that the 2-minute treatment selected larger burrows overall, it is unlikely. Hopefully future research will ultimately answer the question. Interestingly, Ovens' (2011) work on behaviors of female Richardson's ground squirrels encountered burrow systems significantly more complex than the ones described in this paper. Her findings were likely due to the fact that she was studying at a non-agricultural site where the ground squirrels were not persecuted (p. 29).

Finally, it is possible that ground squirrels from untreated areas adjacent to the treatment areas may have confounded results by opening closed holes. While unable to quantify the effect of this behavior, it would be a problem for any study that uses hole closure as a control evaluation with ground squirrels.

CONCLUSION

The BurrowRx carbon monoxide injection device is an effective option for managing Richardson's ground squirrels. Unfortunately, the same cannot be said for the device's use on Columbian ground squirrels using the 3-minute injection time. While the author believes the device would control Columbian ground squirrels in burrows treated with a longer injection time, an injection time of longer than 3 minutes per burrow system is possibly too long for efficient use on sites larger than several acres.

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