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ABSTRACT: Under an Environmental Protection Agency (EPA) contract, we evaluated the hazards associated with strychnine baiting for pocket gophers (Geomys bursarius) with the burrow-builder. On the Sherburne National Wildlife Refuge, Minnesota, we treated 662 ha (1638 acres) with 0.5 percent strychnine-treated bait. Treated fields were scattered throughout 10 sections. Control was effective--data from pocket gopher activity plots showed 87.5 ± 5.9 percent reductions in activity. Populations of other small rodents (while quite low) significantly declined on the treated area, but significantly increased on the control area. To measure secondary effects we equipped 36 raptors and 36 mammalian predators with radio transmitters. We detected little, if any, effect on radio-equipped raptors and mammalian predators. Red-tailed hawks (Buteo jamaicensis), American kestrels (Falco sparverius), great horned owls (Bubo virginianus), badgers (Taxidea taxus), striped skunks (Mephitis mephitis), red fox (Vulpes fulva) and a coyote (Canis latrans) were intensively radio-tracked during treatment; those that utilized treated fields all survived. Mammalian predator tracks and diggings were frequently observed on the burrow-builder tracks after treatment. Red-winged blackbirds (Agelaius phoeniceus) were selected as a representative of seedeating birds. We marked 100 territorial males on both the treated and control area and monitored them during the treatment. Even though some treated grain was available on the surface and marked birds were observed feeding in treated fields, we did not detect any detrimental effects. Nevertheless, we found one treatment-killed mourning dove (Zenaida macroura).

In late 1973, the Environmental Protection Agency (EPA) planned to hold formal hearings to determine whether some rodenticide (1080 and strychnine) uses should be cancelled or amended. However, during informal hearings it was determined that further scientific information was needed on the environmental impact of these rodenticides and the formal hearings were cancelled. Although laboratory studies have shown the theoretical possibility of primary and secondary poisoning of several desirable wildlife species, available field data are limited and contradictory. After considerable discussion between EPA, the Fish and Wildlife Service (FWS), other governmental agencies, and several environmental groups, an Interagency Agreement between EPA and FWS was signed in June 1974. Funds were provided by the Environmental Protection Agency under Interagency Agreement EPA-IAG-D4-0449. This Agreement calls for several studies of the possible effects on non-target wildlife from registered, operational rodent control procedures. The objective of this study was to determine the efficacy of treatment and the primary and secondary hazards to seedeating birds, raptors and mammalian predators resulting from strychnine baiting for pocket gophers (with a burrow-builder). This is one of the major uses of strychnine bait in the United States.

The assistance of Fish and Wildlife Service personnel from Region 3 and the Denver Wildlife Research Center is gratefully acknowledged.

STUDY AREA

The study was conducted on the relatively new Sherburne National Wildlife Refuge in Sherburne County, Minnesota. Land acquisition started in 1965 and was completed in 1974. The refuge consists of 11,906 ha (30,500 acres) of deciduous forests, wetlands and old fields (now mostly grown to mixed grasses and forbs) in approximately equal proportions--one third each. Some pine plantations and native grass plantings are scattered throughout the area and about 560 ha (1400 acres) of the refuge are devoted to corn, rye, oats and clover. Topography is flat to rolling with sandy uplands; lowlands have muck or peat soils and are usually poorly drained.

Pocket gophers (Geomys bursarius) are common in the old fields. The refuge also supports a relatively high population of mammalian predators and raptors.

The treated area is about 9.6 km (6 miles) long and 3.2 km (2 miles) wide on the southern edge of the refuge (Fig. 1). Old fields make up 34 percent of this area. Only the old field type was treated, as pocket gopher populations are sparse in the other habitat types. In a large-scale operational pocket gopher control program, some land managers never treat, some treat only fields with high pocket gopher populations and others treat all fields regardless of pocket gopher density. To simulate this type of program, we treated about 75 percent of the old fields. Treated fields were randomly selected and scattered throughout about 10 sections (Fig. 2). The untreated areas within these 10 sections consisted of a small portion of old fields, and the rest divided between deciduous woods and marshes.

An area about 13 km (8 miles) long and about 3.2 km (2 miles) wide on the northern edge of the refuge was used as a control area for sampling pocket gophers, small rodents and blackbirds. However, any radio-equipped animal that did not utilize the treated area was considered a control animal.

Treatment started 19 June 1975 and was completed 26 June 1975; it consisted of milo treated with 0.5 percent strychnine alkaloid (EPA Reg. No. 6704-58) applied at about 1.4 kg/ha (1.25 lbs/acre) with a burrow-builder. Artificial burrows were spaced about 9 m (30′) apart. A commercial operator applied the bait using two Gopher-Getters[1] (3-point hitch models) manufactured and provided by Rue R. Elston Co., Inc., Minneapolis, Minnesota. To bait the treated area as rapidly as possible, we used one trailer model of Elston's Gophei- Getter[1] and assisted with the bait application. The machines were operated about 14 hours per day.

EFFECT OF TREATMENT--POCKET GOPHERS

The reduction in pocket gopher activity (percent control) was determined by randomly selecting 10 treated and 10 control fields (Fig. 1) and using the "open-hole" technique (Hansen and Ward, 1966). In each field, we marked 50 active pocket gopher systems about 1 week prior to treatment. Seven days after treatment, we opened a burrow at each of these sites. After 48 hours we read and recorded activity (number closed).

The treatment reduced pocket gopher activity an average of 87.5 ± 5.9 percent (Table 1). Chi square analysis showed significant differences between treated plots ($P < .05$) but this was expected because variations in soil conditions and vegetative cover affect the quality of artificial burrows. Despite these variations, Chi square analysis showed a highly significant reduction in activity in all treated fields when compared to control fields opened and read at the same time ($P < .001$).

Table 1. Percent pocket gopher control on the treated area.

Transect Number	Treated Area Number Closed / Number Open	Control Area Percent Activity	Treated Area Adjusted Percent Control[1]
1	9/36	84.3	76.3
2	1/48	84.3	97.6
3	2/47	84.3	95.2
4	4/47	79.7	90.2
5	5/44	83.9	87.8
6	1/48	79.7	97.4
7	8/43	83.9	81.3
8	4/46	88.7	91.0
9	11/39	88.0	75.0
10	7/43	84.0	83.3
			$\overline{X} = 87.5 \pm 5.92$

[1]Adjusted percent control $= \left[1 - \dfrac{\text{number closed after 48 hours}}{\text{number opened (\% activity on control area)}}\right]$

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

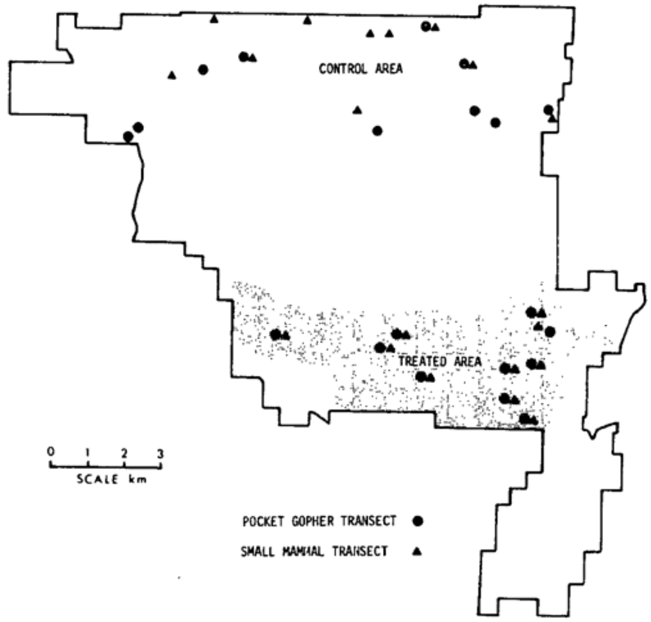

Figure 1. Treated and control area showing locations of pocket gopher and small mammal transects.

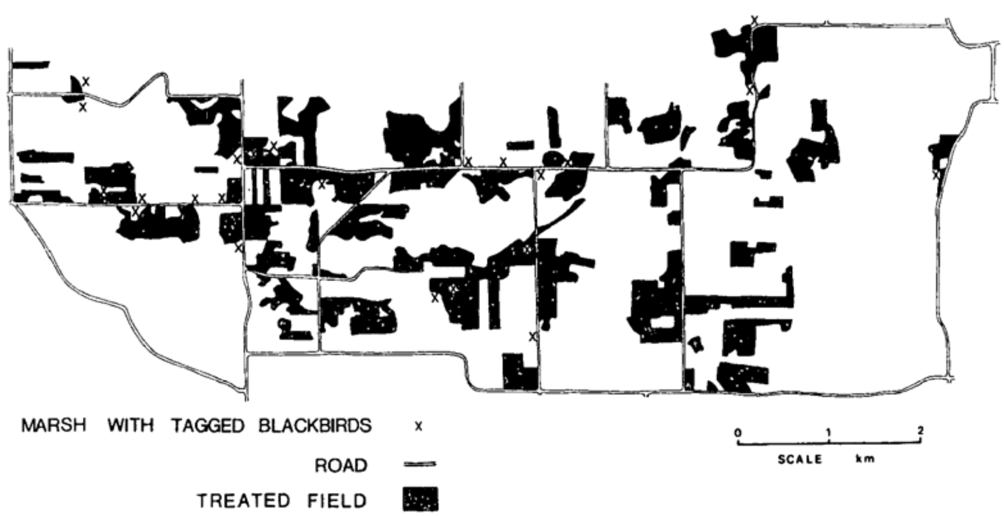

Figure 2. Treated fields and location of marshes with marked red-winged blackbirds.

EFFECT OF TREATMENT--SMALL RODENTS

Small rodent population indices were determined on the treated and control areas by randomly locating (within the old field type) 10 transects of 20 Sherman live traps on each area (Fig. 1). We spaced the traps about 15 m (50') apart, baited them with rolled oats and checked them once daily for 5 consecutive days about 2 weeks prior to treatment. This process was repeated about 2 weeks after treatment. In an effort to increase the number of animals captured, we moved half the traps on half the trap lines (50 traps on each area) to the nearest wooded edge of the field for the last 2 trap nights. This was done during both pre- and post-treatment trapping. We recorded species of each animal caught, toe-clipped and released them.

More small rodents were captured on the control area, primarily because of higher vole (*Microtus* spp.) populations (Table 2). Paired t tests showed a significant reduction in number of animals caught on the treated area ($P < .10$) and a significant increase on the control area ($P < .001$). Chi square analysis showed that the pre- and post-treatment ratios were significantly different between the treated and control area ($P < .005$). The increase on the control area resulted primarily from an increase of thirteen-1ined ground squirrels (*Spermophilis tridecemlineatus*) while the decline on the treated area was primarily a result of the reduction of western harvest mice (*Reithrodontomys megalotis*) (Table 2). Of the animals toe-clipped prior to treatment, only one of 23 was recaptured on the treated area while 20 of 75 were recaptured on the control area. Chi square analysis showed this difference was significant ($P < .10$).

Table 2. Small rodent population indices--treated and control area.

	Number of rodents captured		Recaptures
	Pre-treatment	Post-	Pretreatment Catch
TREATED AREA			
Thirteen-lined ground squirrel	2	4	0/2
Western harvest mouse	13	3	1/13
Deermouse (*Peromyscus maniculatus*)	3	1	0/3
Meadow jumping mouse *Zapus hudsonicus*)	3	0	0/3
Meadow mouse (*Microtus* spp.)	1	0	0/1
Eastern chipmunk (*Tamias striatus*)	1	1	0/1
TOTAL	23	9	1/23
CONTROL AREA			
Thirteen-lined ground squirrel	2	35	0/2
Deermouse	7	12	4/7
Meadow jumping mouse	2	2	0/2
Meadow mouse	64	70	16/24
Eastern chipmunk	0	1	0/0
House mouse (*Mus musculus*)	0	1	0/0
TOTAL	75	121	20/75

To determine the number of animal carcasses on the surface after treatment, we randomly located 10 transects (100 m sections of burrow-builder track) in each of 10 randomly selected treated fields. Immediately after treatment, each transect was searched (within 1 m of the track) to remove any animal carcasses present prior to treatment. However, none was found during this preliminary search. Starting one day after treatment, we searched each transect daily for 3 days. Only two rodent carcasses (a western harvest mouse and a 13-lined ground squirrel) were found during this search; but both contained strychnine residues in the stomach. One dead western hognose snake (Heterodon nasicus) was also found on the transects but contained no strychnine residue. This snake feeds primarily on lizards and amphibians and is unlikely to consume rodent carcasses or treated bait. During this phase of the study we searched an area of 2 ha (about 5 acres), or about 0.3 percent of the treated area, daily for 3 days.

HAZARD TO SEEDEATING BIRDS

With the underground placement of bait by the burrow-builder, the potential primary hazard to birds is greatly reduced. Nevertheless, small amounts of bait may become available to granivorous birds through inadvertent spillage. Bait may also be exposed when the burrow-builder is lifted out of the ground while moving, and when the roofs of the artificial burrow collapse.

We selected territorial male red-winged blackbirds (Agelaius phoeniceus), a common species on the refuge, as an indicator of primary hazards to granivorous birds. According to J. Besser (Personal communication), red-winged blackbirds are also one of the most likely birds to consume strychnine-treated milo. About 3 weeks prior to treatment, we trapped 100 territorial males on both the treated and control area using a modified version of the territorial male trap (Bray et. al., 1975). On the treated area, birds were trapped in marsh areas adjacent to or as near treated fields as possible (Fig. 2). On the control area we trapped in marsh areas adjacent to or as near old fields as possible. Each territorial male was marked with a numbered leg streamer (Guarino, 1968) and released. We ran three surveys prior to treatment and one about 1 week after treatment to determine if each marked male was present on its territory. In addition, we ran an immediate post-treatment survey (1 day after treatment) on the treated area.

The number of territorial male red-winged blackbirds maintaining territories was slightly higher on the treated area (Table 3). A comparison of regression lines plotted from these data shows that while the difference was small it was highly significant ($P < .005$). This difference may be due, in part, to the better visibility of the orange leg streamers used on the treated area. Light green leg streamers, used on the control area, became more difficult to see as the season progressed.

Table 3. Number of territorial male red-winged blackbirds remaining on territory (out of 100 marked).

Date	Treated Area	Control Area
5/28/75	84	83
6/ 4/75	-	79
6/ 5/75	80	-
6/16/75	76	-
6/17/75	-	72
6/20 - 6/28 (one day post-treatment)	75	-
6/29/75	-	67
6/30/75	71	-

We found two areas where treated grain was spilled on the surface within 50 m of territories of marked birds. In addition, marked birds were observed several times feeding in fields; however, we did not detect any detrimental effect. Mourning doves (Zenaida macroura) were frequently observed feeding in treated fields but we found only one dead dove, on a road between two treated fields, that was killed by the treatment (strychnine residue was found in the crop).

HAZARD TO RAPTORS

Pocket gophers are important food items to some raptors during some periods of the year. For example, Bird (1929) reported that in Manitoba, pocket gophers are an important food item for great horned owls (Bubo virginianus), especially during the latter part of May. Maser et al. (1970) reported that in central Oregon pocket gophers constitute 11, 25 and 5 percent of the diet of great horned owls, short-eared owls (Asio flammeus), and long-eared owls (Asio otus) respectively. Howard and Childs (1950) listed the great horned owl, barn owl (Tyto alba), and red-tailed hawk (Buteo jamaicensis) as important avian predators on pocket gophers. Clark and Wise (1974) found pocket gophers made up 51 percent of the barn owl's diet in California. Smith and Hopkins (1937) found pocket gophers second only to voles in an analysis of barn owl pellets in California. Craighead and Craighead (1956) found that in Wyoming, pocket gophers made up 23, 20, 5, 5 and 2.7 percent of the diets of great horned owls, long-eared owls, red-tailed hawks, Swainson's hawks (Buteo swainsoni) and American kestrels (Falco sparverius) respectively. Considering all raptors studied, Craighead and Craighead (1956) found that voles were most frequently represented in the raptor diet followed in order by small birds and pocket gophers. In general, the consumption of pocket gophers by raptors is higher during spring and summer.

Evidence indicates that pocket gophers are more active on the surface than generally thought; however, most affected by the burrow-builder treatment die underground. We recognize that some may die on the surface. In addition, Sargeant and Peterson (n.d.) found that some pocket gophers pouch toxic grain in sufficient quantities (up to 300 seeds) that if captured live or found dead on the surface, could present a secondary hazard to several predatory species.

It is possible that baiting for pocket gophers may make an unusual number of carcasses available to predatory species. Other rodents may be affected by the treatment and may present a secondary hazard to predatory species.

It is not known to what extent most raptors feed on carrion, but Marti (1970) reported that the great horned owl will readily eat carrion. J. Besser (Personal communication) noted that marsh hawks (Circus cyaneus) fed on starlings (Sturnus vulgaris) that were killed by poison bait in cattle feedlots in northeastern Colorado.

We trapped raptors using bal-chatri traps (Berger and Mueller, 1959; Berger and Hammerstrom, 1962), Swedish goshawk traps (Meng, 1971), Verbail traps (Steward et al., 1945), mist nets (M. Fuller, Personal communication) and a jump-bail trap designed by G. Corner (Personal communication). We caught raptors with each trap used; however, most (62 of 96) were caught with bal-chatri traps and mist nets (but we also used more of them).

A total of 17 red-tailed hawks, 10 great horned owls and 9 American kestrels were equipped with radio transmitters. While we captured 60 other raptors we did not radio-equip screech owls (Otus asio), sharp-shinned hawks (Accipiter striatus), Cooper's hawk (Accipiter cooperii), goshawks (Accipiter gentilis), broad-winged hawks (Buteo piatypterus), some American kestrels or nestlings. Reasons for not instrumenting these birds were (1) they are less likely to be affected by pocket gopher control and (2) we did not have the capacity to radio-track additional individuals.

Several of the red-tailed hawks and at least one great horned owl apparently left the area shortly after radios were attached, and one great horned owl on the treated area died prior to treatment. In addition, several radios apparently failed, some shortly after attachment and others a month or more later. Eleven raptors were radio-tracked during and after treatment, but only four, one American kestrel, one great horned owl and two red-tailed hawks, utilized the treated area--al1 survived treatment. Two of these, one red-tailed hawk and the great horned owl, were frequently found in or near treated fields and were still present 2 months after treatment.

Four raptors nests, three red-tailed hawks and one great horned owl, were located on the treated area. All, except one red-tailed hawk nest, were abandoned prior to treatment. Two young were fledged from the active nest. In addition, we found one pocket gopher and one thirteen-1ined ground squirrel carcass at this nest site after treatment but neither contained strychnine residue. On the control area, two great horned owl and three red-tailed hawk nests each fledged two young.

HAZARD TO MAMMALIAN PREDATORS

Of the mammalian predators on the study area, badgers (Taxidea taxus) probably have the highest percentage of pocket gophers in their diet. For example, R. Lampe (Personal communication) stated that, in central Minnesota, badger scat is predominately pocket gopher remains. Sargeant and Warner (1972) also found pocket gopher remains in all badger scats examined in central Minnesota. They also found that the one badger they instrumented with a radio transmitter dug extensively into pocket gopher burrows, apparently in search of food. Errington (1937) and Snead and Hendrickson (1942) found ground squirrels (Spermophilis spp.), voles and mice (Peromyscus spp.) heavily represented in the badger's diet in Iowa. They did not find many pocket gopher remains in scats, but no mention is made of pocket gopher abundance in the area. Apparently badgers readily consume carrion and frequently cache food items (Snead and Hendrickson, 1942). Since badgers expend considerable effort digging for pocket gophers (Sargeant and Warner, 1972), those found dead underground could present a secondary hazard to badgers.

Other mammalian predators that could be affected by pocket gopher control are red fox (Vulpes fulva), striped skunk (Mephitis mephitis), and raccoon (Procyon lotor). Literature on the food habits of red fox shows little utilization of pocket gophers for food; however, other small mammals make up a large part of their diet (Scott, 1943, 1947; Stanley, 1962; Drieslein, 1967; Hatfield, 1939; Korschgen, 1959). Most authors indicated fox will take carrion, if available. Indeed, availability appears to be the key to the feeding habits of most mammalian predators.

Literature on the food habits of the striped skunk generally shows insects and small mammals as important dietary items (Seiko, 1937; Verts, 1967). Small mammals are utilized most in the spring, and availability seems to be important in seasonal variations of the diet (Verts, 1967). Although pocket gopher remains are rare in skunk stomachs or fecal passages, R. Mead (Personal communication) identified one skunk, in California, that died after consuming a pocket gopher that had been killed by a strychnine bait applied with a burrow-bui1der. Seiko (1937) noted that skunks consume some grain; therefore, poison bait, if consumed, could cause direct mortality.

Mammals make up only a small portion of the diet of raccoons (Schoonover and Marshall, 1951; Tester, 1953; Giles, 1940) and they are the least likely of mammalian predators to be affected. Therefore, we did not radio-equip those captured.

Badgers, red fox, a coyote (Canis latrans) and most skunks were trapped with no. 3 offset traps with tranquilizer tabs (Balser, 1965). Two skunks were netted according to procedures outlined by Adams et al. (1964), and one was captured by refuge personnel with a piece of burlap. One badger was captured at night with a rope choker. Ketamine hydrochloride was used (intramuscular), as necessary, as an immobilizing agent to restrain badgers and skunks not tranquilized by the trap tab. Tranquilized or immobilized animals were held several hours to insure complete recovery. All were released at the capture site.

We attached radios to 13 badgers, 12 red fox, 10 striped skunks and 1 coyote. On the control area, four red fox died of unknown causes. Necropsies indicated they were in poor condition and appeared to be suffering from malnutrition. One control badger died shortly after the radio was attached; however, this animal was in poor condition when captured. The rest of the mammalian predators on the control area, five skunks, five badgers, and three red fox, all survived at least 3 weeks after treatment.

On the treated area, three red fox apparently died prior to treatment. The one necropsied was in poor condition and apparently died of malnutrition. One striped skunk also died of unknown causes prior to treatment. The remains of one badger were found about 3 weeks after treatment, but were approximately 3 km (2 miles) from the nearest treated field. It is highly unlikely that it was killed by the treatment. The rest of the mammalian predators, two striped skunks, three badgers, two red fox and one coyote, utilized the treated area and all survived at least 3 weeks after treatment. All, except one badger, were frequently found in or near treated fields. In addition, we frequently found mammalian predator tracks and diggings on the burrow-builder tracks throughout the treated area.

SUMMARY

Treatment of an area for pocket gophers using the burrow-builder and milo treated with

0.5 percent strychnine resulted in a significant reduction in pocket gopher and small rodent populations. However, the hazards to great horned owls, red-tailed hawks, American kestrels, badgers, striped skunks, red fox and coyotes appeared to be minimal. There is some hazard to seedeating birds from the limited amount of bait available on the surface. We found one dove killed by the treatment but many live doves were observed in treated areas. Territorial male red-winged blackbirds were not affected by the treatment.

Based on our observations and the results of this study we concluded that the control of pocket gophers with strychnine bait, properly applied with the burrow-builder, is a relatively safe procedure with few hazards to non-rodent wildlife.

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