

AN ABSTRACT OF THE THESIS OF

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BELDING'S GROUND SQUIRRELS
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Quantitative data concerning bait preference and bait application were collected for Belding's ground squirrels (Spermophilus beldingi) during February-July 1975. Bait materials tested for preference were crimped oats, oatgroats, whole wheat, barley, rolled wheat, rye, chopped lettuce, chopped apple, oatgroats + Rhodamine B dye, oatgroats + starch paste, oatgroats + Rhoplex AC-33, and oatgroats + green food dye. Significant differences occurred in amounts of different types of bait consumed ($\underline{P} < 0.001$) and in amounts of bait consumed seasonally ($\underline{P} < 0.001$). All bait materials were consumed in greatest amounts after young-of-the-year became active and ground squirrel numbers were near the annual maximum. The ground squirrels consumed larger amounts of succulent bait than grain baits during a 2-month period after emergence from hibernation. Oatgroats were consumed in significantly ($\underline{P} < 0.05$) greater quantities than whole wheat, barley, rolled wheat, or rye. Consumption of crimped

oats varied more than any other bait material. Additives (Rhoplex AC-33, starch paste, and green food dye) used in commercially prepared grain baits did not significantly ($\underline{P} > 0.10$) affect amounts of oatgroats consumed. Amounts of bait applied had more affect than placement of bait in determining proportions of ground squirrels consuming oatgroats stained with Rhodamine B dye. No significant differences ($\underline{P} > 0.25$) occurred in proportions of adult male and female ground squirrels marked with stained bait. Differences in proportions of juvenile and adult ground squirrels consuming stained bait were not statistically significant ($\underline{Z} = 0.31$). Proportions of Belding's ground squirrels consuming stained bait were greatest in February, March, June, and July, but declined in April and May. Marking of ground squirrels consuming stained bait decreased from 68 percent within a treated plot to 0 percent within 40 m beyond the same plot. Non-target species of rodents readily consumed stained oatgroats applied for Belding's ground squirrels, regardless of amount or method of application. Broadcasting of bait provided the most economical means of applying bait. Recommendations are presented concerning type and application of bait materials used to control depredations by Belding's ground squirrels.

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for Belding's Ground Squirrels

by

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EVALUATION OF BAITS AND BAITING TECHNIQUES FOR BELDING'S GROUND SQUIRRELS

INTRODUCTION

Belding's ground squirrels (Spermophilus beldingi) range throughout most of Oregon east of the Cascade Mountains, except for the Columbia Basin Province (Bailey 1936, Howell 1938, Miller and Kellogg 1955, Hall and Kelson 1959, Turner 1972a). Originally, these ground squirrels were described as S. oregonus (Merriam 1898) and considered distinct from S. beldingi occurring in California (Merriam 1888). However, Howell (1938) considered that these ground squirrels intergraded, and designated California populations as S. b. beldingi and remaining populations as S. b. oregonus. Hall (1940) considered populations in Utah, Idaho, central and northern Nevada, and extreme southeastern Oregon to be distinguishable from other populations, and designated them a separate subspecies, S. b. creber.

Belding's ground squirrels emerge from hibernation coincident with the emergence of green vegetation (Turner 1972a, Howell 1938). This may be as early as January at lower elevations to as late as April at higher altitudes. Courtship and mating activities begin approximately 1 week after emergence and continue for about a month (Turner 1972a, McKeever 1964). A single litter consisting of about

seven young is produced annually after a gestation period of 27 to 31 days (Bailey 1936, Howell 1938, McKeever 1964, Turner 1972a).

Growth of the young is exceptionally rapid (Turner 1972a). Belding's ground squirrels of all ages feed voraciously on succulent vegetation and plant seeds to accumulate necessary body fat for maintenance during the estivation and hibernation periods. Estivation begins when succulent vegetation is no longer available, usually July to September, depending on altitude (Bailey 1936, McKeever 1964, Harwell 1932, Grinnell and Dixon 1919, Turner 1972a).

Competition with other ground squirrels, availability of water, texture of soils, quantity and type of vegetation, and altitude appear to further restrict populations of Belding's ground squirrels within their geographic range (Turner 1972a, b). Areas supporting greatest densities of the species were reported to have loamy soils and to produce an abundance of succulent vegetation (Turner 1972a, White 1972). Densities were estimated to range from a low of 32 per hectare (13 per acre) to a high of "several hundred per acre" (Turner 1972a, White 1972). Populations of S. beldingi were reported to have increased substantially in irrigated fields, native rangelands, and mountain meadows in eastern Oregon and in northern California (Turner 1972a, White 1972). Ranchers and farmers in these areas reported that depredations by ground squirrels on grain, hay, and pasture crops caused serious economic losses. In areas supporting

dense populations of ground squirrels, ranchers estimate over 50 percent of crop production was lost to squirrel depredations. Ground squirrel mounds and tunnels further damage irrigation ditches and harvesting equipment.

Reduction of the density of populations through use of poisoned baits constitute the principal means by which crop depredations by ground squirrels are controlled at the present time. Currently, the bait being used consists of a commercially prepared mixture of "crimped" whole oats with strychnine alkaloids in an adhesive material. Strychnine alkaloids and sodium monofluoroacetate (compound 1080) are the only toxicants presently registered by the Environmental Protection Agency for use in control of ground squirrels (U.S. Environmental Protection Agency 1972). These toxicants are not presently available to ranchers for preparation of poisoned baits. Sodium monofluoroacetate may be applied only by licensed pest control operators.

Adhesives (starch paste and Rhoplex AC-33) are used in commercial baits to adhere toxicants (strychnine alkaloids) to bait materials. Green food dye (2.5 percent U.S. certified food color in water and propylene glycerol) is used to identify toxic grain baits and to deter consumption of such baits by birds. The effects of these compounds on consumption of bait by Belding's ground squirrels are unknown. Recent complaints by ranchers indicate that the

commercially prepared poisoned bait is not entirely satisfactory for controlling depredations despite increasingly widespread use of the material. Ranchers also report considerable variability in acceptance of poisoned bait by ground squirrels; ground squirrels in some areas appear to consume bait readily, while avoiding bait in other areas (White 1972). Avoidance of baits appears to occur in areas which have not been treated previously as well as in areas treated several times.

Apparently, no quantitatively based information is available on preferences exhibited by ground squirrels for different bait materials, seasonal changes in bait acceptance, and effectiveness of different methods of applying baits. In addition, no information is available concerning the effects of different bait materials and baiting techniques on non-target species of rodents occurring in communities with Belding's ground squirrels. It appears essential to obtain quantitative data on these topics to provide a basis for judging the effectiveness and efficiency of methods of controlling depredations by Belding's ground squirrels through use of poisoned baits.

OBJECTIVES

The objectives of this study were:

1. To determine which of several potential bait materials were most readily consumed by Belding's ground squirrels.
2. To determine if there were seasonal differences in the amounts of several potential bait materials consumed by Belding's ground squirrels.
3. To determine if the proportion of ground squirrels consuming baits was related to the methods of distributing baits.
4. To determine if the proportion of non-target species of rodents consuming baits was related to the methods of distributing baits.

STUDY AREA

This research was conducted on privately-owned ranch lands within a 24-km radius of Monument, Grant County, Oregon (R. 27 E., T. 9 S.). The study area lies within the valley of the North Fork of the John Day River. The region is bordered by three national forests: Umatilla National Forest to the north, Malheur National Forest to the east, and Ochoco National Forest to the south.

Mean annual precipitation is 25.4-50.8 cm (10-20 inches) per year, most of which occurs during the winter and late spring months (Highsmith 1968). The climate of this area is temperate, consisting of hot summers and cold winters (Highsmith 1968). Elevation of the study sites ranged between 548.6-1219.2 m (1800-4000 feet).

Predominant natural vegetation of the area consists of western juniper (Juniperus occidentalis), big sagebrush (Artemisia tridentata), rabbitbrush (Chrysothamnus spp.), bitterbrush (Purshia tridentata), cheatgrass (Bromus tectorum), Idaho fescue (Festuca idahoensis), and bluebunch wheatgrass (Agropyron spicatum).

The chief industry of the area is cattle ranching. Major agricultural crops consist of wheat (Triticum gestivum), barley (Hordeum spp.), rye (Secale cereale) and alfalfa (Medicago sativa). Alfalfa is harvested and stored as hay for winter feeding of local livestock herds. Crops along river valleys are irrigated by sprinkler systems during the hot, dry summer months.

METHODS AND MATERIALS

Bait Preference

Six grain baits were tested for preference by Belding's ground squirrels. The materials were chosen because of their availability, low cost, or previous usage. These baits included crimped oats (oats with hulls), oatgroats (oats without hulls), whole wheat, barley, rolled wheat, and rye. Chopped lettuce and chopped apple were tested to compare consumption of grain with succulent vegetative baits. Oatgroats treated with additives (starch paste, Rhoplex AC-33, and green food dye) used in commercially prepared baits also were tested. Oatgroat bait treated with Rhodamin B dye (used in subsequent testing of methods of bait application) was tested to determine if it affected bait preference of ground squirrels.

All tests of bait preference were conducted on a 5.6 ha plot located in a fallow, non-irrigated field. Two tests of bait preference were conducted each month throughout the season that squirrels were active. Amounts of bait materials consumed by ground squirrels were used to evaluate bait preference. Baits were presented in 36 feed stations placed in a 6 x 6 grid pattern with 30 m between stations. Each station consisted of a 61.0- x 30.5- x 2.5-cm (24.0- x 12.0- x 1.0-inch) board upon which were bolted four cans measuring 4.2 cm high and 8.4 cm in diameter. Twelve 100-g samples of each bait

material were distributed randomly among the feed stations. To estimate changes in weight of baits caused by dehydration and anhydration, three control samples for each bait type were selected at random and covered with wire mesh to prevent consumption of the bait by ground squirrels. Bait materials remaining after 48 hours were weighed to determine consumption by the ground squirrels. Bait stations were covered at night to prevent consumption by nocturnal species.

All weights of bait materials were corrected for losses or gains caused by dehydration or anhydration. Two-factor analysis of variance using logarithmic transformation (Snedecor and Cochran 1967: 329-330) was used to determine if amounts of the various baits consumed differed significantly. The Studentized range test (Snedecor and Cochran 1967:272-274) was used to separate and rank the bait materials according to mean consumption by Belding's ground squirrels.

Bait Application

Chemical marking agents were applied to oatgroat bait to determine proportions of ground squirrel populations consuming bait materials. Linhart and Kennelly (1967) used demethylchlortetracycline (DMCT) to chemically mark bones and teeth of coyotes (Canis latrans). Crier (1970) and Nass et al. (1971) similarly found DMCT

to be an effective long-term marking agent in rats (Rattus exulans, R. norvegicus, and R. rattus). Excessive cost of material and difficulty of mixing DMCT prohibited large scale usage in this project. However, another less effective marker, tetracycline hydrochloride, was tested in the field and on captive Belding's ground squirrels during summer 1974. I found that quantities of the chemical necessary for adequate staining of bone tissue caused an aversion by the squirrels toward the bait material. For these reasons, an alternate marking agent, Rhodamine B, was used. Rhodamine B was successfully used by Evans and Griffith (1973) as a marking and food tracing agent in black-tailed jackrabbits (Lepus californicus), cottontail rabbits (Sylvilagus nuttallii and S. idahoensis), and pheasants (Phasianus colchicus). They reported that it dyed the oral cavity, stomach, intestinal tract, bladder, urogenital openings, urine, and fecal pellets of their experimental animals a brilliant pink color. This stain also fluoresces under ultraviolet light. Preliminary tests conducted in summer 1974 indicated that oatgroat bait stained with Rhodamine B was satisfactory for short-term marking of Belding's ground squirrels. No aversion was found for bait containing 0.50 percent or less of Rhodamine B solution.

Stained bait material was prepared by thoroughly mixing oatgroats and 0.25 percent (by weight) acetic acid solution of Rhodamine B dye (E.I. duPont de Nemours & Co., Los Angeles, California)

in a slurry to evenly spread the dye throughout the grain. To insure even mixing, the materials were tumbled in gallon jars by a mechanical mixer for 10 minutes. The resulting bait material was air dried and stored until needed.

Four methods of applying bait were tested. Oatgroat bait stained with Rhodamin B was applied within a 1-m radius of burrow entrances on separate 1-ha, circular plots at quantities of 1000 g/ha (method 1) and 2000 g/ha (method 2). These quantities were selected because they represent approximate amounts of bait applied during control operations for ground squirrels. Effects of repeated baiting were tested by applying 1000 g/ha of stained bait and reapplying an additional 1000 g/ha 3 days later (method 3). On another plot, 2000 g/ha of stained oatgroats were broadcasted using a manual cyclone seeder (method 4). Plots used in bait application were located in various alfalfa, grain, and non-irrigated pasture fields. Adjacent plots were located at least 200 m apart to minimize interaction of squirrels. Two days after applying the baits, samples of more than 30 Belding's ground squirrels/ha plot were collected by shooting or trapping with 15.2- x 15.2- x 48.3-cm (6- x 6- x 19-inch) single door Tomahawk livetraps. Non-target rodent species were trapped at night using museum special snap traps. Sampling was conducted within a 2-day period to minimize bias caused by the immigration of animals from nearby areas. The specimens were examined internally for the

presence or absence of Rhodamin B stain. Proportions of Belding's ground squirrels stained with Rhodamin B were used as indices to the effectiveness of the methods of applying the baits. The proportion of stained individuals in samples of non-target species was used to evaluate the deleterious effects of the various methods of applying baits.

Chi-square and Z-distribution tests were used to determine if the method of distributing baits significantly affected bait consumption by ground squirrels and by non-target rodent species.

Ground squirrels also were collected at 20-m intervals beyond baited 1-ha plots to determine the size of the area affected during bait application. Two of these trials were conducted during March and July 1975.

In all statistical analyses, the 5 percent fiducial limits were accepted as indicating significance.

Six voucher specimens of Belding's ground squirrels collected on the study area are deposited in the mammals collection at the Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon.

RESULTS AND DISCUSSION

Bait Preference

General

Analysis of variance of amounts of the 12 bait materials consumed by Belding's ground squirrels indicated significant differences in amounts of different types of bait consumed ($\underline{P} < 0.001$) and in amounts of bait consumed seasonally ($\underline{P} < 0.001$) during February-July 1975.

Consumption of all baits was greatest during April and May (Table A, Appendix; Fig. 1) when numbers of ground squirrels increased rapidly as young-of-the-year became active. The magnitude of these increasing numbers was not determined; however, counts of embryos indicated an average of 7.4 ± 0.8 young per female.

Succulent Baits

Amounts of chopped apple and chopped lettuce consumed during February-July were greater than those for all other baits (Table A, Appendix). Apple ranked highest or did not differ significantly from the highest in all tests of bait preference (Table 1). Chopped apple and lettuce were consumed in greatest amounts in comparison with grain baits during the 2-month period (February-March) after the

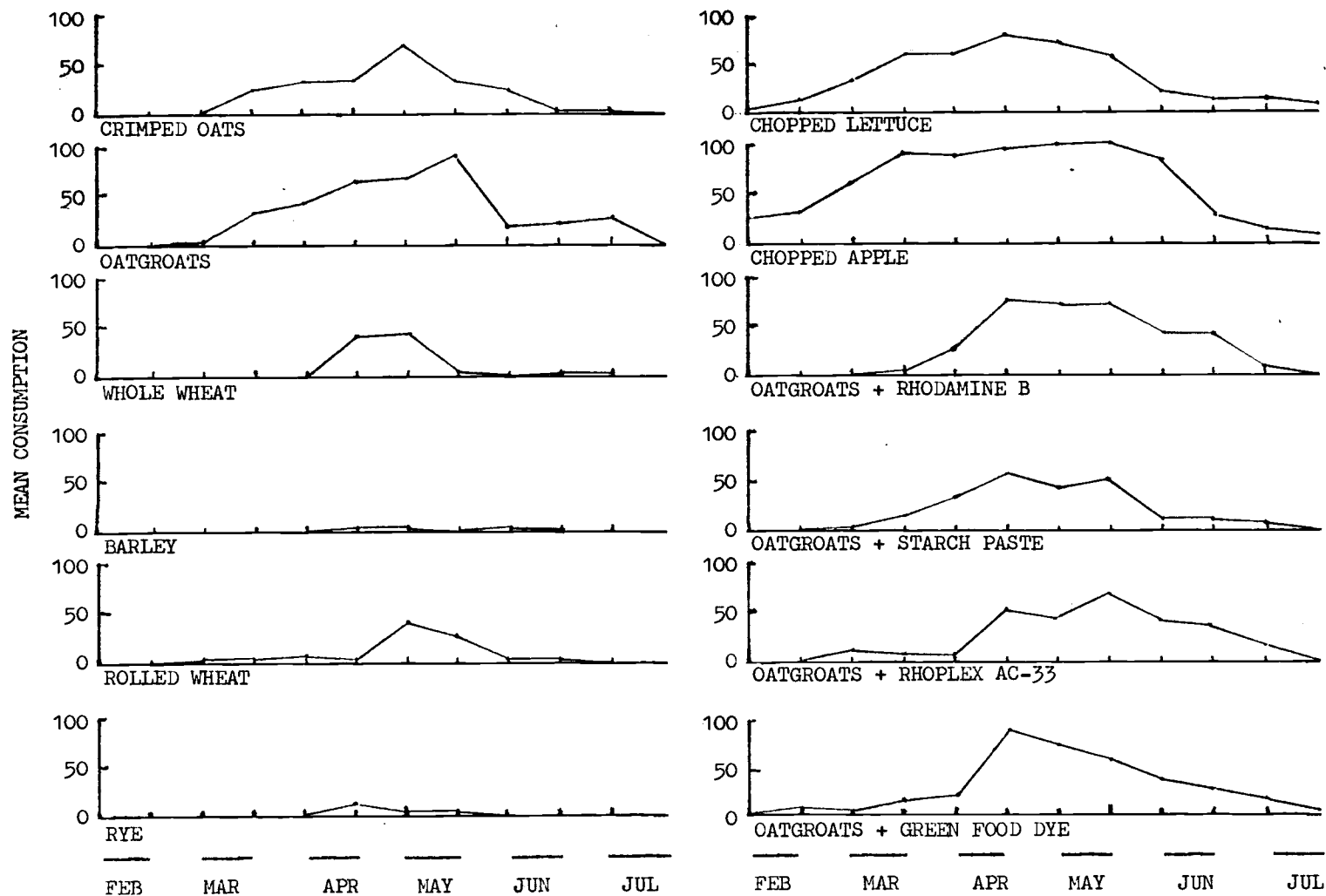


Fig. 1. Seasonal changes in preference exhibited by Belding's ground squirrels for 12 bait materials as indicated by mean amounts (in grams) of the various baits consumed each month, Grant County, Oregon, February-July 1975.

Table 1. Ranking of relative amounts of bait materials consumed by Belding's ground squirrels each month, Grant County, Oregon, February-July 1975. Bait materials tested were crimped oats (1), oatgroats (2), whole wheat (3), barley (4), rolled wheat (5), rye (6), chopped lettuce (7), chopped apple (8), oatgroats + Rhodamine B dye (9), oatgroats + starch paste (10), oatgroats + Rhoplex AC-33 (11), and oatgroats + green food dye^a (12).

Month	Test	Ranking ^b of Bait Materials ^c											
		a	b	c	d	e	f	g	h	i	j	k	l
Feb	a	8	7	5	1	11	12	10	9	3	2	4	6
	b	8	7	12	9	11	6	4	10	1	2	3	5
Mar	a	8	7	2	10	9	11	12	5	4	3	6	1
	b	8	7	2	10	12	1	5	9	11	3	4	6
Apr	a	8	7	1	10	12	2	9	5	11	3	6	4
	b	8	7	12	9	2	10	3	11	1	5	4	6
May	a	8	1	12	7	9	2	11	10	5	3	4	6
	b	8	2	9	11	7	10	12	1	5	3	6	4
Jun	a	8	12	9	7	11	1	10	2	5	4	3	6
	b	9	8	11	7	12	2	10	1	5	3	6	4
Jul	a	7	8	12	2	11	10	9	1	4	3	6	5
	b	8	7	12	11	1	5	2	10	9	3	4	6

^a Contains 2.5 percent U.S. certified food color in water and propylene glycol.

^b Bait materials ranked from highest (a) to lowest (l) according to mean amounts per test of 900-g samples of each bait consumed.

^c Lines connect bait materials consumed in amounts which were not statistically different from each other ($\alpha = 0.05$), Studentized range test (Snedecor and Cochran 1967:272-274).

ground squirrels emerged from hibernation (Table A, Appendix; Fig. 1). Growth of natural vegetation was minimal at this time. Consumption of chopped lettuce decreased after April (Fig. 1) when higher ambient temperatures and lower relative humidities caused dehydration to exceed 50 percent of the sample weight. Natural vegetation became abundant at this time, providing abundant succulent food for the ground squirrels. Dehydration of bait in excess of 50 percent of the sample weight and presence of natural vegetation did not cause a decrease in the consumption of chopped apple. Apparently, ground squirrels were attracted to the apple bait by some factor other than succulence.

Grain Baits

Oatgroats, oatgroats with additives, and crimped oats were consumed in significantly greater quantities than were whole wheat, barley, rolled wheat, and rye (Table 1). Consumption of crimped oats varied more than any other bait material, from lowest ranked in March to highest ranked in May (Table 1). These results tend to add credibility to ranchers' complaints that Belding's ground squirrels did not accept crimped oat-strychnine bait consistently. Large quantities of hulls (paleae and lemmae) were found at feed stations containing crimped oats. Removal of the hulls of crimped oats by captive ground squirrels also was commonly observed.

Amounts consumed of oatgroats with Rhodamin B dye, green food dye, starch paste, or Rhoplex AC-33 were not significantly different ($\underline{P} > 0.10$) from amounts consumed of oatgroats without these additives. These baits were consumed in largest amounts during April, May, and June (Table 2).

Bait Application

Effectiveness

Proportions of Belding's ground squirrels marked by stained oatgroats during February-July (Table B, Appendix; Table 3) differed significantly ($\chi^2 = 10.38$, $\underline{P} < 0.025$) from expected values on the basis of equal proportions marked by stained bait applied by the four methods. Proportions of ground squirrels marked by the stained bait ranged between 62.1-72.3 percent (Table 3). However, proportions of ground squirrels consuming stained bait applied by method 2 were significantly greater than proportions stained by methods 1 and 4 ($\underline{Z} = 2.84$), but did not differ significantly ($\underline{Z} = 1.64$) from proportions stained by method 3. These findings suggested that amounts of bait applied had more affect on numbers of ground squirrels consuming stained bait than placement of bait. No significant differences ($\underline{P} > 0.25$) occurred in proportions of adult male and female ground squirrels marked using the four methods of bait application during

Table 2. Mean amounts per test of oatgroats and oatgroats with additives consumed each month by Belding's ground squirrels from 900-g samples of each bait, Grant County, Oregon, February-July 1975.

		Bait Materials					
Month	Test	Oatgroats	Oatgroats + Rhodamine B	Oatgroats + Starch Paste	Oatgroats + Rhoplex AC-33	Oatgroats + Green Food Dye ^a	Totals
Feb	a	0.1	0.6	0.4	0.7	0.5	2.3
	b	0.7	2.9	1.7	2.3	6.2	13.8
Mar	a	5.6	3.7	3.8	12.7	3.5	29.3
	b	29.9	6.9	16.4	7.8	15.4	76.4
Apr	a	41.9	24.2	28.4	7.5	20.1	122.1
	b	59.3	76.0	53.4	51.3	87.9	327.9
May	a	63.8	69.8	40.3	42.3	76.3	292.5
	b	93.1	72.0	49.7	68.4	62.4	345.6
Jun	a	15.4	37.7	12.9	43.4	40.7	150.1
	b	21.0	36.5	12.6	34.9	24.7	129.7
Jul	a	22.9	7.9	7.9	13.9	19.6	72.2
	b	0.7	0.4	0.5	1.5	4.9	8.0
Totals		354.4	338.6	228.0	286.7	362.2	1569.9

^aContains 2.5 percent U.S. certified food color in water and propylene glycol.

Table 3. Numbers and percentages of Belding's ground squirrels internally marked with Rhodamine B on oatgroat bait each month. Bait was applied within a 1-m radius of burrow entrances at 1000 g/ha (1), at 2000 g/ha (2), in two treatments at 1000 g/ha 3 days apart (3), and by broadcasting 2000 g/ha (4). Specimens were collected in Grant County, Oregon, February-July 1975.

Month	Method of Bait Application												Probability ^a
	1			2			3			4			
	No. Examined	No. Marked	% Marked	No. Examined	No. Marked	% Marked	No. Examined	No. Marked	% Marked	No. Examined	No. Marked	% Marked	
Feb	30	18	60.0	29	26	89.7	32	29	90.6	44	30	68.9	<u>P</u> < 0.01
Mar	71	49	69.0	89	69	77.5	56	34	60.7	37	27	73.0	<u>P</u> > 0.10
Apr	49	23	46.9	54	39	72.2	93	52	55.9	40	23	57.5	<u>P</u> > 0.05
May	48	22	45.8	39	24	61.5	112	54	48.2	78	35	44.9	<u>P</u> > 0.25
Jun	69	49	71.0	85	54	63.5	41	35	85.4	55	49	89.1	<u>P</u> < 0.005
Jul	84	57	67.9	51	39	76.5	30	24	80.0	44	34	77.3	<u>P</u> > 0.25
Totals	351	218	62.1	347	251	72.3	364	228	62.6	298	198	66.4	<u>P</u> < 0.025

^aProbability that proportions of marked ground squirrels differed significantly from expected values on the basis of equal proportions marked by stained bait applied by the four methods.

February-June (Table 4). A significant difference ($P < 0.001$) occurred in proportions of adult male and female ground squirrels marked during July. However, numbers of females collected decreased because of onset of estivation. Differences in proportions of juvenile (52.3 percent) and adult (53.6 percent) ground squirrels consuming stained bait during April and May were not statistically significant ($Z = 0.31$).

All four methods of applying stained oatgroats declined in their effectiveness to mark ground squirrels during April and May, when succulent vegetation became abundant (Fig. 2); greatest proportions of ground squirrels were marked in February, March, June, and July, when succulent vegetation was scarce.

Size of Area Affected by Bait Application

During March and July, proportions of marked ground squirrels decreased from approximately 68 percent within a treated plot to 34 percent within a 20-m interval beyond the same plot (Table 5). Marking ranged from 0-10 percent of the ground squirrels collected beyond 20 m. These data suggest that ground squirrels occupying areas adjacent to fields to which toxic baits are applied are not greatly affected. White (1973) found that populations of Belding's ground squirrels in California immigrated from adjacent uncultivated areas to cultivated croplands when natural vegetation became dry and mature.

Table 4. Numbers and percentages of adult male and female Belding's ground squirrels internally marked with Rhodamine B on oatgroat bait each month. Bait was applied within a 1-m radius of burrow entrances at 1000 g/ha (1), at 2000 g/ha (2), in two treatments at 1000 g/ha 3 days apart (3), and by broadcasting 2000 g/ha (4). Specimens were collected in Grant County, Oregon, February-July 1975.

		Method of Bait Application												Probability ^a
		1			2			3			4			
Month	Sex	No. Examined	No. Marked	% Marked	No. Examined	No. Marked	% Marked	No. Examined	No. Marked	% Marked	No. Examined	No. Marked	% Marked	
Feb	M	10	6	60.0	10	10	100.0	12	11	91.7	16	8	50.0	<u>P</u> > 0.25
	F	20	12	60.0	19	16	84.2	20	18	90.0	28	22	78.6	
Mar	M	27	20	74.1	34	28	82.4	20	15	75.0	14	11	78.6	<u>P</u> > 0.25
	F	44	29	65.9	55	41	74.5	36	19	52.8	23	16	69.6	
Apr	M	20	11	55.0	17	13	76.5	13	7	53.8	17	9	52.9	<u>P</u> > 0.25
	F	24	10	41.7	21	14	66.7	23	12	52.2	22	13	59.1	
May	M	12	5	41.7	7	4	57.1	7	3	42.9	5	1	20.0	<u>P</u> > 0.10
	F	36	17	47.2	27	16	59.3	27	16	59.3	17	7	41.2	
Jun	M	10	6	60.0	39	28	71.8	29	26	89.7	34	29	85.3	<u>P</u> > 0.10
	F	10	8	80.0	46	26	56.5	12	9	75.0	21	20	95.2	
Jul	M	50	33	66.0	42	34	81.0	29	23	79.3	34	26	76.5	<u>P</u> < 0.001
	F	34	24	70.6	9	5	55.6	1	1	100.0	10	8	80.0	
Totals	M	129	81	62.8	149	117	78.5	110	85	77.2	120	84	70.2	<u>P</u> > 0.25
	F	168	100	59.5	177	118	66.7	119	75	63.0	121	86	71.1	

^aProbability that proportions of marked adult males and females differed significantly from expected values on the basis of equal proportions marked by stained bait applied by the four methods.

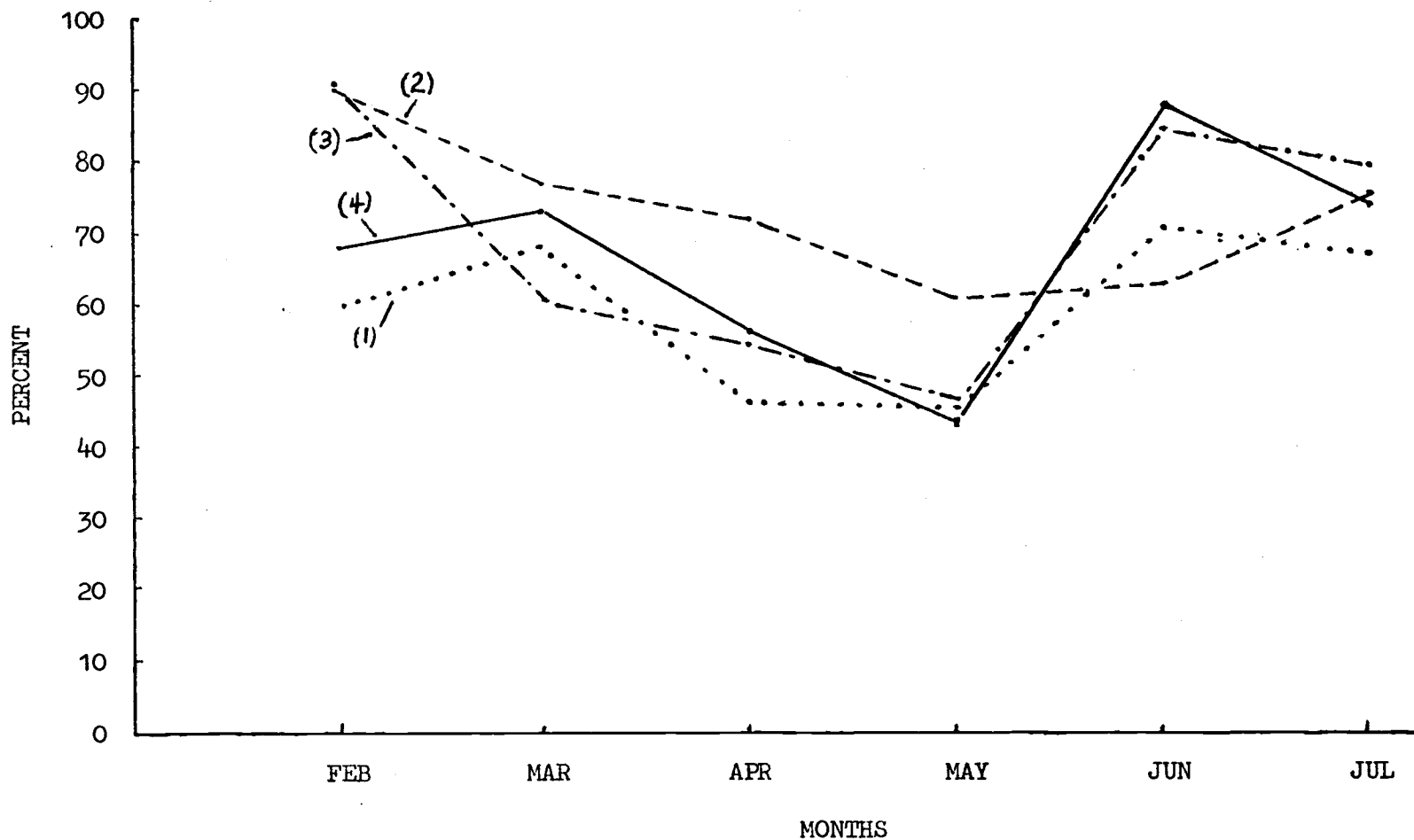


Fig. 2. Proportions of Belding's ground squirrels consuming oatgroats + Rhodamine B bait each month, Grant County, Oregon, February-July 1975. Bait was applied within a 1-m radius of burrow entrances at 1000 g/ha (1), at 2000 g/ha (2), in two treatments at 1000 g/ha 3 days apart (3), and by broadcasting 2000 g/ha (4).

Table 5. Numbers and percentages of Belding's ground squirrels consuming oatgroat + Rhodamine B bait within and at 20-m intervals beyond a treated 1-ha circular plot. Specimens were collected in Grant County, Oregon, March and July 1975.

Month	Within Treated Area			Intervals Beyond Treated Area					
				0-20 m			20-40 m ^a		
	No. Examined	No. Marked	% Marked	No. Examined	No. Marked	% Marked	No. Examined	No. Marked	% Marked
Mar	71	49	69.0	20	7	35.0	31	0	0.0
Jul	84	57	67.9	36	12	33.3	29	3	10.3

^aNone was marked in two 20-m intervals beyond 40 m.

Distances of these immigrations were reported to be as far as 1.6 km (1 mile). It appears that control of depredations by ground squirrels will not be affected by applying poisoned baits to croplands without reducing population densities of ground squirrels in surrounding areas.

Effects on Non-Target Species of Rodents

Deer mice (Peromyscus maniculatus) and Great Basin pocket mice (Perognathus parvus) were the only non-target species of rodents collected on plots treated with baits containing Rhodamine B. Proportions of these species consuming stained bait ranged between 59.4 - 79.4 percent (Table C, Appendix). Proportions of non-target species marked by stained oatgroats during February-July (Table C, Appendix) did not differ significantly ($\chi^2 = 3.78$, $P > 0.25$) from expected values on the basis of equal proportions marked by stained bait applied by the four methods. When present, non-target species of rodents appeared to readily consume stained oatgroats applied for Belding's ground squirrels, regardless of amount or method of application.

Materials and Labor Required

In terms of amount of bait material required, method 1 (1000 g/ha) had the lowest cost of all methods of bait application tested. Cost of bait material was doubled for methods 2, 3, and 4 (2000 g/ha). Increasing amounts of bait applied from 1000 g/ha to

2000 g/ha resulted in an approximate 10 percent increase in numbers of ground squirrels consuming the bait.

Methods 1, 2, 3, and 4 required approximately 40, 40, 80, and 10 minutes/ha, respectively, for bait application. When considering labor costs, broadcasting of bait provided the most economical means of applying bait.

RECOMMENDATIONS

Based on data concerning bait preference and bait application obtained in this study, I recommend the following procedures when toxic bait materials are used to control depredations by Belding's ground squirrels:

1. Succulent baits, such as apple or lettuce, should be used rather than grain baits unless costs and availability are prohibitive.
2. If grain baits are applied, oatgroats (oats without hulls) should be used rather than whole or crimped oats, wheat, barley, or rye.
3. Rhoplex AC-33 and starch paste can be used to adhere toxicants to grain baits without deleteriously affecting consumption of bait.
4. Rhodamine B or green food dye can be used to stain grain bait without deleteriously affecting consumption of bait.
5. Best results should be obtained by applying bait for control of Belding's ground squirrels during the month following emergence from hibernation.
6. Adjacent cultivated and non-cultivated areas supporting populations of ground squirrels also should be baited to prevent immigration of ground squirrels to croplands.

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APPENDIX

Table A. Mean amounts per test of 900-g samples of each of 12 bait materials consumed by Belding's ground squirrels each month, Grant County, Oregon, February-July 1975.

Month	Test	Bait Materials					
		Crimped Oats	Oatgroats	Whole Wheat	Barley	Rolled Wheat	Rye
Feb	a	1.3	0.1	0.3	0.0	2.4	0.0
	b	0.6	0.7	0.4	0.5	0.1	0.7
Mar	a	0.0	5.6	0.2	0.2	4.1	0.0
	b	22.4	29.9	2.6	0.5	6.2	0.3
Apr	a	31.0	41.9	1.0	0.2	10.6	0.9
	b	31.9	59.3	39.3	3.9	3.8	11.8
May	a	70.6	63.8	40.9	4.5	38.9	4.6
	b	29.9	93.1	4.3	1.5	26.1	3.4
June	a	25.9	15.4	1.9	3.7	4.3	1.4
	b	3.5	21.0	3.1	0.7	5.2	1.0
Jul	a	4.9	22.9	0.2	0.3	0.8	0.0
	b	0.8	0.7	0.4	0.2	0.6	0.1
Totals		222.8	354.4	94.6	16.2	103.1	24.2

Table A. Continued.

Month	Test	Bait Materials						Totals
		Chopped Lettuce	Chopped Apple	Oatgroats + Rhodamine B	Oatgroats + Starch Paste	Oatgroats + Rhoplex AC-33	Oatgroats + Green Food Dye ^a	
Feb	a	6.5	27.7	0.6	0.4	0.7	0.5	40.5
	b	16.6	31.1	2.9	1.7	2.3	6.2	63.8
Mar	a	31.4	56.2	3.7	3.8	12.7	3.5	121.4
	b	58.4	94.5	6.9	16.4	7.8	15.4	261.3
Apr	a	56.7	90.7	24.2	28.2	7.5	20.1	313.0
	b	78.0	93.2	76.0	53.6	51.3	87.9	590.0
May	a	71.4	100.0	69.8	40.3	42.3	76.3	623.4
	b	55.7	100.0	72.0	49.7	68.4	62.4	566.5
Jun	a	21.0	83.5	37.7	12.9	43.4	40.7	291.8
	b	13.5	23.8	36.5	12.6	34.9	24.8	180.6
Jul	a	13.8	16.3	7.9	7.9	13.9	19.6	108.5
	b	7.3	9.4	0.4	0.5	1.5	4.9	26.8
Totals		430.3	726.4	338.6	228.0	286.7	362.3	3187.6

^a Contains 2.5 percent U.S. certified food color in water and glycerol.

Table B. Numbers, percentages, and sex of adult and juvenile Belding's ground squirrels internally marked with Rhodamine B on oatgroat bait each month. Bait was applied within a 1-m radius of burrow entrances at 1000 g/ha (1), at 2000 g/ha (2), in two treatments of 1000 g/ha 3 days apart (3), and by broadcast 2000 g/ha (4). Specimens were collected in Grant County, Oregon, February-July 1975.

		Method of Bait Application														
		1			2			3			4			Totals		
Sex	Age	No. Exam .	No. Marked	% Marked	No. Exam .	No. Marked	% Marked	No. Exam .	No. Marked	% Marked	No. Exam .	No. Marked	% Marked	No. Exam .	No. Marked	% Marked
<u>Feb</u>																
M	adult	10	6	60.0	10	10	100.0	12	11	91.7	16	8	50.0	48	35	72.9
	juv	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
F	adult	20	12	60.0	19	16	84.2	20	18	90.0	28	22	78.6	87	68	78.2
	juv	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
<u>Mar</u>																
M	adult	27	20	74.1	34	28	82.4	20	15	75.0	14	11	78.6	95	74	77.9
	juv	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
F	adult	44	29	65.9	55	41	74.5	36	19	52.8	23	16	69.9	158	105	66.5
	juv	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
<u>Apr</u>																
M	adult	20	11	55.0	17	13	76.5	13	7	53.8	17	9	52.9	67	40	59.7
	juv	1	0	0.0	8	6	75.0	28	17	60.7	1	1	100.0	38	24	63.2
F	adult	24	10	41.7	21	14	66.7	23	12	52.2	22	13	59.1	90	49	54.4
	juv	4	2	50.0	8	6	75.0	29	16	55.1	0	0	0.0	41	24	58.5
<u>May</u>																
M	adult	12	5	41.7	7	4	57.1	7	3	42.9	5	1	20.0	31	13	41.9
	juv	0	0	0.0	0	0	0.0	28	15	53.6	25	12	48.0	53	27	50.9
F	adult	36	17	47.2	27	16	59.3	27	16	59.3	17	7	41.2	107	56	52.3
	juv	0	0	0.0	5	4	80.0	50	20	40.0	31	15	48.2	86	39	45.3

Table B. Continued.

Sex	Age	Method of Bait Application												Totals		
		1			2			3			4					
		No.	No.	%	No.	No.	%	No.	No.	%	No.	No.	%	No.	No.	%
		Exam.	Marked	Marked	Exam.	Marked	Marked	Exam.	Marked	Marked	Exam.	Marked	Marked	Exam.	Marked	Marked
<u>Jun</u>																
M	adult	10	6	60.0	39	28	71.8	29	26	89.7	34	29	85.3	112	89	79.5
	juv	17	11	64.7	0	0	0.0	0	0	0.0	0	0	0.0	17	11	64.7
F	adult	10	8	80.0	46	26	56.5	12	9	75.0	21	20	95.2	89	63	70.8
	juv	32	24	75.0	0	0	0.0	0	0	0.0	0	0	0.0	32	24	75.0
<u>Jul</u>																
M	adult	50	33	66.0	42	34	81.0	29	23	79.3	34	26	76.5	155	116	74.8
	juv	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
F	adult	34	24	70.6	9	5	55.6	1	1	100.0	10	8	80.0	54	45	83.3
	juv	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
Totals		351	218	62.1	347	251	72.3	364	228	62.6	298	198	66.4	1360	895	65.8

Table C. Numbers and percentages of non-target species of rodents internally marked with Rhodamine B on oatgroat bait each month. Bait was applied within a 1-m radius of burrow entrances at 1000 g/ha (1), at 2000 g/ha (2), in two treatments at 1000 g/ha 3 days apart (3), and by broadcasting 2000 g/ha (4). Specimens were collected in Grant County, Oregon, February-July 1975.

Month	Species	Method of Bait Application											
		1			2			3			4		
		No. Examined	No. Marked	% Marked	No. Examined	No. Marked	% Marked	No. Examined	No. Marked	% Marked	No. Examined	No. Marked	% Marked
Feb	<u>Peromyscus maniculatus</u>	6	6	100.0	5	4	80.0	3	3	100.0	6	5	83.3
Mar	<u>Peromyscus maniculatus</u>	0	0	0.0	7	7	100.0	0	0	0.0	0	0	0.0
Apr	<u>Peromyscus maniculatus</u>	3	1	33.3	0	0	0.0	0	0	0.0	0	0	0.0
May	<u>Peromyscus maniculatus</u>	10	6	60.0	11	10	90.0	1	0	0.0	1	0	0.0
Jun	<u>Peromyscus maniculatus</u>	3	3	100.0	1	1	100.0	0	0	0.0	4	2	50.0
	<u>Perognathus parvus</u>	0	0	0.0	0	0	0.0	0	0	0.0	1	1	100.0
Jul	<u>Peromyscus maniculatus</u>	10	3	30.0	9	4	44.4	9	6	66.7	18	15	83.3
	<u>Perognathus parvus</u>	0	0	0.0	1	1	100.0	0	0	0.0	0	0	0.0
Totals		32	19	59.4	34	27	79.4	13	9	69.2	30	23	76.7