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ABSTRACT: Damage to conifer seedlings by pocket gophers (Thomomys spp.) is a major factor limiting reforestation in the western United States. To control gopher populations and reduce damage, the U.S. Forest Service annually treats thousands of hectares with strychnine alkaloid bait. Because an underground application of strychnine bait could pose a threat to other species, we monitored small mammal populations before and after a baiting operation conducted in 1979 on the Targhee National Forest, Idaho. Although two deer mice (Peromyscus maniculatus) recovered within baited areas were killed by strychnine, live-trapping revealed no differences in small mammal populations before and after baiting. Thirty yellow pine chipmunks (Eutamias amoenus) and one northern flying squirrel (Glaucomys sabrinus) were fitted with radio transmitters before treatment. Twenty-four of the chipmunks, and the flying squirrel, survived to the end of the study. Transmitter signals were lost on three chipmunks before treatment and they were unaccounted for. Two chipmunks died during the study and contained strychnine residues in body tissues. The remaining chipmunk appeared to have been killed by a predator.

INTRODUCTION

Damage to conifer seedlings by pocket gophers (Thomomys spp.) is a major factor limiting reforestation on over 120,000 hectares of forest land in the western United States (Northwest Forest Pocket Gopher Committee 1976). In conjunction with reforestation programs, the U.S. Forest Service annually treats thousands of hectares with strychnine alkaloid treated grain. Proper below ground bait application has been shown to reduce pocket gopher damage to seedlings (Barnes 1974, Birch 1978, and Crouch and Frank 1979) but hazards associated with these baiting programs have not been well defined.

In July, 1979, we collected data on the effects of strychnine baiting in forest plantations on northern pocket gophers (Thomomys talpoides) and other small mammals on the Targhee National Forest in eastern Idaho (Barnes et al. 1980). One objective was to determine the availability of strychnine alkaloid to grizzly bears (Ursus arctos horribilis) resulting from underground baiting for gophers. Results of that work will be published elsewhere. The second objective, to determine the effect of strychnine baiting on nontarget small mammals, is the subject of this paper.

METHODS

Study Areas

The study was conducted on two sites in the Targhee National Forest in eastern Idaho. The West Bitch Creek site, about 25 km east of Ashton, Idaho, was clearcut between 1967 and 1969; this area underwent site preparation in 1978 and was planted with lodgepole pine (Pinus contorta) seedlings in June, 1979. The South Antelope Flat site, located between 13 and 18 km north of Ashton, was logged in 1962; in the early 1970's the area underwent site preparation, tree planting, and strychnine baiting for pocket gophers. Because of poor tree survival, the area received additional site preparation in 1978 and was replanted with lodgepole pine in 1979.

Two 8-hectare units were selected at each of the two study sites in areas scheduled for planting and underground strychnine baiting. Another 2-hectare unit at each study site served as a control. These control units were planted but were not baited with strychnine. Each unit was subdivided into 1-hectare plots, the corners of which were staked and numbered.

Bait Application

Bait was applied by hand in pocket gopher burrows (Birch 1978) by two crews under contract with the U.S. Forest Service. The bait consisted of 0.5 percent strychnine alkaloid on steam-rolled oats (formulated by Pocatello Supply Depot, Pocatello, Idaho) and was applied at about 1 kg/ha. Clearcut areas were baited as well as a 60 m buffer into adjacent forested areas.

Bait was applied over a six-day period (July 13 to July 18) at West Bitch Creek. Application at South Antelope Flat took eight days (July 13 to July 20).

Small Mammal Population Census

Live-trapping was used to census small mammal populations before and after baiting, Three grids were established on each study site, two within baited units and one in an unbaited unit. Each grid consisted of a 10 x 10 arrangement of 100 Sherman live traps spaced at 15 m intervals. Traps were baited and left open, but not set, for two days before the start of pretreatment trapping to allow animals to become familiar with them. Traps were then set and run for 5 consecutive days. Three days posttreatment, traps were again baited and left open for two days, followed by five days of trapping.

Traps were baited with rolled-oats and peanut butter and checked twice daily in morning and evening. Polyester batting was placed in each trap to reduce mortalities due to cold night temperatures and each trap was placed in a milk carton to prevent heat-related mortality during the day. Each captured animal was identified, sexed, aged (adult or juvenile), marked with two eartags (No. 1 fingerling fish tags), and toe-clipped to allow identification if eartags were lost. Trap-grid coordinates were recorded for each animal before its release.

Statistical Analysis

Pre- and posttreatment estimates of small mammal populations were made using program CAPTURE (White et al. 1978), which chooses an appropriate population model by determining the amount of variation in the data due to effects of time, behavior, and heterogeneity of captures (Otis et al. 1978). Pretreatment and posttreatment population estimates were compared by analysis of variance.

Radiotelemetry

We used radiotelemetry to assess the hazards of strychnine baiting to yellow pine chipmunks (Eutamias amoenus). Before baiting, 14 chipmunks at West Bitch Creek and 16 chipmunks plus one northern flying squirrel (Glaucomys sabrinus) at South Antelope Flat were trapped on areas scheduled for treatment.

Each animal was anesthetized with Metophane (methoxyflurane; 2, 2-dichloro-1, 1-difluoroethyl methyl ether), sexed, aged (adult or juvenile), weighed, eartagged, fitted with a radio transmitter and released at the capture site. Radio transmitters used on chipmunks were built by AVM Instrument Co., Champaign, Illinois.[1] Ten were SMI transmitters with type R collars, weighing 5.8 g; 20 were SMI mouse-style transmitters weighing 2.5 g. All transmitters were attached with neck collars and were in the 164 Mhz band on one of 12 channels. Transmitters were systematically assigned to chipmunks by channel and pulse rate to avoid signal interference with other radio-equipped animals. The flying squirrel was fitted with a 7.6 g transmitter designed and built by the Bioelectronics Unit, Denver Wildlife Research Center.

Radio-equipped animals were located with AVM model LA-12 receivers and hand-held loop and yagi antennas. Animals were tracked until located underground or sighted. Locations were marked, recorded by compass bearing, and paced to numbered study unit corner stakes. Monitoring of radioed animals began before baiting and continued for the duration of the study, when an attempt was made to retrap the animals and recover the transmitters.

Carcass Searches

Carcass searches were conducted at West Bitch Creek and South Antelope Flat one to two days after baiting. Each of the 16 one-hectare plots at each site was divided into four 25 x 100 m strips and one randomly chosen strip was searched on every plot. A 50 x 100 m strip outside of each plot was also searched; most of these strips included wooded areas. Observations of live raptors and seedeating birds and mammals also were recorded.

Strychnine Analysis

Tissue samples from animal carcasses were analyzed for strychnine residue by a gas chromatographic procedure (unpublished) developed at the Denver Wildlife Research Center. A nitrogen specific gas chromatographic detection system was used to optimize the sensitivity of the method.

RESULTS

Small Mammal Population Census

More animals were captured posttreatment than pretreatment on both the baited and unbaited plots (Table 1). On baited plots, 131 animals were captured before baiting and 169 after. On unbaited plots, 56 animals were captured before baiting compared to 65 after. Sixty-one percent of the animals trapped pretreatment on baited areas were retrapped (68.4% on South Antelope Flat and 56.4% on West Bitch Creek). The recapture rate on unbaited plots was 65 percent (100% on South Antelope Flat and 50% on West Bitch Creek). T-tests indicated that the number of animals captured at West Bitch Creek, both before and after baiting, was significantly higher ($P < 0.001$) than at South Antelope Flat.

Deer mice (Peromyscus maniculatus) were captured most frequently, followed by yellow pine chipmunks, masked shrews (Sorex cinereus), voles (Microtus montanus and M. pennsylvanicus), western jumping mice (Zapus princeps), and northern pocket gophers.

The population estimates generated by program CAPTURE are presented in Table 1. There were no significant differences ($P > 0.8$) between pre- and posttreatment population estimates for any of the plots or between treated and untreated plots.

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[1]Reference to trade names does not imply endorsement by the U.S. Government.

Table 1. Number of small mammals trapped on baited and unbaited plots before (Pre) and after (Post) underground strychnine treatment. Population estimates, standard errors (SE) and 95% confidence intervals (CI) were generated by program CAPTURE (White et al. 1978).

	South Antelope Flat*				West Bitch Creek*			
	Baited		Unbaited		Baited		Unbaited	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Number trapped								
Deer mice	31	45	12	19	67	87	19	26
Chipmunks	4	2	0	0	13	16	6	2
Shrews	0	0	1	1	4	7	8	7
Voles	3	4	0	0	1	2	6	5
Jumping mice	1	0	2	2	5	6	0	0
Pocket gophers	1	0	0	1	1	0	2	2
Total	40	51	15	23	91	118	41	42
Population Estimate								
±SE	63±8.7	62±4.4	15±0.1	23±0.3	140±13.2	141±10.5	63±8.4	50±10.6
95% CI	46-81	53-71	14-16	22-24	114-167	120-162	46-80	29-71
Appropriate Model	M(H)	M(H)	M(0)	M(0)	M(H)	M(H)	M(H)	M(BH)

*There were two baited and one unbaited plots on each area; data from the two baited plots were combined prior to analysis.

Radiotelemetry

Twenty-four of the 30 radio-equipped chipmunks and the flying squirrel were alive when field work was terminated. Three chipmunks died during the study. One, recovered the fifth day after baiting at west Bitch Creek, had been decapitated. It contained .29 ppm of strychnine in the body and .1 ppm in the GI tract. Another, found at West Bitch Creek two days after baiting, was stashed in a depression and covered with leaves and litter. It contained .35 ppm of strychnine in the body, the GI tract was too badly decomposed to analyze. A third chipmunk was presumably eaten by an American kestrel (*Falco sparverius*); its radio transmitter was recovered beneath the kestrel's nest three days posttreatment. Transmitter signal was lost on the remaining three chipmunks before baiting, and they were unaccounted for at the end of the study. All of the surviving chipmunks with functional radios were monitored for 5 to 11 days after baiting.

Carcass Searches

We searched a total of 20 hectares in treated sites; 28 live animals were observed and 2 dead animals were found (Table 2). The two dead animals were blue grouse (*Dendragapus obscurus*) found on the West Bitch Creek area. One was badly decomposed and we judged it had died before treatment; the carcass was not collected. Wounds on the other bird indicated that it was probably a predator kill, and tissue analysis revealed no strychnine residue. Although no dead animals were found on the South Antelope Flat site during carcass searches, two dead deer mice were recovered one day posttreatment during other activities. One (found on plot B) contained 36 ppm of strychnine in the GI tract and 2.6 ppm in the rest of the body. The second (recovered on plot A) contained 18 ppm in the GI tract and 5.4 ppm in the body.

DISCUSSION

The population model chosen most frequently by program CAPTURE was M_H, indicating that probability of capture differed between animals. Model M_O, selected for pre- and posttreatment population estimates on the untreated area at South Antelope Flat, assumes the same probability of capture for all animals. In two cases, we did not use the model selected as most appropriate by program CAPTURE. Model M_H. originally selected for the West Bitch Creek unbaited plot (posttreatment), yielded an estimate of 49±3.2($\bar{x}$ ± S.E.). However, because we had a high number of trap mortalities on this plot (eight shrews died out of 42 animals), we considered the removal model (M_{BH}) to be more appropriate; it yielded a similar estimate of 50 ± 10.6. The second case involved the West Bitch Creek baited plots posttreatment; here, because the first day's catch was much higher than on subsequent days (61 animals compared to 38, 37, 43 and 48 animals), model M_{TH} was selected by program CAPTURE as most appropriate. Because this model has no estimator the aberrant first day's catch was removed from the data set; a population estimate of 141 ± 10.5 resulted (model M_H).

Population estimates derived from the live-trapping data indicated that small mammals were more abundant at West Bitch Creek than at South Antelope Flat. This difference was probably due to the more dense herbaceous cover at West Bitch Creek. Despite the difference, population levels in both areas

Table 2. Number and species of animals found during posttreatment carcass searches on South Antelope Flat and West Bitch Creek treated sites.

Site	Hectares searched	Date	Man-hours	Live animals observed*	Carcasses found**
South Antelope Flat:					
Plot A	1	7/15	1.9	3S	
Plot A periphery	2	7/15	3.5	1S, 2C	
Plot B	2	7/19	3.0	1K	
Plot B periphery	4	7/19	6.0	2C, 1R, 10J	
West Bitch Creek:					
Plot C	2	7/15; 7/17	2.3		
Plot C periphery	4	7/15; 7/17	4.4	1R	1B
Plot D	2	7/19	2.7		
Plot D periphery	3	7/19	3.0	1S, 2C, 4B	1B

*S - Vesper sparrow (Pooecetes gramineus); C - Yellow pine chipmunk; K - American kestrel; R - Red Squirrel (Tamiasciurus hudsonicus); J - Dark-eyed junco (Junco hyemalis).

**B - Blue grouse. One of these birds had probably died before treatment; the other contained no strychnine residue and had probably been killed by a predator.

were as high after baiting as before. This indicates that small mammal populations were not adversely affected by the baiting. Nevertheless, the recovery of two strychnine-killed mice shows that some nontarget mortality did occur.

A number of small mammal species are known to use pocket gopher burrows (Howard and Childs 1959, Vaughan 1961). This use is undoubtedly influenced by many factors, including animal species, habitat type, and season; these factors probably also affect exposure to and acceptance of bait. Therefore, the impact of strychnine baiting on small mammals could be expected to vary between areas. Our observations indicate that small mammals in our study did not use pocket gopher burrows extensively. As mentioned previously, this study was conducted in conjunction with another study to evaluate the effect of strychnine baiting on pocket gophers. During the latter study, we live-trapped over 100 pocket gophers within burrows without capturing any other small mammals. This suggests that small mammals in this study area had little exposure to bait in natural pocket gopher runways. In contrast, Hegdal and Gatz (1976) found significant decreases in nontarget rodent populations in a Minnesota study when strychnine treated milo was applied underground in artificial burrows constructed with a burrow-builder. The construction of artificial burrows may have increased exposure of small mammals to the bait.

Low levels of strychnine were found in the body tissue of two dead chipmunks, but this does not necessarily mean that they died from strychnine poisoning. Both animals had been partially eaten by predators. Two alternatives are therefore possible: (1) they died from strychnine poisoning and were then picked up by predators; or (2) they ate a sublethal dose of strychnine, survived it, and were later taken by predators. The second alternative is probably most likely. According to Copeman (1957), absorption of strychnine from the GI tract is not rapid and high concentrations are found in the stomach of animals that have died from strychnine poisoning. Strychnine is a fast acting poison and death takes place before any appreciable elimination from the stomach occurs. The fact that residues were low and that they were higher in body tissue than in the GI tract may indicate that the chipmunks survived the treatment and were later captured by a predator. However, it is possible that a sublethal dose of strychnine could have made them more susceptible to predation. Despite the fact that strychnine residues were present in these two individuals, chipmunk populations were probably not greatly affected by the baiting. Twenty-four chipmunks and the flying squirrel survived the baiting; all were radiotracked in baited clearcuts or in peripheral baited forest and none showed symptoms of strychnine poisoning.

We did not find evidence of secondary poisoning in this study. One chipmunk was apparently killed by an American kestrel posttreatment, and the kestrel was unaffected; the chipmunk carcass was not recovered so it is not known whether it contained strychnine. According to Rudd and Genelly (1956) and Hegdal and Gatz (1976), secondary strychnine poisoning of raptorial birds is unlikely to occur. Secondary poisoning of carrion-eating and predatory mammals may be more likely, as isolated reports of field kills can be found in the literature (Garlough and Ward 1932, and Faulkner 1964). However, we noticed no hazards in this study and Hegdal and Gatz (1976, 1977) found no hazards to mammalian predators in either underground or aboveground strychnine baiting programs.

Although we found two blue grouse during our carcass searches, neither died as a result of the baiting program. Gallinaceous birds are generally not vulnerable to strychnine, partly because they do not readily consume strychnine treated bait (Gabrielson 1938, Ward et al. 1942) and partly because strychnine baits are low in toxicity to gallinaceous birds (Emlen and Glading 1915, Ward et al. 1942, and Hunt and Keith 1962).

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