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A NEW CONCEPT IN POCKET GOPHER CONTROL

Allen D. Tunberg
Wildlife and Fisheries Biology, University of California, Davis, California

Walter E. Howard
Wildlife and Fisheries Biology, University of California, Davis, California

Rex E. Marsh
Wildlife and Fisheries Biology, University of California, Davis, California

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ALLEN D. TUNBERG, WALTER E. HOWARD and REX E. MARSH, Wildlife and Fisheries Biology, University of California, Davis, California 95616

ABSTRACT: A new concept in pocket gopher control is advanced which relies on two behavioral traits common to pocket gophers: 1) gophers are quick to invade unoccupied burrow systems when the previous occupant has been killed by a rodenticide; and 2) the invading animal will use existing food stores (i.e., baits) left by the previous gopher. With long-lasting (i.e., durable) baits containing sufficient toxicant, several pocket gophers can be controlled by a single baiting. This new approach assists in improving gopher control, for control is extended beyond the initial baiting results. Pocket gophers missed in the original treatment or gophers invading from outside areas will continue to be killed for some time following the baiting program. Laboratory and field studies provide supportive evidence concerning the feasibility and practicality of this new concept.

INTRODUCTION

Animal damage to seedling conifers is a major cause of reforestation failure in the western United States. Pocket gophers (Thomomys spp.) are among the most serious of the problem animals, particularly in the far western states (Crouch 1969, Black 1970, Barnes 1973). Their destructive habit of feeding on conifer seedlings, especially in winter months, is a severe hinderance to reforestation efforts and may cause complete failure of plantations (Canutt 1970, Crouch 1971, Barnes 1973, 1974 Capp 1976). This problem is expected to increase in the future as management of forests for wood production intensifies and reforestation delays become less tolerable (Capp 1976).

Poison baits are the most commonly used method of reducing seedling damage on forest lands by pocket gophers; however, other methods such as the use of Vexar® tubing are used also. The application of strychnine-treated grain within burrow systems is currently considered to be the most effective way to control pocket gophers. Hand-baiting of individual burrow systems is much more commonly used than is application with the burrow builder. However, even the most successful baiting programs rarely provide more than temporary protection. Control often must be repeated over a period of several years before young trees become large enough to be safe from serious damage (Barnes 1974, Capp 1976, Crouch and Frank 1979).

Several practical aspects affect the lasting qualities of control. They include the time of year control is conducted, the number of gophers missed in the treatment program, and the adequacy of the buffer zone surrounding the reforested area to be protected.

Largely responsible for the inadequate effectiveness of a baiting program is the ability of pocket gophers to relatively rapidly repopulate an area. There are two biological factors implicated in the repopulation of a baited site: 1) reproduction by surviving pocket gophers, and 2) invasion by gophers from areas adjacent to the treated area.

We have been engaged in the study of pocket gophers and their control in reforested areas for several years. Initially the influence of vegetation and different management practices on pocket gopher numbers were studied along with gopher movements and reinvasion activities.

The studies reported here represent the laboratory and field research conducted in 1982. As a result of much earlier studies of pocket gophers (Howard and Childs 1959), and the additional research conducted the previous two years, we began to piece together a possible new approach to pocket gopher control which would utilize specific behavioral traits of the pocket gopher along with present knowledge of rodent bait formulation.

Based on knowledge of pocket gophers' behavior towards unoccupied burrow systems, it was theorized that we could use these behavioral and territorial characteristics to a control advantage in forest situations with a suitable change in pocket gopher baits and control strategy.

It has long been recognized that pocket gophers are essentially solitary animals except during the breeding season and when females are rearing young. Studies involving live-trapping, marking, and releasing of pocket gophers support the fact that they are relatively quick to invade and utilize a nearby unoccupied or unused burrow system. The monitoring of free-ranging pocket gophers, which have been equipped with radio transmitters, has added immeasurably to our understanding of pocket gopher behavior as it relates to movements in general and specifically to the invasion of unoccupied burrow systems. We speculated that an invading pocket gopher would consume any food stores or caches left by the previous occupant.

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Using this information, we hypothesized that we could possibly improve on pocket gopher control if we designed and used a long-lasting (i.e., durable) pocket gopher bait that would not deteriorate for a long time in the burrow system.

Our new approach relies on the adjacent pocket gopher or dispersing pocket gopher invading and occupying the burrow systems of a gopher previously killed by bait and feeding upon the bait left by the original occupant. This new baiting concept would make it possible to control several gophers with one bait or a single baiting, and would be ideally suited in control situations where it is difficult to locate all of the burrow systems during a hand-baiting operation, and where gopher invasion from surrounding untreated areas is a particular problem. The concept provides for a degree of control perpetuation in that gopher control may continue for several months following the initial baiting and may significantly resolve the problem of missed burrow systems (i.e., missed gophers) in the initial treatment, and the problems of dispersing young gophers and the movement of gophers into a biological void created by the initial control.

This new concept would necessitate the design of baits that would kill the original occupant after it had moved the bait to its nest or food stores, and would not deteriorate in the burrow environment. In addition to being relatively durable in moist environments, it would have to remain acceptable and contain sufficient bait to kill several gophers in succession.

This study phase was thus directed at determining if our theories for this new control concept could, in fact, be proven a sound and effective approach to control. Laboratory bait formulation and testing was conducted at the University of California, Davis. The subsequent field research was conducted during the summer on the Goosenest Ranger District of the Klamath National Forest in Northern California. Both the valley pocket gopher, Thomomys bottae, and the Mazama pocket gopher, T. mazama, were used in the studies. However, the Mazama gopher was the one which occurred in the forest area in which we conducted the field studies and is the species often implicated in conifer seedling losses in the Far West.

LABORATORY TESTS

Methods and Materials

For our initial work we selected one of the new more potent second-generation anticoagulants, bromadiolone. Earlier studies had shown bromadiolone to be effective on pocket gophers of the genus Thomomys (Marsh 1977). At a concentration of 0.025% bromadiolone, one or two feedings of a few grams would produce high mortality in test groups under laboratory conditions (unpubl. data).

Bromadiolone, an effective second-generation anticoagulant (a product of the Chempar Products Division of Lipha Chemicals, Inc.), was selected for these experimental studies because of its future potential availability as a concentrate for specialty bait formulations and because anticoagulants do not generally produce bait-shyness as is more apt to occur with the use of strychnine. Bromadiolone has the ability to produce death in many rodent species with one or two feedings, unlike the first-generation anticoagulants that required multiple feedings to be effective. The older anticoagulants have been registered for pocket gopher control for many years with warfarin being registered in California some 20 years ago. The older anticoagulants, however, require about a half cup (75 to 100 g) of bait per burrow placement to provide sufficient bait for multiple feedings and hence their use is limited mostly to backyards, parks, and playgrounds where strychnine is thought to be potentially too hazardous.

The newer bromadiolone at the right concentration requires only a few grams of bait at one or two feedings to be lethal and is thus a potentially practical and economical rodenticide for forestry and agricultural pocket gopher control. The second-generation anticoagulants eliminate the need for multiple feedings to produce death as was the case with warfarin and other earlier anticoagulants.

Paraffin-embedded rodent baits have long been used in situations where weather- or moisture-proofing of baits is needed (Marsh and Plesse 1960). The experimental use of paraffin baits for pocket gophers was not new to us, for previous studies have been conducted with such bait, but the objectives of those early studies were different. Paraffinized baits, at least initially, offered the best prospect for preparing durable long-lasting pocket gopher baits.

In early January 1982 we commenced preparation of a series of experimental baits which led to a paraffinized bait formulated by combining 0.025% bromadiolone-treated wheat with melted paraffin (i.e., Parowax®, a common household canning wax). The 1% dry concentrate of bromadiolone was adhered to whole wheat with the use of an acrylic emulsion, Rhoplex AC-33. Alkali fast green dye was added to the bait for identification purposes.

We chose to use whole wheat instead of oat groats or steam-crushed oat, which is often used in pocket gopher control, because it was found well accepted by both the valley pocket gopher and the Mazama pocket gopher, and because the intact wheat seed coat was thought to aid in the bait's lasting quality.

Cylindrical-shaped baits 3 cm x 10 cm were produced by spooning the bait mixture of melted wax and bromadiolone-treated wheat into plastic molds. After cooling, the baits were removed from the molds. Each bait weighed approximately 100 g and consisted of 30% paraffin and 70% bromadiolone-treated wheat. Finished baits contained 0.0175% active ingredient (by weight) after dilution with paraffin.

To evaluate their acceptability, we offered paraffinized baits to six individual _T. bottae_. Each animal was housed in a metal box (19 x 44 x 36 cm) containing several centimeters of slightly moist soil, cotton for nest material, Rodent Laboratory Chow® (Ralston Purina Company), and apple. The baits were weighed daily until the entire bait was gone or the gopher was dead.

RESULTS

Under laboratory conditions baits were readily accepted by gophers. Table 1 shows the amount of grain removed daily from the baits by each animal. Note that these figures may be higher than actual consumption because some grains and paraffin residue bait were dropped and lost in the soil. We were as interested in the bait condition and the amount remaining after death of the animals as we were in the actual amount consumed.

Table 1. Time of death and rate of feeding by Valley pocket gophers (_T. bottae_) on paraffinized wheat baits containing 0.0175% bromadiolone in a laboratory study.

Gopher No.	Sex	Weight (g)	Starting wt. of bait (g)	Amount (g) of bait consumed in each consecutive day[1]														Percent of bait consumed
				1	2	3	4	5	6	7	8	9	10	11	12	13	18	
1	M	195	81.7	3.2	3.7	6.0	4.4	5.1	3.7	4.4	3.5	4.4	4.8	1.3	0.0	D[2]		54
2	M	147	79.4	8.7	47.3	23.4[3]	-	-	-	-	-	-	-	-	-	-	D	100
3	M	160	87.6	7.7	3.2	5.8	3.8	7.0	0.7	0.0	0.0	0.0	D					32
4	F	101	85.0	2.4	1.7	2.9	2.2	2.5	0.8	0.0	D							15
5	F	98	85.2	9.1	0.0	3.8	3.0	2.8	D									22
6	F	147	81.9	33.4	5.5	23.8	14.1	5.1[3]	-	-	D							100

[1]Figures given indicate amount of paraffin and wheat removed from the bait each day. The actual consumption may be less.

[2]D = the day of gopher death.

[3]Entire bait consumed or crumbled.

Gophers in cages 2 and 6 crumbled their entire bait by days 4 and 6, respectively. Although this is undesirable from a long-lasting bait perspective, we were *very* encouraged by the acceptance of grain in a paraffinized formulation and the resulting 100% mortality. Baits recovered from the other four gophers were still in excellent condition after their deaths, indicating a good potential to produce multiple-deaths under field conditions. Based on the limited laboratory data, baits could potentially control from one to six pocket gophers, depending on the rate of feeding. While we used the valley pocket gopher in our laboratory tests, we were quite sure that--based on our previous work with the Mazama pocket gopher--the results could be safely extrapolated to that species.

FIELD TESTS

Methods and Materials

The paraffinized bromadiolone wheat baits prepared in the laboratory were evaluated on a 13.8-hectare (34-acre) clearcut made in 1963-64 in old growth red fir (Abies magnifica). The site, located at an elevation of 1935 m (6350 ft.), was restocked with seedlings of Jeffrey pine (Pinus jeffreyi) in 1966. A survey several years later revealed that regeneration efforts had failed. Pocket gophers were believed to be the primary cause of failure.

An extensive live-trapping, marking and releasing program was initiated on the study site prior to the paraffinized durable bait studies. All captured gophers were identified by toe-clipping. Traps were set at all burrow systems with fresh mounding activity. Many gophers were captured several times in different localities within their individual territories. This provided us with information on the size, shape, and distribution of individual gopher territories on the study site. This was helpful in determining where to place paraffin baits and whether baits were carried to more than one territory by pocket gophers.

One hundred different pocket gophers were captured a total of 253 times during the study period. Most of the captures occurred in the periods July 6-17 and August 9-22. Twenty-nine percent of the gophers had been marked during earlier studies in 1980 and 1981. Of the 71% new captures in 1982, 56% were subadults and 44% were adults.

In order to test the hypothesis that invading pocket gophers will find and consume acceptable baits they find in abandoned burrow systems, we radio-tagged most baits by casting a lima bean-size (5 g) radio transmitter into the center of the cylindrical-shaped bait. SMI transmitters (purchased from the AVM Instrument Company, Dublin, California) were equipped with 3-month batteries and encapsulated in acrylic prior to placement in baits (Figure 1).

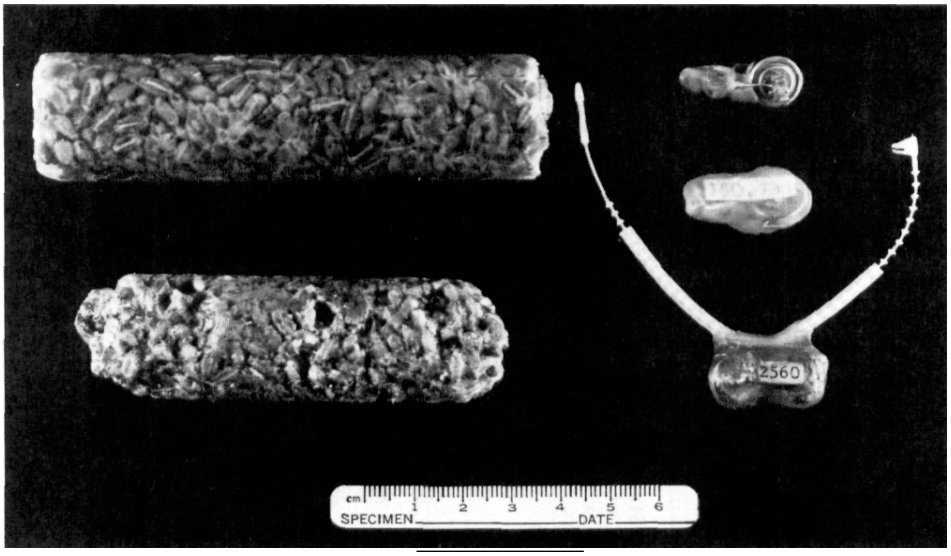

Fig. 1. Top left, cylindrical-shaped paraffinized bromadiolone bait; bottom left, partially eaten bait; top right, SMI radio transmitter; center right, transmitter embedded in acrylic ready for placement in paraffin bait; bottom right, radio transmitter and collar for attachment around the neck of pocket gopher.

The transmitters operated in the 150.7-151.7 MHz range, with an average pulse rate of 80 beats per minute. When placed underground, baits could be detected with a LA12-DS portable telemetry receiver equipped with hand-held Yagi antenna at distances up to 75 m. Baits could be located quite accurately by the signal strength and they often could be pinpointed within 30 cm, with a custom antenna, depending on the depth of the transmitter.

The specific objectives of these field studies were to determine: 1) the efficacy of paraffinized bromadiolone baits in controlling Mazama pocket gophers, 2) where the paraffin baits are moved within the burrow system by pocket gophers, 3) the amount of durable bait remaining after a gopher is killed, 4) if adult gophers from adjacent territories enter vacated burrow systems and steal or consume bait from food stores, 5) if dispersing subadults take over vacated burrow systems and feed on baits left behind by the original occupants, and 6) the number of gophers which can potentially be controlled by the same bait.

Although procedural details were necessarily varied throughout the study to address the various objectives, the same basic method was used throughout the study to evaluate paraffin baits. Each paraffin bait was inserted in a section of tunnel adjacent to a recently formed mound. Soil was then used to close the opening to exclude light and air. Initial bait placement locations were identified above ground with wire-stemmed plastic flags. Each burrow system was then monitored daily with a hand-carried portable receiver to determine if baits were moved by pocket gophers. Whenever a bait was moved, the new location was flagged and distance and direction of movement were measured and recorded. In some situations gophers were live-trapped and fitted with radio collars so that both the radio-tagged baits and gophers could be monitored.

Preliminary Field Bait Acceptance Tests

Eight burrow systems were chosen to evaluate the acceptability of durable baits weighing about 100 grams each. Four baits were nontoxic and four contained bromadiolone. All baits were placed in tunnels on July 13 and recovered 8 to 10 days later.

In order to evaluate the efficacy of bromadiolone, we opened the tunnels of each gopher that received a toxic bait 3 weeks after baiting. Each burrow system was opened in three different locations and checked the following day. If all openings remained unplugged after one day, the gopher was assumed dead. If fresh plugs appeared, traps were then set to determine whether the original or an invading gopher was responsible.

Invasion Studies

Ten burrow systems, each separated by a minimum of 50 m, were selected to evaluate the potential of durable baits to control two or more gophers in succession. In order to obtain a greater amount of data in the limited time period, we simulated poisoning death of gophers by removing each animal with traps after they had moved the bait within their burrows and presumably began to feed on the nontoxic paraffin placebo bait offered. This was in lieu of offering bromadiolone-treated baits and letting the gophers die. After each subsequent bait movement, traps were again set to remove the responsible invading pocket gopher.

With this method we were able to eliminate the expected lag period from the consumption of a lethal amount of bait to time of death, which is commonly 6 to 10 days with bromadiolone baits. Thus, we were able to observe the invasion of burrow systems within a compressed time frame.

Single paraffin baits were placed in each of three burrow systems. In 6 of the 10 burrow systems, second bait was added to the burrow system after the occupant gopher was removed. The second bait was used to increase our ability to detect invading gophers (refer to Results of Invasion Studies). Invasion studies were conducted from July through September, ranging from 20 to 40 days in length.

At the tenth burrow system, instead of removal by trapping, we live-captured, radio-collared, and released the gopher and placed two toxic baits in its burrow system. We assumed the gopher would die long before it consumed both baits. Our objective was to determine whether an invading gopher would enter the vacant nest area and feed on the same bait in the presence of the original dead occupant. Both of the radio-tagged baits and the radio-collared gopher were monitored for 22 days.

RESULTS

Preliminary Field Bait Acceptance Tests

All eight paraffin baits were moved by gophers from their original locations (Table 2). Seven of the eight baits were taken by gophers to their nest area for feeding. Bait consumption was extensive with bait remaining on only two of the transmitters. Thus, although results were very encouraging based on bait acceptance, they also clearly indicate that baits were not large enough to sustain feeding by several gophers. The bromadiolone baits were very often consumed in their entirety, even though they contained enough toxicant to kill several gophers. This is due to the slow-acting nature of anti-coagulant rodenticides.

Five of the six bait-embedded transmitters were recovered with no bait remaining and were found in burrow cavities which we refer to as "dumps." Dumps are chambers or short tunnels, usually located within one meter of the nest chamber, that gophers use apparently for discarding unwanted materials and body waste. The most common items found in these dumps include urine, fecal pellets, and grass clippings from old nests. We also found moldy lab chow pellets (obtained by gophers from our live-catch traps), gopher skeletons, and one recently deceased subadult gopher, presumably buried by its mother. Frequently, dumps were sealed off from the main tunnel or nest chamber with a plug of soil.

Table 2. Details of the preliminary field tests conducted with radio-tagged paraffinized baits (weighing 100 g each) on Mazama pocket gophers (T. mazama) in the Klamath National Forest.

Burrow system no.	Sex	Type of Bait[1]	No. days before bait reached nest	Distance bait moved (m)	Depth bait taken (m)	Percentage of bait consumed[2]	Final location of transmitter
1	M	C	5	18.9	1.73	100	dump
2	M	T	4	6.4	0.41	100[3]	nest
3	M	T	2	8.2	1.02	100	dump
4	M	C	5	24.4	1.04	100	dump
5	F	T	3	15.2	1.09	100	dump
6	F	C	1	10.7	1.04	65	food cache
7	unknown	T	3	12.2	1.88	0	dump
8	unknown	C	recovered from runway	0.5	0.08	50	runway

[1]C - clean (nontoxic); T - toxic

[2]Percentage actually represents amount of bait removed from transmitters; some of the bait may have been cached elsewhere.

[3]Approximately 75% of bait was found crumbled in gopher's nest.

Our records of bait movement and subsequent discovery of radio-tagged baits indicate that baits were most often fed on in the gophers' nests. Bait carried to the nests remained for a period ranging from 1 to 5 days. One final movement of 50 to 100 cm was recorded for each bait (transmitter), which corresponds to the gophers' dumping of the transmitters once they had consumed all the bait. These observations suggest that gophers are tidy animals and prefer to keep their nest areas free of any useless items.

Each nest chamber generally had two tunnel entrances, although some had three, that led either to other adjacent chambers (used for food storage or waste disposal), or to the shallower runways used for foraging. Nest chambers are usually somewhat spherical or egg-shaped, being about 20 cm in length and width and about 15 cm in height. It appears as though some of the waste disposal chambers or "dumps" are actually old nests that have been abandoned.

As expected, gophers given the bromadiolone baits were by all indications killed. The open-burrow census method was used at two treated burrow systems and the burrows remained open, indicating the gophers were dead. This was further supported by the fact that neither of the gophers was recaptured during subsequent trapping periods. At a third treated burrow system, traps were set after plugging indicated that a gopher was still present. A gopher from an adjacent territory was captured and believed to be responsible for the plugging. The original occupant was presumed killed since it was never captured again. At the fourth site, open burrows were plugged the next day, but because the bait was given to an unmarked gopher, we were unable to determine with confidence whether plugs were formed by the original animal or an invader.

Additionally, bait efficacy was studied at two other burrow systems where gophers were radio-collared, released, and each given a bromadiolone bait. Due to the fact that all the transmitters were in use, these baits were not radio-tagged. Ten days later the gophers were excavated from their burrow systems. One was found dead in its nest adjacent to a chamber containing the remaining bait. Only 16 g were removed from the bait which was still in excellent condition. The other gopher was also found dead in a deep tunnel that presumably led to the nest area. Neither the nest nor the remaining bait was found.

Invasion Studies

The preliminary field tests made it clear that larger or less acceptable bromadiolone paraffin baits would have to be developed in order to produce multiple kills because the gophers continue to consume bait after a lethal amount has been eaten and before death occurs. However, since one of our foremost objectives was to determine whether additional bait movements and subsequent feeding occur after the first gopher dies, we did not feel it was necessary to either redesign the baits half-way through the study or change rodenticides. Therefore we proceeded with the summer's study. We believed that by removing each gopher by trapping after it had had a few days' feeding on the bait, we would be able to simulate natural events to satisfactorily determine the practical value of the invasion theory to produce multiple kills with one bait.

The preliminary field tests also indicated that gophers usually take paraffin baits to their nest area for feeding. This behavior presented us with the problem of detecting secondary feeding (i.e.,

feeding by an invading gopher) after the occupant gopher was removed or killed. We believed that a dispersing gopher that takes over an abandoned territory (and presumably abandoned nest) would probably feed on the remaining bait at the same location in which it was found (i.e., the nest). Therefore, additional bait movement might not occur and the second and third invading gopher may go undetected if above-ground radio-monitoring is all that is used for such determinations.

Thus, to increase our ability to detect invasion of an abandoned burrow system, we used two paraffin baits at six of our study burrow systems. After the first gopher was removed, a second bait was placed in the same location where the first bait was originally offered. We assumed that any gopher that would take over an abandoned nest would also find and move the second bait back to the nest.

Results of the invasion studies indicate that pocket gophers often investigate and take over abandoned burrow systems relatively soon after the original occupant gopher is removed by trapping (Table 3). In 8 of the 10 systems, invasion and subsequent bait movements were noted, all within 7 days after removal of the original occupant (or death as in burrow system number 10). Assuming the radio-collared gopher in burrow system number 10 given bromadiolone baits died about 10 days later, then invasion of its burrow system apparently occurred about 6 days after death.

Table 3. Results of study where pocket gophers were removed from their burrow systems after they began feeding on paraffinized baits. Traps were used to remove the invading gopher after each subsequent bait movement. The time for the invading gopher to appear after removal of the previous occupant is indicated in days.

Test burrow system	Age[1] and sex of gophers and time (days) for invaders to take over unoccupied burrow system				Length of test (days)	No. gophers feeding on bait
	Original occupant	1st invader	2nd invader	3rd invader		
1	S♂	-	-	-	20	1
2	A♀	A♂(6 days)	S♂(8 days)	S♀(6 days)	40	4
3	A♀	-	-	-	20	1
4	S♀	(1 day)[2]	-	-	20	2
5	A♂	S♂(1 day)	S♂(8 days)	-	38	3
6	A♀	(1 day)[2]	-	-	23	2
7	A♀	S♂(5 days)	(4 days)[2]	-	21	3
8	A♀	S♀(5 days)	-	-	24	2
9	A♂	A♀(7 days)	S♂(6 days)	-	22	3
10	S♂[3]	(16 days)[2]	-	-	24	2

[1]A = adult; S = subadult.

[2]Age and sex of invader unknown.

[3]This gopher was trapped, radio-collared and released in its burrow system. Rather than removing this animal from its territory, it was given two toxic paraffinized baits. Days reported for the invader to appear are the days after baits were given to the first gopher.

Baits were most frequently fed upon by the invading gopher in the same burrow system in which the baits were originally placed; but in at least four cases, they were carried long distances to apparently a different burrow system. The distance of secondary bait movements (i.e., distance baits were moved by invaders) ranged from 0.3 m to 33 m. The average distance of secondary movements was 7.9 m, excluding the 6 baits which were not moved by invaders. A total of 14 individual cases of secondary feeding and bait movements were monitored.

Most of the baits were taken to their nests by the original gophers. At four of these nest sites, baits did not move again after removal of the original occupant. However, this does not mean that these baits were not or would not be found by invading pocket gophers in the future. In fact, in three of the four sites, subadult gophers appeared and began feeding on a second bait that was provided. Rather than carry the baits back to the abandoned nest, they moved them only a short distance before feeding. The baits were probably too large for the smaller gophers to conveniently transport through the burrow system. Perhaps if these subadults had not also been removed by trapping, the second baits might have eventually been moved to the nest as they grew smaller in size due to bait consumption.

We were able to document the takeover and continued use of abandoned nests by invaders at two of the monitored burrow systems. In one instance an adult male gopher was removed after it took the bait back to its nest. Sixteen days later a subadult male gopher appeared in the territory and took the

second bait back to the same nest chamber that contained the remaining first bait. When the baits were recovered later, they were in the same area and separated by a distance of only 69 cm. Also found in the nest were fresh grass clippings and pieces of lab chow stolen from the live-catch traps and that had been recently cached by the new occupant.

In another monitored burrow system we documented the occupation of the same nest by three different gophers during a 2-month period. The nest was initially occupied by an adult female gopher which, according to earlier trapping records, had occupied the territory since the summer of 1980. A nontoxic bait was taken by this gopher to her nest during our preliminary bait acceptance studies. We recovered the transmitter from her "dump" nine days later without disturbing the nest. This gopher was never captured again during subsequent trap efforts and was assumed dead from natural causes since it had not had access to toxic bait. Possibly it had been captured by a predator.

A subadult male gopher was later captured in the same burrow system as the female earlier and was presumed to be the current occupant of the abandoned territory. This same gopher had been previously captured in July (one month earlier) at a location 31 m north of the original female's nest chamber. Because it was a subadult, it is unlikely that this gopher had established its own territory at the time of the July trapping. However, apparently the subadult found the abandoned system and took up residency.

We placed a radio collar on the gopher, released it back into its burrow and offered it two bromadiolone paraffin baits. Three days later it had taken one of the baits back to its nest. Both the bait and collar radio signals were located in the exact spot that the female gopher had taken her bait earlier, confirming that the subadult had indeed taken over the same nest chamber.

As we continued to monitor the burrow system, we noticed that the gopher began to move from its nest site 16 days after the two bromadiolone baits were offered. By the 21st day, the gopher was located a distance of 2.9 m from the nest and the bait had shifted slightly within the nest. We then excavated the bait and gopher and discovered that the gopher had been dead for some time, possibly as long as 10 days. In an attempt to reconstruct what happened, it appeared that the invading gopher entered the burrow system, dragged the dead gopher from the nest, and deposited it in a runway nearly 3 m from the nest. Fresh grasses and forbs found in the nest indicated that the invading gopher had already begun to occupy the nest. It also apparently consumed what remained of the first bait because it removed the transmitter from the nest and buried it in a dump 50 cm away.

This invader during its travels through the burrow system apparently also found the second bromadiolone bait we had offered and moved it 14.3 m. Instead of carrying the bait to the nest, it took it to a runway where it consumed approximately 50 percent of the bait. We later made three openings in the burrow system and checked for burrow plugs the following day. Since no plugging appeared, we assumed that the invading gopher had been killed by the bromadiolone baits.

Although these studies are quite limited, the results are very encouraging because they prove that nests are likely to be reutilized by numerous gophers. Further, it appears that the presence of a dead gopher within a nest has no adverse effect on the invasion of that territory.

CONCLUSION

The amount of time and effort involved in conducting such field behavioral type studies is great and thus limited the number of pocket gophers and their burrow systems that could be studied and monitored. However, in spite of these relatively limited data, we were highly encouraged with the results.

Using palatable long-lasting baits, multiple kills with a single bait or baiting were indeed possible when invading gophers took over unoccupied burrow systems.

The study supported to various degrees the following points:

1. Bromadiolone-treated wheat embedded in paraffin was highly acceptable and sufficiently moisture-resistant and durable to remain acceptable and toxic for a number of weeks during the summer months at the study location.

2. Bromadiolone at the concentration of 0.025% formulated on wheat and then cast in paraffin was lethal to pocket gophers. The active ingredient of the finished bait was 0.0175%.

3. The slow onset of symptoms associated with bromadiolone provided ample time for the gophers to move the bait back to their nests even if some bait was consumed at the placement site.

4. There is good evidence that the slow action of the anticoagulants gives the gopher time to continue to feed on the bait, even though it has ingested a lethal dose. This often meant that no bait remains for the second or subsequent gophers.

5. There is good evidence that gophers take the bait to their nests to consume. The exception may be the subadult animal, possibly due to its lack of experience or inability to manipulate and move the 100-g baits.

6. Both adult and subadult pocket gophers readily invade unoccupied burrow systems either after a gopher is poisoned or its poisoning is simulated through trapping the gopher from the system.

7. Unoccupied burrow systems taken over by the invading gophers seem to be extensively used. Even the original nest chamber is frequently used by the new occupant.

8. If a new or additional bait is placed in a recently vacated (i.e., poisoned or trapped out) burrow system, an invading gopher will in most instances find it.

9. There is nothing to suggest that a dead gopher carcass deters the invasion of other gophers. In fact, in one instance the evidence suggests that a dead gopher was moved and apparently deliberately buried.

10. Nest chambers are usually spherical or oval-shaped and slightly flattened from top to bottom. They are about 20 cm in diameter and about 15 cm in height. Their depth below ground varies anywhere from 0.41 m to 1.88 m and averaged 1.17 m (3.8 ft.) at the study site.

In these preliminary field studies with a limited number of monitored gophers, baits and gopher systems, this new concept in pocket gopher control appears to have considerable promise.

The major problem confronting us was that the bromadiolone experimental bait used—although containing enough toxicant to kill several gophers--was frequently consumed entirely by the first gopher, leaving none for the subsequent gophers.

This problem can be resolved in several possible ways, all of which were given consideration. The following solutions were addressed:

1. To make the bait larger, although previous laboratory studies in glass-covered observation burrow systems suggest that larger baits would be more difficult for the gopher to carry and manipulate back to the nest.

2. To insert two separate baits rather than to increase their size, although this would make control more expensive in materials and labor.

3. To devise some means, either chemically or physically, to slow the feeding rate on the bait so that death occurs before the bait is all consumed.

4. To switch to another anticoagulant rodenticide that had a taste factor which would tend to reduce bait consumption.

5. Another option would be to switch rodenticides and use a more rapid-acting acute rodenticide, although this might risk problems of developing bait-shyness. If too rapid an acting rodenticide were used, it might also diminish the time the gopher would have to carry the bait to the nest before death, assuming the gopher consumed some bait at the point of placement.

Most of these options have been evaluated to some degree and the significant results will be reported elsewhere.

Our experimental results reported in this paper confirm our hypothesis and support the feasibility of our new concept in pocket gopher control for use in reforestation situations. At the completion of the studies there remain some questions concerning bait size and bait feeding rate; however, these are believed to be solvable problems that do not alter the practical benefits of this new pocket gopher control concept.

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