

GROUND SQUIRREL
SPERMOPHILUS BEECHEYI

Contra Costa
County
Department Of
Agriculture

*LIVE TRAP VERSUS TREATED
GRAIN BAIT GROUND SQUIRREL
CONTROL METHODS*

EMPIRE MINE ROAD ANTIOCH, CALIFORNIA

AUGUST 6-10, 2012

Contra Costa County Agriculture Department

Ground Squirrel *Spermophilus beecheyi*

Empire Mine Road Antioch, California

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Abstract:

This field trial was undertaken to compare the efficacy of live trapping with the use of diphacinone treated bait. The study site was along Empire Mine Road located in the agricultural rangeland area of Antioch, California. This area supports a moderate to high population of ground squirrels and is typical of areas treated by our department. The area is open grassland prairie with oak woodland grassland mix. This 3.3 mile road is closed to vehicles and has minimal foot traffic. Twelve live traps were placed equidistant along a 1,200 linear foot stretch of roadway with a 1,500-linear foot non-trapped/non-treated control area on each side. Oat grain bait treated with 0.01% diphacinone was used to treat both extremities of Empire Mine Road outside of the live trap test area. A total of 152 ground squirrels were captured and dispatched using the live trapping method over a period of one work week (five days) in the 1,200-foot test area. Live trapping costs equated to \$7,311.85 per linear mile (\$5,074.36 when adjusted for efficiencies) and did not result in an acceptable level of control to provide protection of the roadway from ground squirrel damage. Those areas of Empire Mine Road treated with 0.01% diphacinone treated bait in a 12 foot swath broadcast at 10 pounds (0.016 ounces diphacinone) per acre (2-3 kernels per square foot) equated to a cost of \$220.40 per linear mile and did provide the desired level of control. Though live trapping was 23 times more costly, it may provide a viable alternative control in highly sensitive areas where treated bait use is not desired or allowed such as in certain endangered species habitat areas or in areas of low population isolated squirrel colonies. It was also found that live trapping was not the humane method that we expected. Trap vandalism, which was experienced during the study, presents a danger to the public through exposure to possible bites, scratches and zoonotic disease.

Introduction:

The California ground squirrel *Spermophilus beecheyi* is native to Contra Costa County. Its burrows provide positive effects on soil, habitat for burrowing owls and tiger salamanders, and the squirrel itself is a food source for many native predators. In certain situations it is considered a pest that can cause damage to public roadways and culverts, railroad beds, and other infrastructure, including earthen dams, levees and bridge abutments. Ground Squirrel burrowing can result in washouts, erosion, gully formation, undermining and weakening of levees and other structures and can lead to catastrophic structural failure. In addition, ground squirrel soil excavation can lead to injury of horses and cattle, and people walking and using playgrounds. Ground squirrel feeding can cause economic damage to crops, and to vegetation in parks and recreational areas. Individual burrows can extend up to 135 feet or more [4]. It is the department's goal to provide a relatively ground squirrel-free buffer of 100 to 200 feet adjacent to or around sensitive structures. The baiting strategy used by the department takes advantage of the ground squirrel's natural behavior of foraging up to 300 feet from its burrow. A 12-foot wide swath of ground around the structure to be protected is treated with 0.01% diphacinone treated bait. The department does not treat ground squirrel populations that are generally present beyond this buffer.

Aside from infrastructure protection, there is one area our department treats that involves human health risk. A buffer area is treated along a community pool and playground that are adjacent to an open space area on the side of Mount Diablo that has a very high ground squirrel population. The ground squirrels had infested the community area where small children and a community swim team utilize the facilities frequently. Besides the direct health concerns of children being in close proximity to ground squirrels, there is a high population of rattlesnakes feeding on squirrels in this area. There were many sightings at the pool and playground area, and removing the prey from that area has eliminated snake sightings.

Control methods for removing ground squirrels from designated areas have brought forth some concern as to what is most cost effective, and more importantly, what is safest for public health and the environment. This experiment was conducted to determine the effectiveness and cost of

live trapping in a moderate to high population of ground squirrels as compared to the use of diphacinone 0.01% treated bait. Also considered in this study were the hazards of handling the rodents, public health concerns, likelihood of effects on non target species, and humaneness of control methods.

The California ground squirrel can transmit a number of diseases including bubonic plague, Colorado tick fever, Lyme disease, Rocky Mountain spotted fever, tularemia, leptospirosis, anaplasmosis, babesiosis, relapsing fever, and tick paralysis [2, 18, 24, 25]. California's plague surveillance system regularly finds ground squirrels that are positive for plague in multiple California counties [2]. This is a cause for concern to biologists, field assistants, and other individuals who may come into close or direct contact with the animal or its ectoparasites that may transmit disease to humans. Live trapping of ground squirrels requires direct contact between people and the animals. Since ground squirrels carry diseases and are agricultural pests, California Fish and Game Code specifies it is illegal to release ground squirrels elsewhere without a written permit [11, 18, 20].

Diphacinone is a first generation anticoagulant. It is an organic compound that consists solely of carbon, oxygen and hydrogen atoms. Breakdown of the compound occurs naturally with sunlight and soil microbial action [22]. It requires multiple feedings for effective control and breaks down relatively rapidly in animal tissues when compared to second generation anticoagulants [5, 7]. It has not been found to contaminate surface or ground water and would not be expected to do so [7, 17]. First generation anticoagulants are often confused with and blamed for anticoagulant secondary poisoning that is the result of second generation anticoagulant use. Second generation anticoagulants, sometimes referred to "one feeding kill" rodenticides; include brodifacoum, bromadiolone or difethialone. They are the active ingredient in most common home use mouse and rat bait products such as D-Con. These products are more persistent in animal tissue and though one feeding provides a lethal dose, the animal does not die for two to five days or more. After receiving a lethal dose these animals also have a tendency to stay above ground prior to dying versus the tendency with the first generation anticoagulants of the animal to die in their burrow. Secondary poisoning of non target species from second

generation anticoagulants is prevalent and is becoming a real problem. A study was done by Lima and Salmon to determine the presence of anticoagulants in raptors in urban San Diego and agricultural central valley counties of Fresno, Kern and Tulare. In all four counties there was state-reported use of diphacinone in amounts very similar to the amount used in Contra Costa. There was also prevalent use of all three second generation anticoagulants with especially high amounts of reported use of bromodialone in San Diego and Fresno counties. Ninety-two percent, or 49 of the 53 raptors tested in San Diego County for second generation anticoagulants were positive. Sixty-nine or 34 of the 43 raptors tested in the central valley agricultural areas tested positive for second generation anticoagulants. Of the 96 raptors tested, none were found to have diphacinone contamination, two were found to contain trace levels of the first generation material chlorophacinone, and 83 had detectable levels of second generation anticoagulants present in their liver tissues [3].

In a Cornell University study involving a 56-day secondary poisoning trial with diphacinone 0.005% bait (50mg active ingredient/kg) revealed no hazard to sparrow hawks under conditions likely to be encountered in nature [6]. In addition, diphacinone is less toxic to birds as it is less persistent in the tissues of primary feeders, and must be eaten over a period of several days to cause mortality in comparison to second generation rodenticides such as brodifacoum, bromodialone and bromethalin [6, 7].

Another study involved an ecological risk assessment on coyotes, American kestrel, burrowing owl, golden eagle, red-tailed hawk and the common raven from the use of diphacinone broadcast and spot treatment. This study concluded that this method “will not cause unreasonable adverse effects on coyote populations or those of other predators/scavengers that feed on squirrel carcasses” [23].

Diphacinone degrades fairly rapidly with a half-life of 44 days, and vitamin K is antidotal in cases of needed treatment [14]. Vitamin K1 can be found in plants and Vitamin K2 can be synthesized by specific bacteria and is an essential cofactor for activating Vitamin K dependent proteins in the liver [14]. Prothrombin is dependent on vitamin K in order to execute its primary function in coagulation of blood. Prothrombin is another alternative that can aid in accidental

consumption of diphacinone. Diphacinone application is most effective and safe when allowing one day between each application because it allows the anticoagulant to work better over time and reduces the consumption by the squirrel reducing secondary poisoning. Diphacinone does not kill other species that may cohabit with ground squirrels in their burrows.

Rolled or flattened grain is used as the diphacinone carrier. The flattening makes the bait less attractive to birds. The bait is also dyed blue. This makes it less attractive to non target species.

It need also be noted that direct feeding on diphacinone by domestic dogs and other canines will produce toxic effects. That is why it is so important to properly use the treated bait by broadcasting the bait at a rate of only a few grains per square foot and immediately cleaning up any bait spillage that may occur around bait stations or with the broadcast material. Misuse of this material would include “piling” the bait or throwing “handfuls” of the bait down or at ground squirrel burrows. As an added precaution there are use restrictions in areas of endangered kit fox habitat in our county.

Objectives

The objectives of this study were to compare the effectiveness and costs of live trapping versus broadcast treatment of 0.01% diphacinone treated bait on a moderate to high ground squirrel population. Also, it was our desire to gain direct experience with live trapping to gain knowledge of possible benefits and problems. This study is consistent with our departmental integrated pest management (IPM) goal of evaluating the feasibility of control methods that involve potentially least toxic or lower toxicity alternatives. This study is not intended as an official scientific study but as a departmental evaluation. Through this study we also want to address concerns that have been expressed by the public with our program.

Procedure:

- 1) Photos were taken of area to be trapped and of the control and baited areas. Twelve [Black Fox] traps were set at 100 ft spacing, and 1,500 feet of un-trapped and un-baited control area was left on either side of the trapped area. Initially traps were wired open

and untreated rolled oats were placed inside and scattered around the outside of the trap.

- 2) Each trap was covered with a non-transparent/non-cloth material (i.e., plywood) to provide adequate protection from predators and the heat. Note: Traps #4 & #5 were left uncovered for the first two days to check the difference in catch rate between uncovered/covered and to identify other differences. Plywood was placed under some of the traps where grounds squirrels were found digging under the trap to obtain and consume the bait.
- 3) Each trap was identified by a number from 1 to 12.
- 4) Labels were placed on the traps to inform the public that an experiment was underway and to warn them to stay away.
- 5) The wired open traps were pre-baited over at least a two-day period using clean untreated rolled oats.
- 6) Pre-baited with clean rolled oats prior to treating with Diphacinone 0.01% bait.
- 7) Time spent setting traps out and pre-baiting was documented.
- 8) After the pre-baiting period, the traps were set early in the afternoon (~2 p.m.) in order to minimize the number of captured squirrels that would be in traps overnight to lessen stress for the squirrels and attractiveness to nocturnal predators that may tamper with the squirrel(s) and traps. Clean untreated rolled oats were again placed inside the trap.
- 9) Traps were checked and serviced at least once in a 24-hour period.
- 10) Captured squirrels were euthanized according to Institutional Animal Care and Use Committee (IACUC) and American Veterinary Medical Association (AVMA) guidelines [1]. We determined the flow rate necessary for the size of the CO₂ chamber so as to induce anesthetic effects rapidly, prevent distress to the animal and achieve respiratory arrest within 5 minutes.

- 11) Squirrels were euthanized using the proper personal protective equipment to avoid exposure to fleas, which may carry an array of diseases (minimizing the time of human exposure to the ground squirrels is imperative).
- 12) The number of ground squirrels in each trap was recorded.
- 13) Once the traps were emptied, they were reset.
- 14) The time spent live trapping and diphacinone baiting was recorded.
- 15) Step 5 through 14 was repeated as applicable. Diphacinone pre-baiting was conducted only on Day 1. The application of diphacinone treated bait was done on Day 3 and 5.
- 16) The following week staff returned to survey the effects in the area of live trapping versus that of the diphacinone 0.01% treated area.

Materials and Costs:

Live Trapping

Materials	Cost	Reusable	Unit	Total Cost	Actual Cost (prorated)	Comment
Traps	\$54.75	X	1 cage	\$657	\$33.73	Cages 3 year life 8 weeks of use per year 8/52 weeks in a year=0.154, cost for this application
Re-bar	\$4.47	X	15 ft	\$22.35	\$7.45	3 ft/piece 24 pieces needed for 12 cages – 3year life
Hammer	\$19.98	X	small sludge	\$19.98	\$6.66	3 year life
Flags Markers	\$5.5	X	100 flags	\$0.66	\$0.22	Used one flag per trap site – 3 year life
Untreated Rolled Oats	\$20.57		50 lbs	\$82.28	\$82.28	Four 50 pound bags used

Gas Chamber	\$200	X	1 chamber	\$200	\$40	9 cubic feet gas chamber 5 year life
CO ₂ Tank + CO ₂	\$169.93	X	20 lb tank	\$169.93	\$49.99	Tank \$149.94 + CO ₂ \$19.99 (per refill) 5 year life
Plywood	\$31.36	X	1 sheet	\$94.08	\$31.36	3 sheets needed to cover 12 cages top and bottom – 3 year life
Labor	\$19.94		1 hour	\$867.39	\$867.39	Labor + Workers Comp Benefits 43.5 hrs total
Overtime Labor	\$27.13		1 hour	\$298.43	\$298.43	OT Labor @ Base Salary X1.5 (11 Total OT hours)
Rubber Gloves	\$3.48		1 pair	\$13.92	\$13.92	2 pairs per week
Cable Ties	\$3.98		20 ties	\$4.78	\$4.78	2 cables per trap 12 traps in experiment
Pliers	\$7.58	X	1 plier	\$7.58	\$2.53	Modify traps if necessary i.e. trap door stuck shut 3 year
Labels	\$21.17		100 sheets	\$2.54	\$2.54	Only 12 labels needed
Pressure Washer	\$599	X	washer + gas	\$603	\$52	1 pressure washer + 1/2 gallon for fuel \$50/day rental
Vehicle Cost	\$231.76		\$0.555/per mile	\$231.76	\$177.15	\$0.555/mile includes vehicle use and fuel (42.6 mi round trip+3.0 mile stretch to and from Trap Location on Empire Mine Road x 7 trips x 0.555 for one vehicle used)
Total Cost Per Site					\$1,670.43	Total Cost per 1200 ft (live trapping)
					\$7,311.85*	Total Cost/Linear Mile (Minus Reusable Items live trapping)
					\$10.99	Total Cost Per Squirrel per 1200 ft (152 ground squirrels)

Table 1: The table displays the material cost for live trapping at the site of Empire Mine Road, Antioch.

*Adjustments for efficiencies (see below text) bring this to \$5,074.36/linear mile.

Diphacinone Bait Broadcast Treatment

Materials	Cost	Reusable	Unit	Total Cost	Actual Cost	Comment
Diphacinone 0.01%	63.50		50 lbs	\$401.96	\$401.96	Broadcast 3.3 mile stretch of Empire Mine Road (CDFA Research Surcharge @\$0.50/LB) + Cost of Treated Bait (6.33 bags used)
Labor	19.94		1 hour	\$119.64	\$119.64	Cost per week for Empire Mine 1 day Untreated (placebo) Grain plus 2 days Diphacinone treated grain bait (6 hours total)
Untreated Rolled Oats	20.57		50 lbs	\$82.28	\$82.28	Cost for Broadcast 3.3 mile stretch of Empire Mine Road (4 bags)
Seed Spreader	710.00	X	1 Hopper	\$710.00	\$14.20	Spreader 5 year life (1/10) use (Spreader + Rheostat)
Vehicle Cost	0.555		Per Mile	\$109.22	\$109.22	\$0.555/mile 42.6 mi roundtrip + 6.6 miles for Empire Mine Rd X 4 trips (one for trap placement and placebo; three days for treatment/survey)
Total Cost Per Site				\$1,589.14	\$727.30	Total Cost for 3.3 mile stretch of Empire Mine Road
				\$481.56	\$220.40	Total Cost per mile (treated bait) on Empire Mine Road

Table 2: The displays the material cost for spreading treated bait on Empire Mine Road Antioch.

RESULTS AND FINDINGS:

Cost Analysis:

Total live trapping cost in our experiment, not including any additional supervisory or clerical time, was \$7,311.85 on a per linear mile basis. When adjusted for efficiencies (see below) this totaled \$5,074.36 per linear mile. The cost for the directed strip broadcast method using diphacinone treated bait was \$220.40 per linear mile. This is more than a 23 fold cost difference. The high cost of live trapping was due to increased labor and handling time, equipment costs, trap maintenance, and a higher number of site visits relative to where treated bait was used.

These costs are documented in Tables 1 & 2 above. We did not include travel time, mileage or other expenses for the USDA Wildlife Specialist that assisted with the euthanizing of the ground squirrels, however, we did include the actual start to finish time of euthanizing at the hourly rate of our staff because this part of his time would have been spent by our staff had he not assisted. We did not include time or expense for trap set up help from staff other than the two core employees that ran the experiment nor did we count time or expense of two post trapping surveys that staff performed. Also not included in the total cost of the live trapping is added supervision and clerical time required to support additional staff that would be needed if the live trapping method were to be used more extensively.

With that being said there were certain efficiencies that could be realized that would bring the cost down from that of the experiment. For the experiment we had two staff members involved with the actual trapping. This could be done by one person with an estimated time savings of about 25%. Thus the hours needed would be reduced from 43.5 to 31.625 actual hours or 139.15 hours on the per linear mile basis. Also, the evening check of the traps that was done on overtime could be eliminated. This would also reduce the number of round trips from seven to six resulting in a mileage cost reduction of \$25.31. The total savings of these efficiencies would result in a cost of **\$5,074.36** per linear mile (still not including costs of additional supervision or clerical). With these efficiencies live trapping for five days plus the one day set up/placebo is a little more than 23 times more costly than bait treatment. We feel this is not a wise or efficient use of public funds with which we are entrusted.

For comparison purposes, quotes were obtained from commercial pest control operators that could treat using non chemical live traps or other methods. The quotes ranged from \$90 to \$125/hr plus mileage for nonchemical ground squirrel control using live traps or other methods. At 139.15 hours per linear mile for the five days of trapping this would amount to \$12,523.50 to \$17,393.75 per linear mile plus mileage. We also received two quotes of \$20 and \$25/ground squirrel captured. These quotes on the per squirrel basis convert to a per linear mile rate of \$13,360 and \$16,700 respectively considering that 668 squirrels were captured on a per linear mile basis.

These finds are consistent with other studies that found "trapping and mechanical devices to control ground squirrels will rarely be used as part of the IPM program due to the inefficiencies, expense and incompatibility with facility structures." [27]

Effectiveness:

Table 1 shows 152 ground squirrels were caught in the 1,200 foot test area. This supports that our methods were very effective in capturing ground squirrels in the study area. Per linear mile, this would equate to 668 squirrels trapped. Although the live trapping was effective, the survey of the trapped area on the Monday following the five days of live trapping found a significant and unacceptably high amount of ground squirrel activity in the trapped area. The activity included ground squirrel use of burrows that were in the trapped area close to and immediately adjacent to the roadway as well as significant foraging activity in the intended buffer area adjoining the road (see Appendix A, pages 12 and 13). Failure of live trapping to adequately reduce the population of ground squirrels was predicted by the lack of a decline in the daily catch rate over the five day trapping period (see Appendix A, Figure #3, page 4). In fact the last trapping day had the highest number caught at forty squirrels trapped. The lack of significant reduction in population is consistent with reports from a local pest control operator (PCO) who experienced the same outcome using live trapping. This same operator also reported vandalism to traps and numerous catches of non-target skunks. It was fortunate for us that we did not capture skunks as they are difficult to safely release from live traps and may require euthanizing. Euthanization is how the PCO dealt with the situation. Conversely, significant and acceptable reductions of ground squirrels were found in the areas of the roadside that were treated with diphacinone 0.01% away from the live trap and control study area.

As previously stated on the Monday following the completion of the live trapping experiment, numerous ground squirrels were observed using empty burrows as well as roadside burrows located in the live trap buffer. This ground squirrel occupation of empty burrows in the live trapped area was not anticipated as it does not occur in diphacinone 0.01% treatment areas even though ground squirrel populations remain high beyond the treated buffer area. We speculate that in treated areas the squirrels do not use these burrows for an extended time due to

the treated squirrels that die in the burrows. This seems to act as a deterrent in bait treated areas. This deterrent effect helps with our departmental goal of providing a squirrel free, or nearly squirrel free, buffer area adjacent to the critical infrastructure that we are trying to protect. The lack of acceptable control with 5 days of active live trapping resulted in the need to treat the live trapped area the next week following the study.

There is the possibility that live trapping for longer periods of time, possibly two or three weeks or more, would have resulted in creating the desired buffer. However, this would greatly increase the cost. There is also a possibility that live trapping at a different time of year may give different results. Live trapping in the winter would likely not be effective because of hibernation. In late winter/spring the finding an acceptable bait to draw in the ground squirrels into the trap would be a challenge because they are typically consuming grasses at this time and would not be interested in the grain bait.

Concerns

Observations:

In Appendix A, figure 4 the graph displays an increase in the number of ground squirrels caught due to the addition of plywood covering the trap. We initially used only metal discs on these traps to provide weight, to keep predators from moving the traps and to provide shade. We were concerned with heat radiating off this disc and therefore adding to the stress to the captured squirrels. To remedy this we added total plywood coverage to the top of the trap. This increased the catch rate in these two traps from 2/day to 5/day. The cover apparently made the squirrels more comfortable in entering the traps.

The weather was hot in the afternoons, especially toward the end of the week (Appendix A, Figure 5, page 6). This did not seem to significantly affect the catch rate, though on Wednesday of the trapping week we checked the traps twice, once at about 2PM and again at dusk, about 8PM and found only four of the 38 captured that day were caught in the afternoon (Appendix A, Table 1, page 1).

Disposal of trapped squirrels presented a hazard to staff, and were required to wear protective gloves and take precautions necessary to protect them from the spread of diseases via flea and tick vectors on the ground squirrels. These precautions were necessary when handling dead squirrels, especially those found dead in the traps.

Though not required, we had certified personnel to apply CO₂ to the squirrels for proper euthanization.

Traps consistently needed modification and maintenance in order to attract the ground squirrels.

We also found cleaning of cages at completion of the experiment to be imperative. At the end of the study cages contained the dry residue of blood from the squirrels as well as a strong odor. As we conducted the experiment the squirrels were observed to be frightened and would therefore gnaw on the metal cages causing their mouths to bleed. Further observation throughout the week supports the behavior of squirrel territorialism. Ground squirrels were observed fighting and wounding each other in the traps. There were four dead squirrels in traps through the duration of the study, their deaths probably due to fighting within the trap and heat stress. Deceased squirrels lose body heat after all bodily functions cease and therefore fleas leave the host looking for another warm-blooded animal. In addition, the deceased squirrels tend to emit an unpleasant odor in the surrounding area. The presence of open wounds and blood further presented the health issue of blood borne pathogens.

We also experienced trap vandalism. Two traps were found with the tops open in an apparent attempt to free captured squirrels. This occurred even though the traps were clearly labeled as a live trap experiment. This vandalism leads to great concern about the exposure of the public to bites, scratches and transmissible diseases.

Observations made from the experiment indicate that the live trapping method would not be well accepted by the public and would result in concerned citizens and complaints.

On the other hand ground squirrels controlled with treated bait alleviated most of the observations mentioned above because we have found that the squirrels with rare exception will

die in their burrows using this method. All areas treated with diphacinone 0.01% are surveyed by our staff at the end of the treatment specifically for the presence of squirrels that have died above ground. The entirety of the 2012 treatment season involved a total of 925 treated linear miles. The department performs a carcass survey of all diphacinone treated areas. In the areas treated by the department for ground squirrels during the 2012 season, these surveys found 6 ground squirrel carcasses above ground. No non target species were found during these surveys. A Ventura County study found no carcasses above ground during broadcast baiting trials [27]. Though it is acknowledged that these surveys will not find all above ground carcasses, we estimate above ground kills to be an extremely small percentage of ground squirrels affected with the rest dying in the burrow. This is consistent with what is expected of first generation anticoagulant rodenticides and is consistent with the results found in the previously mentioned raptor studies.

An additional survey of Empire Mine Road was performed on September 14th, 2012, roughly one month after treatment. The survey found no ground squirrel activity in the treated buffer area though high activity beyond it. No evidence of deceased squirrel carcasses or non target species was found.

Live trapping may be effective in highly sensitive areas that are known to be inhabited by endangered species, such as the San Joaquin Kit Fox, or in other sensitive areas of small, isolated colonies.

The timing and attractant bait for live trapping is an important consideration to effectiveness. Our experiment was done in August in a rangeland situation where the ground squirrels were readily taking grain bait. In the winter and spring it is unlikely that we would have had the level of success in trap numbers because during those seasons ground squirrels in range land areas are foraging on green grasses. Other baits that are more specific to the squirrels current diet may be necessary for success in crop land areas. These baits may be almonds, melon or other food items and may require trial and error to find successful bait. Also ground squirrels tend to hibernate in the winter and success with live trapping will be reduced. In the heat of the summer ground squirrels will often aestivate (summer equivalent to hibernation) and success may be reduced.

Although in our study this was not a problem even though there were two days with afternoon temperatures in excess of 100°F. There was reduced squirrel activity in the afternoon but not an indication of aestivation during our study.

Other Control Method Options Used and Considered By the Department:

Burrow fumigation using carbon monoxide producing **gas cartridges** is a method that is sometimes used by the department. This method produces positive results when conditions and circumstances are right. Soil moisture is necessary to provide a seal to sufficiently hold the carbon monoxide. Because of this, the use of gas cartridges is usually limited to the springtime. Also vitamin K, the antidote for anticoagulants, is found in green grasses that are foraged by ground squirrels in springtime and diphacinone baits are not effective during this season if the squirrels are feeding on green grasses. With gas cartridges there is no chance of secondary poisoning. However, there are drawbacks. The use of gas cartridges involve added staff time and treatment cost. Gas cartridges are ineffective when squirrels are hibernating or aestivating due to the squirrel internally plugging their burrow at these times. There is also the possibility of direct primary kill to non target organisms and endangered species if gas cartridges are not properly used. Endangered California tiger salamanders and California red-legged frogs cohabit in active ground squirrel burrows. The endangered species act prohibits gas cartridge use in California tiger salamander habitat and though not restricted by the act, we will not use this method in red legged frog habitat. Endangered burrowing owls only inhabit abandoned ground squirrel burrows. Our staff is trained to recognize and to not treat these burrows. Fire danger is another issue to consider when using gas cartridges when grasses or other material is dry. Due care to follow any special use restrictions and precautions, including in some cases no use, must be taken by staff. It also must be noted that in some areas of the county and under certain climatic events hibernation and aestivation may not occur. For example we have found minimal hibernation on south west facing slopes in certain areas of East County. Evaluation may justify burrow fumigation in the winter in some of these areas.

O₂/propane is an effective control measure. It works by injection of the gas mixture into the burrow system the igniting which causes an explosion. This method has an added benefit of partial burrow destruction. The department has attended demonstrations of this method. We have chosen not to use the method mainly because it also kills other non-target organisms that may be in the burrow, it presents a danger from flying material that may harm the applicator or by-standers and can possibly cause damage nearby structures. It also attracts attention from the public that may be in earshot of the applications.

CO₂ is also used as a burrow fumigant. Our department does not have experience with this material, though we would expect similar results as to gas cartridges though we expect that efficacy would be less due to difficulty in finding burrow escape holes. With gas cartridges these burrow system escape holes are rapidly apparent because of the smoke that the cartridges produce. They holes are plugged by our staff to prevent loss of carbon monoxide thus giving effective control. This may not be an issue with CO₂ on flat ground because it is heavier than air, but could be an issue in hilly or sloped areas. We also have concerns with non-target kills in the burrows and the extra weight that our applicators would need to carry. The California Department of Pesticide Regulation requires that the material (CO₂) or the treatment device be registered. On checking neither are so legal use of this method is pending registration.

Aluminum phosphide is another legal burrow fumigant. This material is highly toxic if not used properly. It requires a restricted use pesticide permit. Non-target and efficacy concerns are very similar to that of CO₂. We choose not to use this fumigant in our ground squirrel program because safer alternatives such as the gas cartridges are available.

Zinc phosphide treated bait is similar to the diphacinone bait in usage as a broadcast of treated bait. Ten or more years ago we did use small amounts of this material but have decided since to no longer use it as diphacinone is a less toxic and safer material to use. Zinc phosphide is labeled “Warning” because it is moderately toxicity category as compared to diphacinone which is labeled “Caution” or least toxic. There is a greater risk of direct non target kill and a greater hazard to our applicators. The risk of secondary poisoning is less because the moisture in the animal tissues rapidly converts zinc phosphide to phosphine gas which kills the animal.

Phosphine gas dissipates rapidly reducing the potential of secondary non target kill. Bait acceptance by ground squirrels in our county was also found to be lower than that of diphacinone bait.

Bait stations containing anticoagulant bait is another method that is used by the department in certain instances. This usually involves high damage areas where the broadcast method is not allowed or desirable. This method can provide a satisfactory reduction in ground squirrel populations in a buffer area near a sensitive site. Bait station use involves greater staff time and cost. The PVC pipe type bait stations that we use exclude access by non target species and the design prevents bait kick-out by the squirrels. Our staff is trained to clean up spillage that may lead to concentrations of bait and unintentional poisoning of non-target animals. The bait stations, though properly marked, present a danger to children. Tampering may also result in concentrations of bait spilled outside of the bait station which will present a danger to non-target animals. Control using bait stations is slower due to attractiveness to individual squirrels that come to the bait station versus taking advantage of the natural foraging habit of the squirrel. Squirrels in the immediate area come first to the stations and as they die out squirrels remote to the bait stations find their way to them. This process can take two to three weeks or more as compared to the four to six days that the broadcast method requires for a similar level of control. Ground squirrels that come to bait stations also have a tendency to load up on more bait than those that are foraging which can contribute to higher levels of toxicant if taken by non target predators. In one study in Ventura County the pounds of bait used in bait stations was about ten times as much as that used for similar control when treating by the broadcast method [27]. Bait in bait stations that is ruined by moisture or mold must be handled as hazardous waste. This can add to expense.

Raptor perches have been used in experimental areas by our department. They have not proved to be successful in reducing ground squirrel populations. Three species of raptors in our area are large enough to take ground squirrels, the red-tailed hawk, the red-shouldered hawk and the golden eagle. Unfortunately of the 20 perches that our department put up in three different locations, only a few have been rarely used by these species. On numerous occasions our staff

has observed red-tailed hawks being chased away from the perches by kestrels, which are a small territorial hawk. Ground squirrels have borrowed against some of the concrete filled post holes used to place the perch. This is consistent with a ground squirrels affinity to borrow at the edge of concrete and asphalt apparently because this makes them feel more protected from predators.

Owl Boxes Do not work for ground squirrel control for two basic reasons. One is that the biology of the owl as a night time hunter and that of the ground squirrel that is active only during the day make it such that the two do not cross paths. The other reason is that none of our native owls are large enough to take a ground squirrel with the exception of the great horned owl. Very rarely a great horned owl is found to have feed on a ground squirrel, likely one that was out at dusk which is much later than normal for a ground squirrel to be out.

Kill Traps have not been used by the department. These will only capture one ground squirrel at a time and may be effective in small light population areas. There are many kinds of traps. However, use of kill traps will present potential to non-target animal capture and are of concern in any area where there is the possibility of children coming into contact with them. They are also very time consuming and therefore costly to implement.

Summary:

The experiment supported the following data and observations:

Negative Findings:

- Five consecutive days of live trapping was not effective in sufficiently reducing the ground squirrel population to an acceptable level.
- Live trapping was over 23 times more expensive than treated grain bait application. \$5,074.36/linear mile compared to \$220.40/ linear mile.

- Our program in 2012 involved treating 925 linear miles. Besides the additional cost in time and materials of live trapping, this method would require a substantial increase in staff, the number of trucks needed to accomplish the workload, and administrative time.
- The number of ground squirrels trapped in the test area as evidenced by the number live trapped (152 or 668/linear mile) in one work week of trapping was not sufficient to reduce the population and establish a buffer area to a desired level.
- A significant portion of squirrels that were live trapped were injured and bloodied from squirrels fighting within the trap.
- Four squirrels died in the traps, though the traps were checked a minimum of once per day. The deaths were apparently due to fighting, heat or other stresses or combination of stresses.
- Trapped ground squirrels were observed heavily bleeding from the gums due to chewing on trap wire in an apparent attempt to escape from the trap.
- Disposal of fumigated wounded and non-open wounded squirrel carcasses involved reaching into the cages increasing the chance of operator exposure to disease and ectoparasites and blood borne diseases.
- Uncovered traps were not as effective in attracting ground squirrels. The catch rate of uncovered traps was 2/day whereas the catch rate of the same traps when covered was 5/day.
- Vandalism of traps by people occurred to two traps despite conducting the experiment in a remote area with very little foot traffic and no vehicle traffic. This is cause for great health concern to the public due to the possibility of bites, scratches and exposure to transmissible disease.

Positive Findings:

- The study showed that with the methods used a high number of ground squirrels can be trapped.
- Live trapping may be an effective method at protecting small sensitive areas where treated bait is not allowed and ground squirrel reduction is needed.
- Live trapping may also prove to be effective in a small area if it is desirable to remove an isolated colony of ground squirrels.
- Using the broadcast method of treating with 0.01% diphacinone bait (a first generation rodenticide) results in a very low rate of above ground squirrel death.
- Broadcast is generally better than the use of bait stations for treated bait in the risk to children and to direct non-target species affects.

This experiment may serve as a foundation for future experiments to develop further information on secondary poisoning or explore other cost effective or least toxic methods to reducing ground squirrel populations.

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Table 1: Live Trapping for Ground Squirrel *Spermophilus beecheyi*

Trap Apparatus	Trap #	8/6/12	8/7/12	8/8/12 Day/Evening	8/9/12	8/10/12	Total (Trap)	Comment
Plywood+Rocks+Under Tree	1	2	4	1/0	0	7	14	Squirrels digging underneath cage; trap adjusted; 8/8: Cage found open
Plywood	2	0	2	3/0	1	5	11	
Plywood	3	1	0	1/0	0	2	4	8/8/12 1 GS found deceased possibly due to heat exposure
No Cover-1 st 2 days then Plywood added	4	2	1	5/0	2	3	13	Plywood Cover added 8/7/12 (5); 8/7/12: 1 GS found deceased possibly due to heat exposure or fighting
No Cover-1 st 2 days then Plywood added	5	1	0	2/1	1	1	6	Plywood Cover added 8/7/12 (6)
Plywood +Rocks	6	2	1	1/0	2	2	8	
Plywood	7	4	2	3/1	1	4	15	
Plywood	8	1	0	2/1	2	3	9	
Plywood	9	3	1	3/0	2	1	10	8/8/12 Cage found open during evening
Disc Cover + Rocks/Plywood added on 3 rd day	10	3	2	4/0	7	5	21	Rock Apparatus drew more ground squirrels due to trap appearing more natural
Disc Cover/Plywood added on 3 rd day	11	5	1	2/0	2	2	12	8/6/12 2 GS found deceased due to heat exposure or fighting
Disc Cover + Plywood	12	5	8	7/1	4	5	30	Trap on edge of buffer barrier bringing in higher yields of ground squirrels
Total (Day)		28	22	38	24	40	152	Total (Week)

Table 1: The table exhibits traps #1-12 and its description. The efficacy of each trap and its' ground squirrel counts. Traps #1-12 were placed on a 1200-foot buffer zone (each trap 100 feet from each other) along Empire Mine Road, Antioch, California.

Ground Squirrel *Spermophilus beecheyi*
Empire Mine road, Antioch, CA
August 6-10, 2012

Traps #1-12
Buffer Barrier



Figure 1: The figure displays traps #1-12 in order along Empire Mine Road, Antioch, California. The trap area consisted of stretch of twelve unique traps along a 1200-linear foot roadside area. Two 1500 feet untreated control areas were at either end of the trapping area.

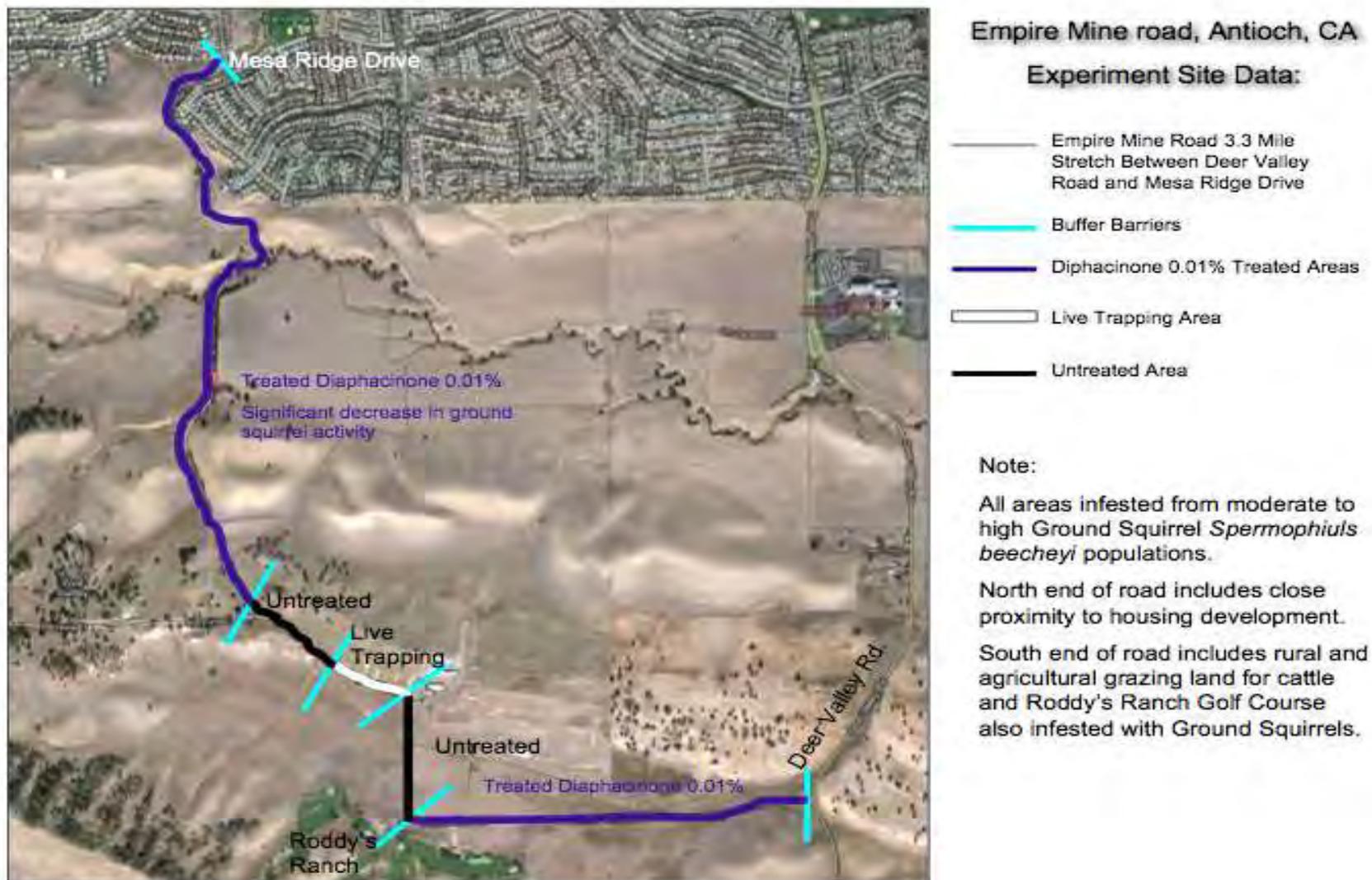


Figure 2: The figure displays the areas of diphacinone 0.01% treatment (2.5 miles), untreated control (1,500ft), and the live trapped area (1,200ft).

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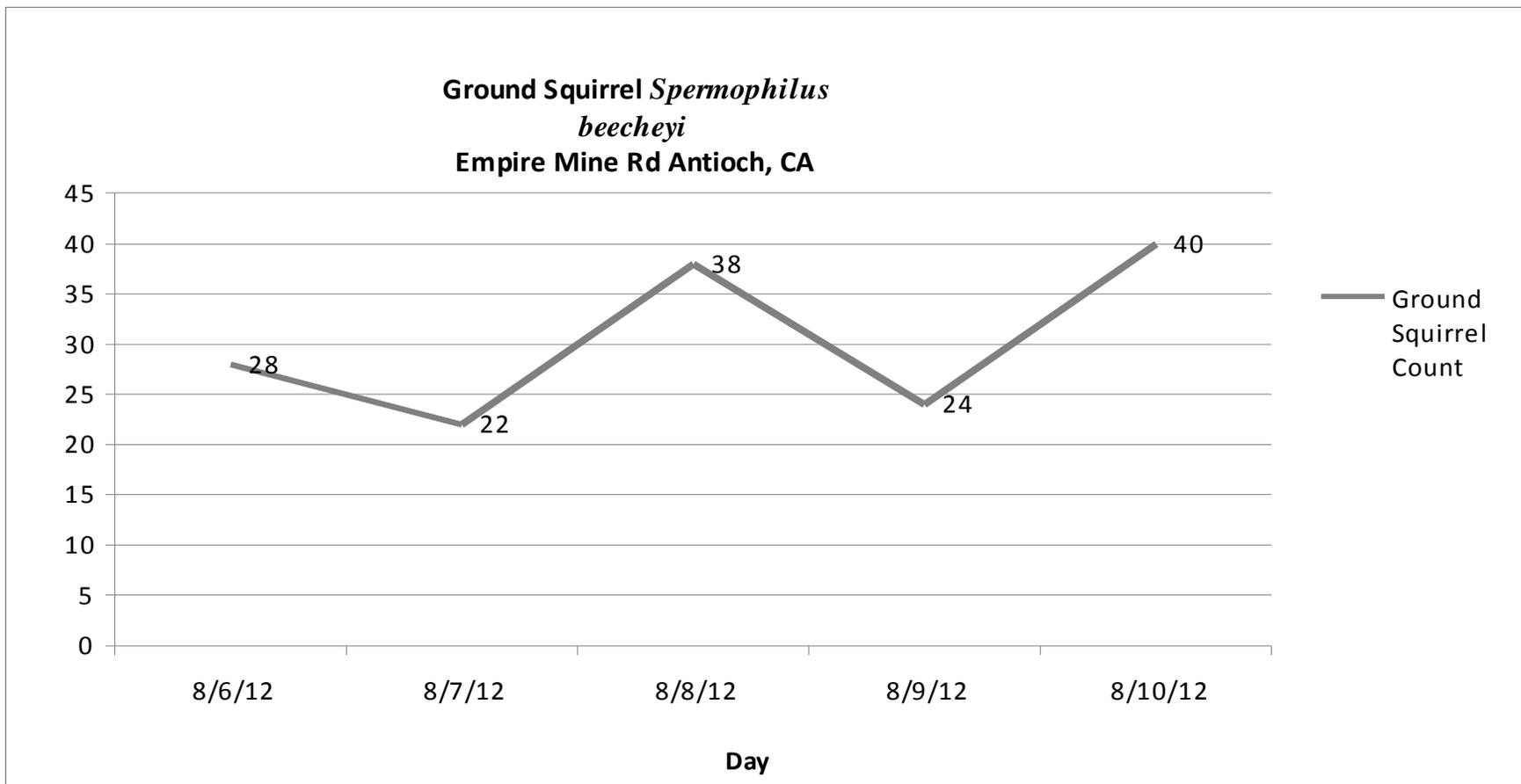


Figure 3: The figure displays the number of Ground Squirrels *Spermophilus beecheyi* caught via live trapping over a period of five days in a 1,200 foot trapped area. The total number of squirrels caught for the week totaled 152. However, the impact on reducing the population of ground squirrels via live trapping was insignificant.

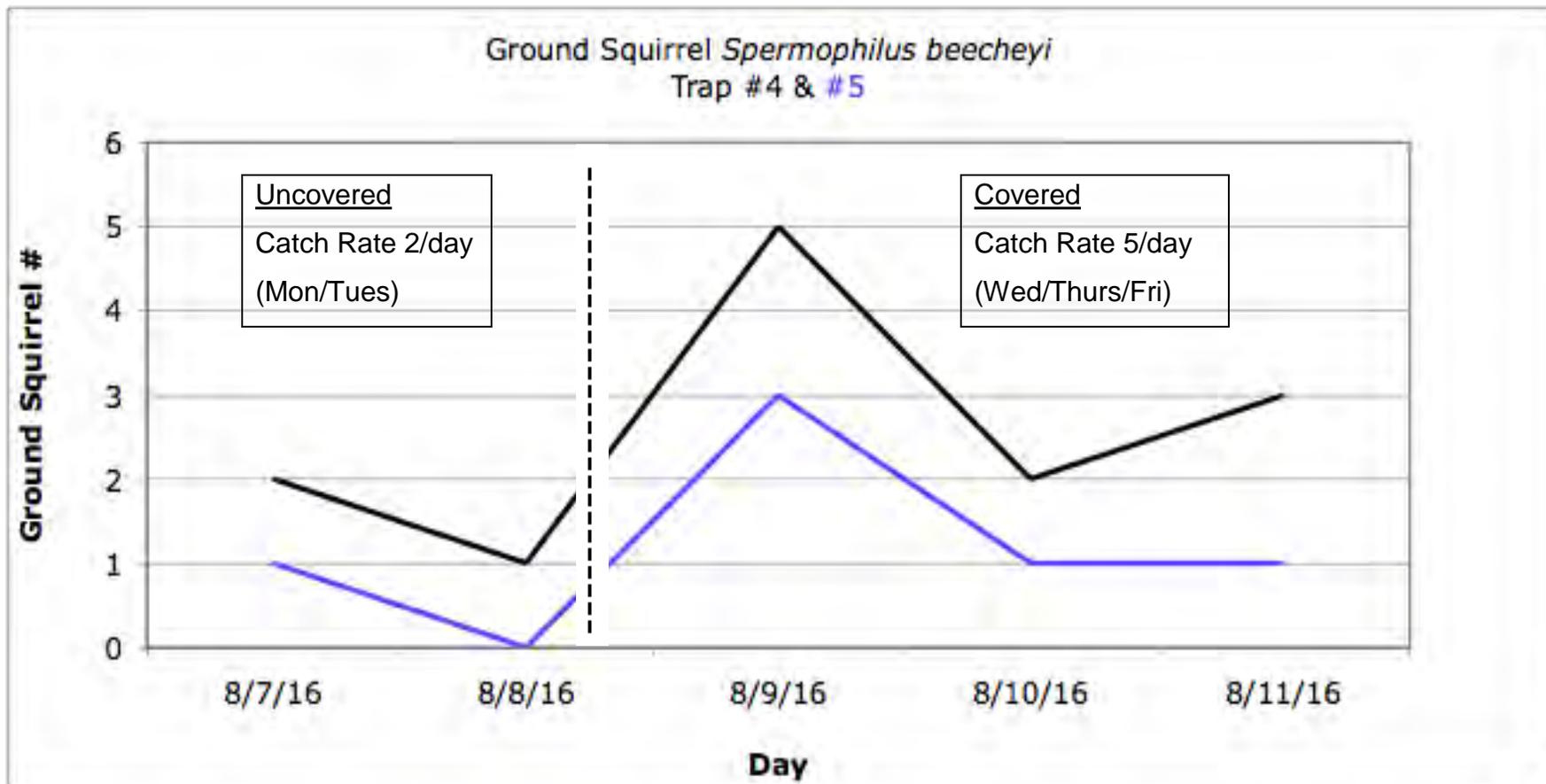


Figure 4: The figure displays the Ground Squirrel Traps #4 and #5. The graph shows the reported number of ground squirrels caught each day. A trap adjustment was made on 8/8/12 in which a plywood cover was added to reduce heat exposure, predatory animals, and increase coverage.

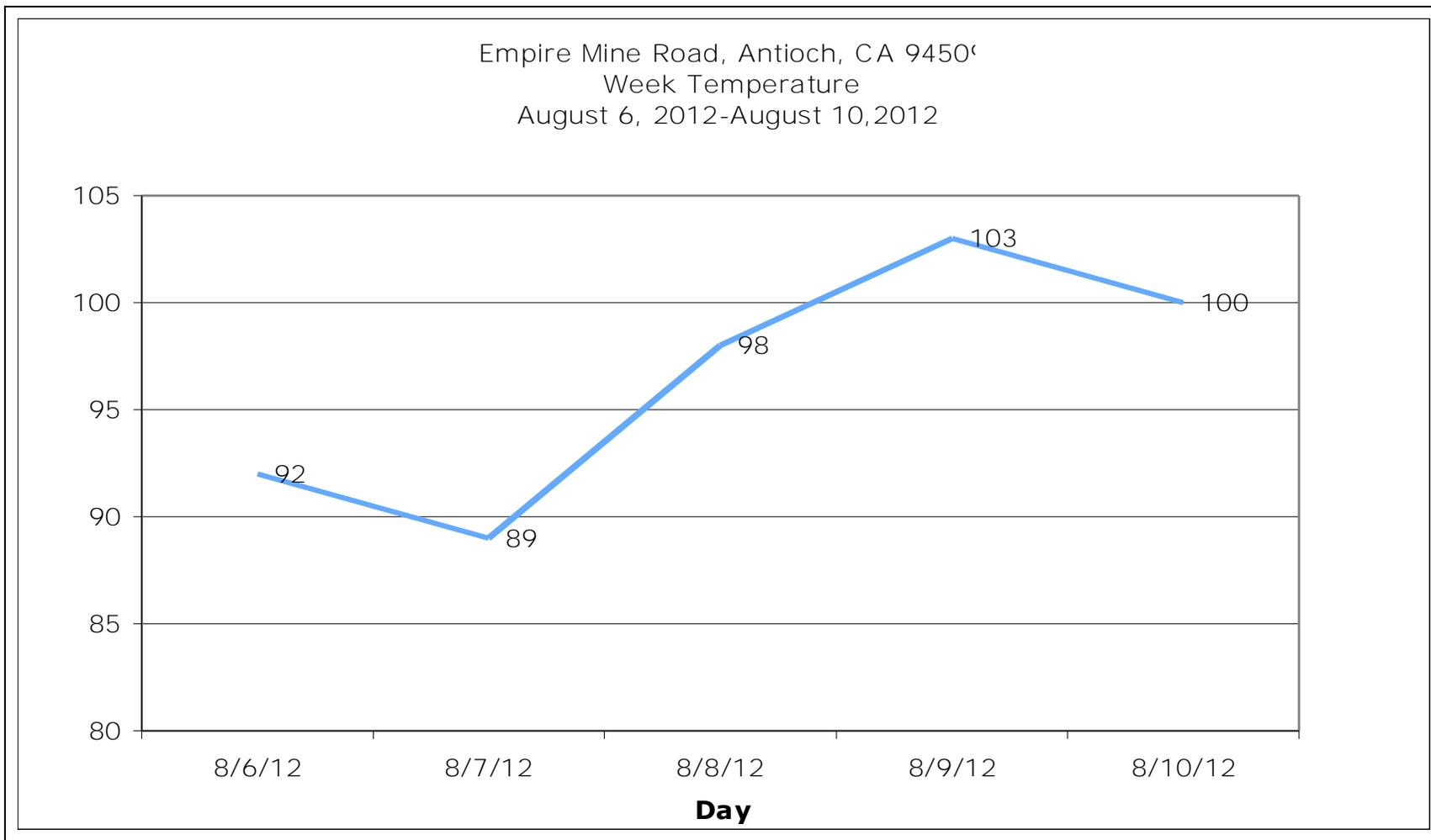


Figure 5: The figure displays the average high temperatures August 6, 2012-August 10, 2012 at Empire Mine Road, Antioch, CA. The temperatures recorded display that a significant amount of shade coverage was necessary for squirrels to survive while in the cages. In addition, the cages would require more man-hours in order to create each individual shaded cage habitat.



Figure 6: Empire Mind Road. Observing and determining the necessary areas for live trapping and diphacinone treatment.



Figure 7: A trap with proper coverage from predators and heat exposure was imperative to building a successful and viable apparatus.



Figure 8: Traps were set open to allow ground squirrels to gain familiarity with the foreign apparatuses in their natural habitat. Subsequently, the traps were set closed and baited with clean unrolled oats.



Figure 9: Ground squirrels were removed. Observations on the efficacy of the trap location and apparatus were made to determine its feasibility. Traps were re-baited and serviced once sometimes twice daily.



Figure 10: IACUC and AVMA guidelines were carefully followed in ethically euthanizing the ground squirrels as well as supervision of CO₂ certified personal in application on ground squirrels.



Figure 11: An array of observations were made on the efficacy of live trapping versus treated bait. In addition, multiple health risk and obstacles were identified and the necessary procedures and precautionary measures were taken to proceed with the experiment.



Live Traps #1-6

Each individual trap was needed to be built with the necessary accessories to provide protection against heat exposure and predatory animals for the ground squirrels.



Plywood cover applied 8/8/12



Live Traps #7-12

Each individual trap was needed to be built with the necessary accessories to provide protection against heat exposure and predatory animals for the ground squirrels.



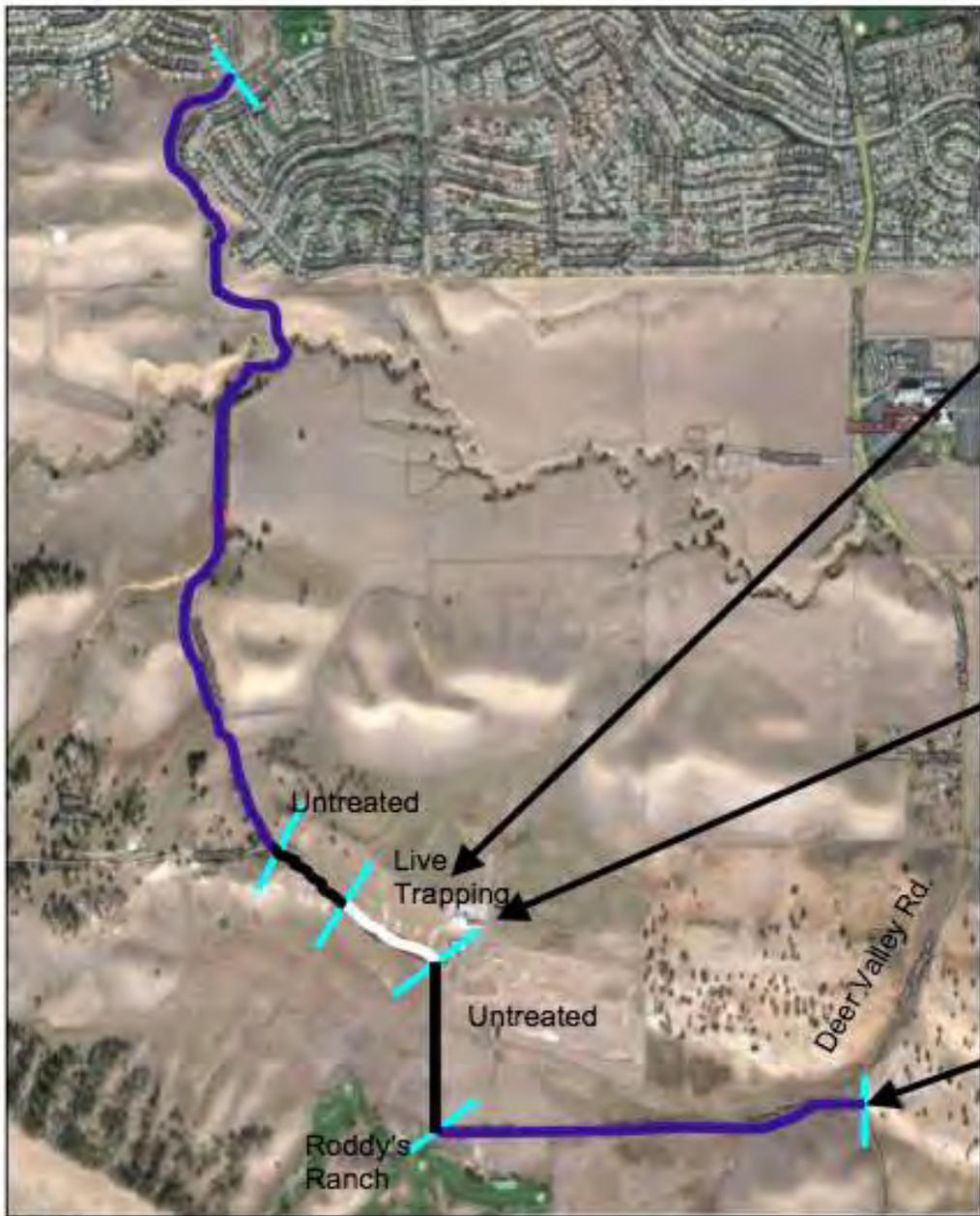


Figure 12: Empire Mine Road., Antioch, CA. 8/13/2012. The road still remained infested with ground squirrel activity in the live trap buffer area.



Figure 13: Ground squirrel activity remained in the same location as live trap #1.



Figure 14: The east side entrance of Empire Mine Road adjacent to Deer Valley Rd., Antioch, CA.



Empire Mine Road, Antioch, CA
Site Location and Infestation





Pre-experimental observations:

Ground squirrels were frightened due to our presence and retrieved from foraging activity. Ground squirrel acclimation to traps is imperative.

Post-experimental observations:

Ground squirrel activity continued although the close proximity of the biologists was present post-experiment. The figures display ground a significant amount of activity in the live trap buffer post-experiment.





Post-experimental observations:

Ground squirrel activity remained after live trapping in the live trap buffer. Ground squirrels continued to forage and occupy empty burrows along Empire Mind Road live trap buffer.



Habitat Observations:

Ground squirrel activity causes detrimental road damage to Empire Mine Road as well as adjacent roadways. In addition, ground squirrel control has led to local agricultural land infestations.

