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HAZARDS TO GOLDEN-MANTLED GROUND SQUIRRELS AND ASSOCIATED SECONDARY HAZARD POTENTIAL FROM STRYCHNINE FOR FOREST POCKET GOPHERS

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ABSTRACT: Radio telemetry and capture-recapture techniques were used to evaluate the hazards to golden-mantled ground squirrels (*Spermophilus lateralis*) from hand baiting with 0.5% strychnine-treated oats for western pocket gophers (*Thomomys mazama*) on conifer plantations in eastern Oregon. Toxicology data were collected on field-killed and caged ground squirrels and on caged mink (*Mustela vison*), great horned owls (*Bubo virginianus*), and red-tailed hawks (*Buteo jamaicensis*). Ground squirrel populations were reduced 50% to 75% following underground baiting for pocket gophers. Maximum amount of strychnine alkaloid found in cheek pouches and carcass of a field-killed golden-mantled ground squirrel was 2.88 mg. Mean amount of strychnine in carcasses was 0.35 mg; almost all occurred in the gut. The estimated LD₅₀ for mink was 0.6 mg/kg. The lowest lethal dose for great horned owls and red-tailed hawks was 7.7 mg/kg and 10.2 mg/kg, respectively. The LD₅₀ for owls and hawks was not determined. Long-term effects on golden-mantled ground squirrel populations and secondary hazard potential to owls and hawks were judged to be minimal. Wild mustelids as large as mink could be adversely affected by consuming the gut content of strychnine-killed golden-mantled ground squirrels.

INTRODUCTION

Underground baiting with strychnine alkaloid oat bait is commonly used to control pocket gophers (*Thomomys* spp.) in western forests (Crouch 1969, Barnes 1973, Northwest Pocket Gopher Committee 1976). Control effectiveness has been demonstrated (Barnes et al. 1970, Barnes 1974, Birch 1978, Crouch and Frank 1979); however, little has been done to evaluate hazards in forest environments. Lack of hazard data concerns the U.S. Forest Service (Barnes et al. 1982). This concern led to interagency studies of potential hazards of gopher baiting to grizzly bears (*Ursus arctos horribilis*) and small mammals in eastern Idaho (Barnes et al. 1980, Fagerstone et al. 1980) and to this study on golden-mantled ground squirrels (*Spermophilus lateralis*) in eastern Oregon. The study consisted of the following: strychnine TOXICOLOGICAL DETERMINATIONS on golden-mantled ground squirrels, western pocket gophers (*T. mazama*), and caged mink (*Mustela vison*); FIELD EVALUATIONS on hazards from baiting gophers; and, determination of SECONDARY HAZARDS to caged mink, red-tailed hawks (*Buteo jamaicensis*), and great horned owls (*Bubo virginianus*). The study was from June 1982 through December 1983. Field work was done on the Deschutes National Forest in Oregon; laboratory work was carried out in Olympia, Washington and Denver, Colorado.

TOXICOLOGICAL DETERMINATIONS

LD₅₀ Tests

Methods. The LD₅₀ of strychnine to golden-mantled ground squirrels and domestic mink was determined by a method described by Thompson (1947) and Thompson and Weil (1952). Only female mink were available for testing. Test animals received pure strychnine alkaloid suspended in propylene glycol and controls received only propylene glycol administered by gavage. Each animal was conditioned to a holding cage for at least five days prior to testing and was observed for seven days after testing. All animals were fasted for four hours before and two hours after treatment; food and water were available at other times.

Results. The estimated LD₅₀ from the dose ranging procedure used for the mixed sample of male and female golden-mantled ground squirrels was 3.6 mg/kg (CL₉₅, 2.4 - 5.4 mg/kg). The estimated LD₅₀ for the female mink used in the study was 0.6 mg/kg (no confidence limits established).

Bait Bioassays

Methods. Bait acceptance by five golden-mantled ground squirrels and five western pocket gophers was measured for three days according to a method described by Lindsey (1977). Test animals were offered 20 g of 0.5% strychnine-treated oats daily. Control groups were given untreated oats under the same testing regime. Animals were fasted for four hours before testing. Supplemental food was given after the first day of testing.

Results. Four of five golden-mantled ground squirrels and four of five western pocket gophers died following consumption of bait. All deaths occurred within 4-1/2 hours after bait presentation. Mean amount of bait consumed by ground squirrels and pocket gophers that died was 1.03 g and 1.02 g, respectively. Mean amount of strychnine alkaloid consumed by each species was 5.1 mg. The one surviving ground squirrel consumed almost 29 mg of strychnine in four consecutive days (about 44 mg/kg per day for four days) and the one surviving pocket gopher consumed over 125 mg (about 272 mg/kg per day) for four consecutive days with no ill effects. These high intakes strongly indicate resistance to strychnine.

FIELD EVALUATIONS

Impact on golden-mantled ground squirrels from operational baiting of pocket gophers on forest plantations was studied in 1982. Recovery of populations and effects of rebaiting were studied in 1983. All study plots were on the Sisters Ranger District of the Deschutes National Forest. Evaluation included estimating bait abundance, pre- and post-treatment counts of ground squirrels, periodic live-trapping to estimate ground squirrel abundance, and radio telemetry to determine activity and fate of ground squirrels.

Impact of Baiting - 1982

Methods. Two 8-ha treated plots (T1 and T2) and one 8-ha control plot (C1) were established in a mixed conifer community dominated by ponderosa pine (*Pinus ponderosa*) at 1400- to 1500-m elevation. Plot T2 had been logged and planted in the late 1970s; plots T1 and C1 had been planted repeatedly since the late 1950s because of loss of trees to pocket gophers.

Contract crews applied 0.5% strychnine oat bait in pocket gopher burrows on September 14, 1982, following hand-baiting specifications of the Deschutes National Forest. The control plot received untreated oats. Bait distribution was estimated by counting the number of bait sets found within each of 40 81-m² subplots randomly located on each plot. Bait abundance was estimated by weighing 20 bait sets collected at random on each plot. Bait abundance and density were tested for significance using analysis of variance.

A direct-count method of estimating ground squirrel abundance (Fagerstone 1982) was used to determine relative differences among study plots and to detect changes in populations following baiting. Golden-mantled ground squirrels were counted on a 1-ha subplot from an elevated location at each plot during eight consecutive 15-minute periods from 9 A.M. to 11 A.M. on three consecutive days before and after baiting. The pretreatment observation began four days before baiting; posttreatment counts began eight days after baiting. The highest count for each 15-minute period was used for comparison.

Golden-mantled ground squirrels equipped with 164 MHz radio transmitters were located daily to determine the fate of poisoned individuals and to estimate the proportion of the population affected. On each plot, 31 ground squirrels were captured, aged, sexed, weighed, eartagged, fitted with 5- to 6-g radios and immediately released at their capture sites. Radio tracking began five days before baiting and continued daily for ten or more days after baiting. Night tracking was done to verify nest locations; daytime tracking verified movement (or non-movement) of individual animals. Dead animals were recovered and frozen for later strychnine analysis. Radios were removed from survivors during the final days of the evaluation.

Results. Bait application on Plot T1 was significantly greater ($P < 0.01$) than Plot T2. The difference was primarily a result of more bait sets (hence, more gopher sign) rather than more grain per set. About 3.5 kg/ha of bait was applied on Plot T1 (6.1 g/set with 477 sets/ha); whereas, about 0.8 kg/ha of bait was applied at Plot T2 (4.4 g/set with 182 sets/ha).

Peak counts of golden-mantled ground squirrels before and after baiting occurred on the same day for all plots. On Plot C1, eight ground squirrels were observed pretreatment; on Plots T1 and T2, four and three ground squirrels were observed, respectively. Ground squirrel counts decreased to one on both treated plots after baiting--a decrease of 72%. On the control plot, the count rose to 14 during the posttreatment observation period--a 75% increase in observed individuals.

Because of radio malfunctions and animals beginning hibernation before baiting, the effective number of radio-tagged ground squirrels in the study was reduced from 62 to 53 on treated plots and from 31 to 25 on the control plots.

On the treated plots, 49% (26 of 53) of the radioed squirrels were found dead. Eighty-eight percent (23 of 26) of the mortalities occurred within five days after baiting. Seventy-three percent of the carcasses (19 of 26) were found above ground. Five of the carcasses found below ground were in burrow systems of pocket gophers, whereas, only two were found in their own nest. In addition, badgers (*Taxidea taxus*) killed two treatment squirrels and three others began hibernating before treatment. Of 28 squirrels on the control plot, none were found dead, two were taken by badgers and three began hibernating before treatment. No other animal species were found dead.

Chemical analysis confirmed that strychnine was the cause of death in all recovered animals except one. Mean amount of strychnine in ground squirrel carcasses was 0.35 mg (range 0.09 - 1.08 mg, CL_{95} , ± 0.10 mg); 99% of the toxicant was found in the gastrointestinal (GI) tract.

Two of 26 poisoned ground squirrels had 16 and 21 kernels of bait, respectively, in the cheek pouches. This bait was not analyzed for strychnine; however, estimated amount based on other analyses of pouched grain is 1.4 and 1.8 mg of strychnine, respectively.

Mean weight of animals found dead was 152.4 g (CL_{95} , ± 7.3 g) compared to 185.5 g (CL_{95} , ± 11.6 g) for survivors. This difference was significant ($P < 0.05$).

Population Recovery - 1983

Methods. In 1983, three widely separated pine plantations baited with strychnine for pocket gophers in 1982 were selected as treatment areas (B1, B2, and B3) to determine recovery of golden-mantled ground squirrel populations. Three other plantations with similar habitat characteristics but no recent history of baiting were selected as control areas (C1, C2, and C3). Plantations were about 8 ha each.

We trapped ground squirrels during three 5-day periods in early June, mid-July, and late August. In each study area we used 50 uniformly distributed live traps. Traps (13- x 13- x 41-cm and 15- x 15- x 48-cm) were covered with milk cartons for protection, left open, and baited with peanuts for a 3-day "familiarization" period before each trapping period. Trapping was then conducted for five consecutive days between about 7 A.M. and 3 P.M. Peanuts were used as bait.

Trap doors were equipped with flags that indicated trap closure to facilitate tending of traps. Traps containing ground squirrels for the first time on a particular day were closed for the remainder of the day. Traps that contained other small mammals or ground squirrels previously caught during that day were reset. Captured ground squirrels were sexed, aged (adult or young-of-the-year), weighed, marked with two No. 1 ear tags and released.

Trapping data were analyzed with the computer program CAPTURE (White et al. 1978) which estimates populations using a model based on trapping results (Otis et al. 1978). Population estimates among trapping periods were compared using one-way analysis of variance (ANOVA) and two factor repeated measures ANOVA as in Winer (1971).

Results. Golden-mantled ground squirrel population levels on plots baited for pocket gophers the previous year appeared to be considerably lower than levels on unbaited plots despite excellent recruitment of young-of-the-year (Table 1). However, there were no significant differences between population means in July and August. This was due to variations between plots within treatments. One-way ANOVA verified the two factor repeated measures ANOVA used to analyze results.

Table 1. Estimated golden-mantled ground squirrel populations and standard errors in June, July, and August 1983 on plots baited for pocket gophers in 1982 (B1-B3) and on unbaited plots (C1-C3) as generated by program CAPTURE (White et al. 1978). Means with the same letter within treatment groups are not significantly different ($P \leq 0.05$). Numbers in parentheses represent percent young-of-the-year captured.

Plots	June	July	August
B1	40* (0)	82±11 (0)	95±5 (65)
B2	20* (0)	35± 1 (6)	37±3 (100)
B3	12* (0)	17± 1 (0)	25±1 (96)
Means	24 (0)A	45 (2)A	52 (87)A
C1	59±5 (0)	72±4 (0)	104±7 (60)
C2	58±4 (0)	79±5 (31)	62±4 (84)
C3	66±4 (0)	87±7 (15)	75±8 (89)
Means	61 (0)A	75 (15)B	80 (78)AB

*Total number of animals captured. Program CAPTURE could not be used in June treatments because of insufficient numbers of captured animals.

Effects of Rebaiting - 1983

Methods. To determine repeated effect of gopher baiting on golden-mantled ground squirrels and for supplemental information on onset of ground squirrel hibernation, radio-tracking transmitters were attached to 10 or more golden-mantled ground squirrels on all six 1983 study units. Sites B2 and B3 were operationally baited October 14, 1983. Plot B1 was not contracted for retreatment by the U.S. Forest Service; therefore, tracking was used only to establish onset of hibernation. Radio tracking began September 13, 1983 and ended October 21, 1983. Recoverable transmitters were removed at study completion. Estimates of baiting densities were made as in 1982.

Results. Considerably less bait was applied in 1983 than in 1982. In 1983, about 0.4 kg/ha of bait was applied to Plot B2 (4.7 g/set with 93 sets/ha); and about 0.2 kg/ha of bait was applied on Plot B3 (4.7 g/set with 467 sets/ha). (In 1982, Plots B1 and B2 received 3.5 kg/ha and 0.8 kg/ha, respectively.) The lower rate in 1983 was because of lower populations of pocket gophers as a result of baiting in 1982.

A total of 64 ground squirrels (24 on baited plots and 40 on unbaited plots) were equipped with radios. None of the treatment or control squirrels died as a result of strychnine bait. No bait was found in nine excavated ground squirrel nests.

Raptors took five of six animals that were preyed upon; a badger consumed the other radio-equipped ground squirrel. Five ground squirrels were hibernating before treatment and thereby escaped exposure to bait.

SECONDARY HAZARDS - MINK

Domestic mink were treated for acute and chronic intoxication with golden-mantled ground squirrels killed with 0.5% strychnine oat bait used for pocket gopher control. Mink also were tested for sensitivity to strychnine levels found in golden-mantled ground squirrels recovered in the 1982 pocket gopher baiting program. Test levels of strychnine in sensitivity testing and corresponding levels found in golden-mantled ground squirrels were as follows:

<u>Test level</u> <u>(mg)</u>	<u>Level of strychnine (mg) in field-killed</u> <u>ground squirrels</u>
0.5	0.35 mg: mean level in the gut.
1.0	1.07 mg: maximum level in the gut.
2.0	1.94 mg: mean level in the gut and cheek pouches.
3.0	2.88 mg: maximum level in the gut and cheek pouches.

Tests with Strychnine-Killed Ground Squirrels

Methods. Only adult female mink were tested. Each animal was held and tested in an individual wire holding cage and received a daily ration of 200 - 225 g of plain or reformulated commercially prepared mink food. A "switchback" method was used to test effect of 10 mink each consuming one or three golden-mantled ground squirrels at one feeding. In this method, each of five mink in Group I received a ration containing one groundup ground squirrel carcass (less head, feet, and skin) and Group II served as controls. After five days, each mink in Group II received a ration with three stomachs of poisoned ground squirrels and Group I survivors plus a replacement served as controls. Following a 7-day rest period, test animals were again switched so that Group I mink received three stomachs and Group II mink received one carcass.

Results. Of 10 mink receiving 200 g of feed mix containing one poisoned ground squirrel, one rejected the mix after consuming only 34 g and another died after consuming 150 g of the mix. In the test with three ground squirrel stomachs per mink in a single feeding, one of the 10 mink died after consuming 130 g of the mix. There was no observable effect on other test mink when compared with controls. Chemical analysis indicated a mean of 0.85 mg (CL_{95} , ± 0.82 mg) strychnine for the one squirrel-mink feed mix and 1.62 mg (CL_{95} , ± 0.80 mg) strychnine for the three squirrel-mink feed mix per 200 g ration. Estimated consumption of strychnine by the two dead mink was 1.5 mg/kg and 1.0 mg/kg, respectively. Mink carcasses contained 0.1 and 0.15 mg of strychnine, respectively.

Sensitivity to Strychnine

Methods. Mink were given a single dose of 0.5, 1.0, or 3.0 mg of strychnine alkaloid in corn oil after feeding on 100 g of mink feed--the approximate weight of a skinned, decapitated ground squirrel. Control mink received plain corn oil. All received normal rations of mink feed immediately after treatment.

To study effect of repeated exposure and chronic toxicity, a group of mink that had been exposed to strychnine at least six days previously were tested under a continuous feeding regime. In this test, each mink received a single 1.0 dose of strychnine in corn oil for five consecutive days.

Results. Effects of acute and chronic strychnine alkaloid sensitivity tests on ground squirrels are summarized in Table 2. Ingestion of 1 mg of strychnine (about 1 mg/kg) was lethal to some mink; 3 mg (about 2.3 mg/kg) was lethal to all test mink. Food consumption and body weights of survivors did not change significantly during or after treatment.

SECONDARY HAZARDS - OWLS AND HAWKS

Tests with Strychnine-Killed Ground Squirrels - Owls

Methods. Owls were kept in individual holding pens and maintained daily on a ration of chicken heads and occasional small rodents, birds, and other meat. Water was available at all times. Each of five owls were first conditioned to untreated golden-mantled ground squirrels and then presented one whole poisoned ground squirrel. Another group of five owls received the equivalent of three poisoned ground squirrels in a single feeding. To assure consumption of three poisoned squirrels per owl in one day, each owl received three eviscerated deer mice (*Peromyscus maniculatus*), each containing the stomach of a poisoned ground squirrel. To test chronic effects, three owls each received one poisoned ground squirrel per day for 16 days. Food was provided daily to all test and control birds.

Table 2. Effect of select levels of strychnine alkaloid on domestic mink.

Strychnine intake		No. deaths/ no. tested	Remarks
Mg	\bar{X} mg/kg		
- - - - - Acute - - - - -			
0	0	0/5	No effect.
0.5	0.42	0/5	No reaction to strychnine.
1.0	0.96	2/5	Two surviving mink showed no reaction; third mink exhibited exaggerated responses to sound and light for 6 hours.
3.0	2.33	5/5	Died within 6 hours.
- - - - - Chronic - - - - -			
1.0*	0.84*	1/5	Three surviving mink showed no reaction; fourth mink exhibited exaggerated responses to sound and light for 4-5 hours following each daily dose.

* Mean daily intake for 5 consecutive days.

Results. Of five owls tested on one whole strychnine-killed ground squirrel, one rejected the GI tract and another regurgitated an undigested stomach and liver. Of five owls presented ground squirrel stomachs sewn into eviscerated deer mice, one regurgitated all three undigested mice and another rejected part of a mouse and the stomach of a poisoned ground squirrel. In the 16-day chronic feeding test, treatment owls consumed carcasses but avoided the GI tract of poisoned ground squirrels in 48% of the feedings. Controls did not regurgitate untreated mice or ground squirrels and only occasionally (less than 5%) rejected GI tracts. Chemical analysis showed that poisoned ground squirrels contained a mean of 0.41 mg (range 0.08 to 0.93 mg) of strychnine alkaloid; almost all (99%) of the strychnine occurred in the gut of poisoned squirrels.

Sensitivity to Strychnine - Hawks and Owls

Methods. Hawks and owls were conditioned before testing and maintained in the same manner as owls used in tests with poisoned ground squirrels. Birds were held in individual cages and tested in groups of two at levels of 3, 6, 9, 12, and 15 mg of strychnine; these levels equalled 1, 2, 3, 4, and 5 times the 3-mg maximum level found in field-killed golden-mantled ground squirrels during 1982. To insure ingestion of these exorbitant dose levels, the appropriate amount of strychnine was injected into the body of a dead deer mouse and, along with an untreated mouse, immediately force-fed to a test bird. Control birds each received two mice without strychnine. Following force feeding, all birds received normal food rations.

Results. Table 3 summarizes the effects of dose levels of 3, 6, 9, 12, and 15 mg of strychnine given to hawks and owls; the 12-mg dose appeared to be close to the tolerance limit for both species. The owls reacted (recurring convulsions, seizures, inability to remain on limb perches) to 3 mg of strychnine--about 2 mg/kg--the lowest level of strychnine administered in the test. Toxic symptoms occurred in hawks beginning at the 6-mg level (about 4.5 mg/kg). Death of owls occurred at 7.7 mg/kg level, hawks at 10.2 mg/kg.

Owls that promptly regurgitated treated mice were not as severely affected as those that failed to regurgitate or took two to three hours to regurgitate. Emesis probably saved the lives of owls receiving 6, 9, and 12 mg of strychnine. None of the hawks regurgitated.

DISCUSSION AND CONCLUSIONS

Our study showed an immediate but not long-term adverse effect on golden-mantled ground squirrel populations from underground baiting with strychnine-treated oats used to control pocket gophers in a forest environment. Our data suggest that baiting as late as possible in the year might reduce inadvertent poisoning of golden-mantled ground squirrels because of their greatest weight gain near hibernation (McKeever 1964) and because of hibernation itself.

Secondary poisoning of mustelids--particularly mink, marten (*Martes americanus*), and fisher (*M. penanti*)--seems possible if the stomach contents of a strychnine-killed ground squirrel is consumed. Potential of acute poisoning of raptors consuming golden-mantled ground squirrels killed with 0.5% strychnine oat bait for gophers appears minimal.

Table 3. Effects of ingesting deer mice injected with 3, 6, 9, 12, and 15 mg of strychnine alkaloid on great horned owls and red-tailed hawks (two birds per treatment level).

Great horned owls			Red-tailed hawks		
Strychnine dose		Toxic effect	Strychnine dose		Toxic effect
Mg	Mg/kg		Mg	Mg/kg	
0	0.0	None visible	0	0.0	None visible
	0.0	None visible		0.0	None visible
3	2.1	Convulsions; unable to perch	3	2.0	None visible
	2.5	Convulsions; unable to perch		2.9	None visible
6	3.8	Emesis; unable to perch	6	4.6	Convulsions; unable to perch
	3.9	Convulsions; unable to perch		4.5	Convulsions; unable to perch
9	5.0	Emesis; unable to perch	9	6.2	Convulsions; unable to perch
	5.1	Emesis only		6.9	Convulsions; unable to perch
12	7.5	Emesis only	12	9.2	Convulsions; unable to perch
	7.7	Dead within 24 hours		12.3	Dead within 24 hours
15	10.5	Dead within 24 hours	15	10.2	Dead within 24 hours
	11.8	Dead within 24 hours		11.2	Dead within 24 hours

There is insufficient information to assess the full impact of strychnine on all wildlife under all possible habitat conditions and baiting regimes. We believe that underground baiting forest pocket gophers with 0.5% strychnine-treated grain normally will not cause unreasonable long-term adverse effects on nontarget wildlife species. Nevertheless, precautions--prepoisoning surveys for sensitive and endangered species, post-baiting carcass searches and removal, late baiting, use of grain baits and not fresh baits for carrying strychnine, and nontoxic alternatives (Anthony et al. 1978)--should be taken to minimize potential hazards.

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