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EFFICACY OF TWO GAS CARTRIDGE FORMULATIONS IN KILLING WOODCHUCKS IN BURROWS

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For over 40 years, the U.S. Government has manufactured and sold a pyrotechnic fumigant, known as the Gas Cartridge (U.S. Environmental Protection Agency [EPA] Regist. No. 56228-2), for killing burrowing rodents. Reregistration of this gas cartridge, as presently required by the EPA, would be expensive and difficult because of the numerous active ingredients involved (Table 1). The identification, biological activity, and environmental fate of the various combustion products would have to be determined. To avoid these difficulties, Savarie et al. (1980), based on earlier work by the U.S. Army, proposed a new cartridge formulation using only 2 active ingredients (sodium nitrate and charcoal). The primary combustion products produced from this 2-ingredient cartridge are carbon monoxide, sodium carbonate, and nitrogen gas. Small amounts of 3 inert ingredients (Table 1) subsequently were added to this formulation to slow the burn time of the cartridge, thereby reducing the hazard to personnel placing cartridges into burrows (P. J. Savarie, Denver Wildl. Res. Cent., Denver, Colo., unpubl. data).

Both the old and new gas cartridge formulations have been evaluated in field studies for killing ground squirrels (*Spermophilus* spp.) (Matschke and Fagerstone 1984, Salmon and Bentley 1982). The new cartridge formulation has also been field tested on coyote (*Canis latrans*) pups and Norway rats (*Rattus norvegicus*) (Savarie et al. 1980). However, there has been only 1 reported evaluation of the old cartridge formulation for woodchucks (*Marmota monax*) (de Vos and Merrill 1957). This evaluation was of limited usefulness because no pretreatment measurement of burrow activity was made nor was excavation done to confirm kill. Furthermore, immigration of woodchucks into the control area confounded the results. No data are available on nontarget vertebrate mortality resulting from gas cartridge use in woodchuck burrows. This paucity of data for woodchucks is surprising because the old cartridge has been used extensively in the eastern United States. For example, about 50,000 cartridges were sold annually in Ohio from 1987 to 1990 for killing woodchucks causing agricultural, landscaping, or structural damage (D. A. Andrews, U.S. Dep. Agric., Columbus, Oh., pers. commun.).

Our objective was to compare the effectiveness of the old and new gas cartridges in killing woodchucks in their burrows. To evaluate the accuracy of estimating mortality using the percent of burrow systems not reopened after fumigating, we excavated burrow systems. Excavation also permitted determination of the frequency and species of nontarget vertebrates killed in the burrow systems. We also compared characteristics of burrows where woodchucks survived fumigation with burrows where woodchucks were killed.

METHODS

The main study was from 18 July to 10 September 1990 at Plum Brook Station, Erie County, Ohio. Plum

Table 1. Physical and chemical characteristics of 2 gas cartridges evaluated for killing woodchucks in Ohio, 18 July–10 September 1990.

Cartridge type	Dimensions (cm) of cartridge		Net wt (g) of ingredients (n = 6)[a]		Cartridge composition	
	Length	Diameter	$\bar{x}$	SD	Ingredient	% (by wt)
Old	9.0	4.2	96.1	2.4	Sodium nitrate	43.4
					Charcoal	17.3
					Mineral oil	14.1
					Sulfur	10.8
					Sawdust	3.5
					Red phosphorus	3.3
					Other	7.6
New	15.2	4.2	117.3	5.0	Sodium nitrate	58.1
					Charcoal	31.2
					Mineral oil	5.3
					Fuller's earth	4.5
					Borax	0.9

[a] Six cartridges of each type were randomly selected from the shipment provided by Pocatello, Idaho Supply Depot, U.S. Department of Agriculture.

Brook Station is a 2,200-ha fenced facility administered by the National Aeronautics and Space Administration consisting of primarily relic prairie, woodlots, and old fields in early successional stages of reforestation.

Fumigation was done only in burrows where it was highly probable that a woodchuck was present. Woodchucks first were located outside their burrows by 1 to 4 people driving vehicles along roads within Plum Brook Station during daylight hours. Once a woodchuck was observed, the person got out of the vehicle and attempted to follow the woodchuck to its burrow. Woodchucks often went into tall vegetation, making it difficult to trail them to their burrow entrance. We only used gas cartridges at burrows where a woodchuck was seen entering or at burrows where a woodchuck was last seen approaching to within 5 m of an entrance that appeared active as judged by the presence of loose soil and disturbed vegetation. The type of cartridge (old or new) used in each burrow was randomly determined. Woodchucks that entered culverts or burrow systems under buildings were not treated.

Fumigation was done immediately after chasing a woodchuck to a burrow. The area within 5 m of the known entrance was searched, and additional burrow entrances were sealed with plugs of sod slightly larger than the holes. The first entrance located was then sealed after the cartridge, with fuse ignited, was placed by hand into the burrow as far as the arm could reach. The immediate area was observed carefully for about 5 minutes for smoke exiting from previously undetected entrances and for escaping woodchucks. Any entrances leaking smoke were covered with additional sod or soil.

Each burrow system was then completely excavated by hand using shovels and mattocks 3–24 hours after fumigation. We used 3 hours as a minimum interval because our prior experience indicated that woodchucks surviving fumigation would reopen the burrow entrance within this period of time. Burrows were assumed to have had a woodchuck present during fumigation if the excavation revealed either an entrance or escape hole reopened from the inside or a woodchuck in the burrow system. Measurements taken during excavation included total length of burrow system, maximum burrow depth, burrow and chamber diameters, and the number of dead woodchucks and other vertebrates within the system. Dead woodchucks were removed to the laboratory where body measurements were made and sex and age (<1 year and ≥1 year) were determined by autopsy (Davis 1964).

An additional field study was conducted at the Port Columbus Airport, Franklin County, Ohio. Habitat was open fields of mowed grass with adjacent hedgerows. Two to 6 observers walked through the fields on 14 and 23 August 1990 and treated burrow systems that appeared active (i.e., entrances with loose soil, disturbed vegetation), regardless of whether or not a woodchuck was seen at or near the entrance. Those burrows where a woodchuck was definitely seen entering were noted. The status of burrow entrances (plugged or unplugged) was recorded 24–48 hours after treatment. No excavations were done to confirm kill.

The proportion of treated burrows with woodchucks surviving or dying was compared for old and new cartridges by Chi-square analysis in 2 × 2 contingency tables. Mean dimensions of burrows with woodchucks surviving or dying were compared with t-tests.

RESULTS

Plum Brook Station

Ninety-seven burrows were treated with gas cartridges (old = 48, new = 49) and subsequently excavated. Based on the percent of burrows not reopened at the time of reinspec-

Table 2. Efficacy of 2 types of gas cartridges in killing woodchucks in underground burrows, Plum Brook Station, Erie County, Ohio (18 July–10 September 1990).

	Efficacy based on inspection of plugs for all burrows		Efficacy based on excavation of burrow	
Cartridge type	No. of burrows treated and plugged	No. (%) of burrows not reopened	No. of burrows determined to have woodchuck present during treatment	No. (%) of burrows with dead woodchuek
Old	48	45 (94)[a]	36	28 (78)[b]
New	49	44 (90)[a]	41	33 (80)[b]
Total	97	89 (92)	77	61 (79)

[a] $P = 0.46$, Chi-square test.
[b] $P = 0.80$, Chi-square test.

tion, mortality was similar ($\chi^2 = 0.51$, 1 df, $P = 0.46$) for old (94%) and new (90%) cartridges (Table 2). Excavation of the 97 burrows revealed that 77 were occupied by a woodchuck at the time of treatment. The actual percent kill for these 77 occupied burrows was lower (79%) than the assumed percent kill based on all 97 burrows (92%); however, the kill was again similar ($\chi^2 = 0.08$, 1 df, $P = 0.80$) for old (78%) and new (80%) cartridges (Table 2). Two of the 16 woodchucks surviving fumigation were found in their burrows during excavation. Both burrows were excavated 3–4 hours after fumigation. One had been treated with the old and the other with the new cartridge.

Of the 97 excavated burrows, 58 contained a single dead woodchuck, 3 contained 2 dead woodchucks each, and 2 (as noted above) contained 1 live woodchuck each. Age and sex were determined for 63 of the 64 dead woodchucks. The adult (age ≥1 year) to juvenile (age <1 year) ratio was 37:26. The male : female ratio for juveniles was essentially equal (12:14); however, the adult sex ratio (13:24) was skewed toward females ($\chi^2 = 3.27$, 1 df, $P = 0.08$). Four nontarget vertebrates (all dead) were found in burrows: a juvenile (417 g) cottontail rabbit (*Sylvilagus floridanus*) in 1 burrow and a total of 3 mice (*Peromyscus* sp.) in 2 other burrows. These 3 burrows each also contained a dead woodchuck.

The excavated burrows had a mean total burrow system length of 3.09 m (SD = 1.67) and a mean total volume of 85.8 L (SD = 59.3). Burrows in which woodchucks survived fumigation were longer ($t = 3.15$, 75 df, $P < 0.01$) and had greater ($t = 2.26$, 75 df, $P = 0.03$) volume compared to burrows in which the woodchucks died (Table 3). Also, 81% of the burrow systems in which woodchucks survived had more than 1 entrance compared to only 36% of the burrow systems where woodchucks died ($\chi^2 = 10.33$, 1 df, $P < 0.01$).

Port Columbus Airport

A total of 98 burrows was fumigated, 49 each with the old and new cartridges. Results were similar to those at Plum Brook Station. Overall, 87% of the 98 burrows were not reopened. Seventeen of the 98 burrows definitely were occupied at the time of fumigation (i.e., woodchuck was seen entering burrow immediately before treatment); of these burrows, 71% were not reopened within 2 days. There were no significant ($\chi^2 = 2.22$, 1 df, $P \geq 0.14$) differ-

Table 3. Characteristics of 77 occupied woodchuck burrows excavated after being fumigated with a gas cartridge at Plum Brook Station, Erie County, Ohio (18 July–10 September 1990).

		Maximum burrow depth (m)		Total burrow length (m)		Total burrow volume (L)		No. of burrow entrances		
Status of woodchuck	n	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	1	2	3
Killed	61	0.64	0.21	2.78[a]	1.50	77.9[b]	56.0	39	20	2
Survived	16	0.63	0.10	4.27[a]	2.26	115.7[b]	72.3	3	11	2

[a] $P < 0.01$, t-test.
[b] $P = 0.03$, t-test.

ences between old and new cartridges in the proportion of burrows reopened (Table 4).

Table 4. Efficacy of 2 types of gas cartridges in killing woodchucks in underground burrows, Port Columbus Airport, Columbus, Ohio, 14 and 23 August 1990.

	Efficacy based on inspection of plugs for all burrows		Efficacy based on inspection of plugs for burrows known to contain woodchuck during treatment	
Gas cartridge type	No. of burrows treated and plugged	No. (%) of burrows not reopened	No. of burrows treated and plugged	No. (%) of burrows not reopened
Old	49	45 (92)[a]	9	7 (78)[b]
New	49	40 (82)[a]	8	5 (63)[b]
Total	98	85 (87)	17	12 (71)

[a] $P = 0.14$, Chi-square test
[b] $P = 0.48$, Chi-square test

DISCUSSION

Not surprisingly, mortality estimated by the percent of all burrows not reopened was greater than mortality determined by excavation of burrows. Still, efficacy of the old and new cartridges based on confirmed kill in excavated burrows was 78 and 80%, respectively, which is well above the 70% minimum standard recommended by EPA for registration of a rodenticide (Matschke and Fagerstone 1984).

The new cartridge was clearly as effective as the old type, indicating that efficacy would not be compromised with the new formulation. The efficacy level was similar to the 84% kill determined, via radiotelemetry and excavation, for ground squirrels (*S. richardsonii*) whose burrows were fumigated with a slightly smaller (97 g) version of the new cartridge (Matschke and Fagerstone 1984). The only disadvantage to the new cartridge tested in this study compared to the old cartridge was the greater length (+69%) and weight (+22%) which would increase shipping costs and storage space. However, the advantages of a simpler formulation with fewer combustion products make the new cartridge superior to the old cartridge.

As would be expected, woodchucks were more likely to survive fumigation in larger burrow systems with multiple entrances. One recommendation to increase the likelihood of kill would be to use 2 cartridges in burrow systems that have >1 entrance. The increase in overall rate of kill that this practice would bring to a control operation would have to be weighed against the increased expenditures for cartridges. Old cartridges presently cost about $60.00 for 200 ($0.30/cartridge) when ordered from Pocatello, Idaho Supply Depot, U.S. Department of Agriculture. The Pocatello Supply Depot plans to phase in production of the new cartridge by 1992 but the cost of the new cartridge has not been determined (C. J. Packham, U.S. Dep. Agric., Pocatello, Id., pers. commun.).

Overall, nontarget mortality was minimal during this late summer study, occurring in only 3 of 97 burrows excavated. However, use of burrows by nontarget animals might be higher at other times of year (Grizzell 1955, Schmeltz and Whitaker 1977). Similar evaluations need to be made in spring and autumn before any general statement can be made regarding the impact on nontarget species of using gas cartridges. We also emphasize that we treated only those burrows that appeared to be in active use by woodchucks. Indiscriminate treatment of all burrows in an area, regardless of the likelihood of woodchucks being present, might increase the negative impacts on nontarget animals.

One final point regards the long-term effects on woodchuck populations from management programs using gas cartridges. Our study demonstrated that gas cartridges, when properly applied, usually kill woodchucks in burrows. However, overall reduction of the woodchuck population in a given area may be difficult to achieve because of enhanced survival and reproduction of remaining woodchucks and rapid recolonization from surrounding areas (de Vos and Merrill 1957, Davis et al. 1964, Byers 1980, Swihart and Conover 1988). Thus, the

overall success of a control program using gas cartridges will depend on the proximity and extent of surrounding untreated woodchuck populations as well as the frequency and thoroughness with which burrows in the treatment area are monitored and fumigated.

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