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Control of plague vectors on diurnal rodents in the Sierra Nevada of California by use of insecticide bait-boxes

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INTRODUCTION

Suggestive evidence of plague epizootics in wild rodents was found in Contra Costa County, California, as early as 1903 (Meyer, 1942). The infection was conclusively demonstrated in ground squirrels, *Citellus beecheyi*, in the same county by McCoy (1908) and Wherry (1908). Since that time, surveys by responsible public health agencies have shown plague to be enzootic in three-quarters of the State, excluding only the north coastal counties and Imperial County in the extreme south. Despite a relatively high incidence of plague in native rodent populations, human cases from this source have been few; two cases occurred during the summer of 1959 (Murray & Kartman, 1959). Nevertheless, considerable effort has been directed toward controlling rodent reservoirs in areas of risk to man.

In the mountain recreation areas of California the small mammals most often subjected to control are various chipmunks (*Eutamias* spp.) and the golden-mantled ground squirrel (*Citellus lateralis*). These conspicuous rodents are objects of interest and delight to countless vacationers in the western United States, and as such are considered among the more important aesthetic resources of recreation areas where they occur. Poisoning campaigns directed at their control have understandably brought about public resentment and protest.

In recent years attention has shifted toward flea control as a means of decimating active foci of wild rodent plague or as a prophylactic measure where man is exposed to potential disease hazard in the form of high rodent-ectoparasite densities. Insecticide dusting of burrows (Ryckman, Ames & Lindt, 1953) and area dusting (Miles & Wilcomb, 1953) have been tested with good results. A combination of these two methods has been used successfully by the California State Department of Public Health to control fleas parasitizing *Citellus beecheyi* during and after plague epizootics in a Kern County mountain recreation area (Mortenson, unpublished report, Bureau of Vector Control, 1956).

During the summer of 1959, a co-operative study was undertaken in the Sierra Nevada mountains by personnel of the U.S. Public Health Service and the California State Department of Public Health. The primary object of this study was to test the effectiveness of insecticide bait-boxes developed by Kartman (1958, 1960) against fleas of diurnal small mammals in the Sierra Nevada. With this control method, the host serves as a vehicle for the insecticide, carrying it to its nest where most of the fleas occur. Additional objectives of the study were to examine host-flea relationships and to evaluate home range and activity patterns of several rodent species. These aspects of the study are to be presented in separate papers.

THE STUDY AREA

The area in which the study was made is near Sagehen Creek, 3·2 to 4·7 miles north and 2·3 miles west of Hobart Mills, Sierra County, California. The elevation varies from 6400 to 6600 ft. Although much of the surrounding country is rather precipitous, the study area slopes gently to the south and east. Trees were removed in the particular locality many years ago and it is now liberally dotted with partially decomposed logs and stumps.

The habitat is characterized by open pine-fir forest with intruding Great Basin shrub elements. Predominant tree species are Jeffrey pine (*Pinus Jeffreyi*), lodgepole pine (*P. Murrayana*), and white fir (*Abies concolor*). In open areas, low sagebush (*Artemesia tridentata*) is often the major plant cover. In other spots, dense patches of tobacco bush (*Ceanothus velutinus*) or greenleaf manzanita (*Arctostaphylos patula*) dominate. Mule ears (*Wyethia mollis*) and squaw carpet (*Ceanothus prostratus*) are prominent beneath larger Jeffrey pines. Single bushes of wax currant (*Ribes cereum*) and bitterbrush (*Purshia tridentata*) are of scattered occurrence. Bush chinquapin (*Castanopsis sempervirens*) occurs in partially shaded spots beneath white fir.

WEATHER

The summer of 1959 was preceded by an abnormally mild winter throughout the Sierra Nevada. The snowpack at Sagehen Creek usually persists until mid-May, but in 1959 it was gone by the middle of April. During the course of the study, temperatures often varied from minima below 32° F. at night to maxima near 90° F. during the day. Measurable precipitation occurred once during the summer; a thundershower producing 0·20 in. of rain on 24 August. As is typical for the east side of the Sierra Nevada, humidities were generally low.

METHODS AND MATERIALS

The bait-boxes used in this study were described by Kartman (1958). They are made of a floorboard ($\frac{1}{2}$ in. thick, 12 in. long and 8 in. wide) covered by a metal inverted U-shaped roof either nailed to the edges of the floorboard or simply worked into the soil at its sides. Bait-pans, made from oval sardine tins, are held by nails or a screw to the centre of the floorboard; these pans hold about 100 g. of rolled oats. The insecticide powder is placed at each end of the baseboard when the bait-boxes are in operation.

Only live traps were used during this study: a wire-mesh type (Young) and a sheet metal type (large Sherman). Mammals trapped were marked by a code of toe and ear clipping. In each case records were kept of capture time, site, reproductive status, and number and species of fleas. To remove ectoparasites, the hosts were placed in a wide-mouth quart jar, lightly anaesthetized with ether, and the fleas then combed into a white enamelled pan.

Two grids with trapping stations at 100 ft. intervals were utilized. Grid 1 consisted of five lines having ten trapping stations each, and served as the control area. Grid 2 was located 1·5 miles north in similar habitat and had ten lines with ten trapping stations each; this plot served as a check on success of control in the DDT area.

Preliminary trapping was carried out in Grid 1 on 30–31 May and again on 15–18 June to check flea density. Both grids were trapped during the week of 29 June to 3 July. Host and flea densities were judged sufficient by early July to allow measurement of control results. On 14 July Grid 1 was trapped again. Unfortunately, only one *Citellus lateralis* specimen was captured; therefore flea density could not be ascertained for that species. Nevertheless, fleas on *Eutamias* spp. had reached their highest density and it was decided to activate the bait stations.

On the evening of 14 July, after trapping, the first test was begun. One bait-box was set up at each trapping station. Each was baited with 100 g. of rolled oats and provided with 50 g. of 10% DDT dust in pyrophylite; about 25 g. placed in a ridge across each end of the baseboard of a bait-box. The boxes were baited daily for 12 days and removed on 26 July. Trapping and flea collecting were carried out in both grids at appropriate intervals; in Grid 1 to check on immediate and residual effects of the DDT, and in Grid 2 to ascertain normal flea population density.

On 12 August bait-boxes were again placed in Grid 1 and supplied with bait and 10% DDT dust as before. The boxes were then baited twice weekly and removed on 8 September; the amount of bait used was less than before (25–30 g.). DDT was replenished in some of the stations on 24 August after a thunder-shower had wet them. Trapping in both grid areas was again done at appropriate intervals; the last trapping was done on 16 October.

In addition to the above two experiments, another was carried out on Grid 1 to determine the extent of the area influenced by the bait-boxes. On 8 September, Grid 1 was extended to include five more lines of ten stations each. From 8 to 11 September the entire grid of 100 stations was trapped; 20 or more chipmunk captures were made in each of the new lines. The DDT-treated area was trapped more lightly and the data were combined for comparison with each line in the adjacent area.

DATA AND DISCUSSION

Table 1 summarizes rodent captures made during the study. The predominant chipmunk species, *E. amoenus*, was about three times as abundant as its relative, *E. speciosus*. *E. amoenus* individuals also tended to be captured more often.

Citellus lateralis, the second most abundant diurnal species, was inconsistently captured. Several times during the study an insufficient number of *C. lateralis* specimens were taken to provide adequate flea data.

Table 1. *Summary of rodent captures in study Grids* 1 *and* 2, *Sagehen Creek, Sierra County, California*, 1959

Rodent species	Grid	Number of captures* By grid	Number of captures* Totals	Number of individuals taken† Once only	Number of individuals taken† Totals
Eutamias amoenus	1	401	732	57	95
	2	331 (224)		39	75
E. speciosus	1	117	181	23	34
	2	64 (45)		14	24
Citellus lateralis	1	274	544	50	77
	2	270 (185)		43	70
Totals	1	792	1457	130	206
	2	665 (454)		96	169

* All captures in Grid 1 were combed for fleas; numbers in parentheses are captures in Grid 2 combed for fleas.

† Those individuals captured only once were presumed to be non-residents.

Table 2. *Species of fleas and their relative occurrence on rodents in study Grids* 1 *and* 2, *Sagehen Creek, Sierra County, California*, 1959

Flea species	Total fleas taken from *Eutamias* spp.	Total fleas taken from *Citellus lateralis*
Monopsyllus eumolpi	571	5
M. ciliatus	328	4
M. wagneri	10	6
Diamanus montanus	11	272
Oropsylla idahoensis	6	160
Catallagia rutherfordi	13	7
Orchopeas nepos	2	0
Malaraeus telchinus	2	2
Peromyscopsylla hesperomys	1	0
Megabothris abantis	1	0
Totals	945	456

Flea data from the three rodent species are summarized in Table 2. *Monopsyllus eumolpi* and *M. ciliatus* were the major fleas on both chipmunk species, although they did not occur in the same proportions on both hosts. For convenience, chipmunk fleas have been combined in the data. Fleas occurred on *Citellus lateralis* in smaller numbers than on *Eutamias* spp. during most of the study, but in early July they reached a peak of 2·9 per host in Grid 2. The most numerous flea on *C. lateralis* was *Diamanus montanus*. *Oropsylla idahoensis* was second in abundance.

Chipmunks and chipmunk fleas offered much more consistent data during the

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study than did *Citellus lateralis* and its fleas. This is important since, during the course of the study, it was noted that one or both of the predominant flea species on chipmunks bit man quite readily. Observers were bitten by these fleas many times while checking chipmunk captures for the concurrent home range study. Other observers have noted that wild rodent fleas are generally reluctant to take human blood (Pollitzer, 1954). The tendency to bite man gives chipmunk fleas considerable importance in mountain recreation areas where they may be a link between man and sylvatic plague foci. Of the two principal species, *Monopsyllus eumolpi* has been found naturally infected with plague and *M. ciliatus* has been experimentally infected (Pollitzer, 1954). During 1959, tissues from chipmunks,

Table 3. *Effect of* 10 % *DDT dust in bait-boxes on the incidence of fleas* parasitizing chipmunks*, Eutamias *spp., during two exposure periods;* 14–26 *July and* 12 *Aug.*–8 *Sept.* 1959

Treated plot (Grid 1)				Check plot (Grid 2)			
Dates	No. hosts/ no. fleas	Mean fleas	% hosts infested	Dates	No. hosts/ no. fleas	Mean fleas	% hosts infested
18–19 June	17/20	1·2	47	—	—	—	—
30 June–1 July	43/69	1·6	58	2–3 July	12/23	1·9	50
14 July	16/39	2·4	69	—	—	—	—
15 July	31/23	0·7	32	—	—	—	—
16 July	22/6	0·3	14	—	—	—	—
17 July	34/12	0·4	20	—	—	—	—
20–21 July	30/11	0·4	13	21–22 July	20/44	2·4	80
26–27 July	26/19	0·7	42	29–31 July	30/53	1·8	77
6–7 Aug.	25/31	1·2	48	—	—	—	—
11–12 Aug.	32/76	2·4	81	—	—	—	—
13 Aug.	19/12	0·6	37	—	—	—	—
14 Aug.	23/11	0·5	22	14–15 Aug.	18/36	2·0	72
20–21 Aug.	39/32	0·8	33	19–22 Aug.	40/65	1·6	70
26–27 Aug.	34/5	0·1	9	25–29 Aug.	34/63	1·9	79
8–11 Sept.	37/6	0·2	11	6–7 Sept.	33/29	0·9	36
23 Sept.	23/11	0·5	43	22 Sept.	18/22	1·2	61
15 Oct.	29/15	0·5	38	16 Oct.	22/38	1·7	65

* The identification and abundance of flea species are shown in Table 2.

Eutamias speciosus, collected in Yosemite National Park, California, were found plague positive, and *Monopsyllus eutamiadis* from *Eutamias speciosus* was found infected during a plague epizootic near Mono Hot Springs, Fresno County, California (Murray & Kartman, 1959).

The effects of 10 % DDT dust on flea species parasitizing chipmunks and squirrels are summarized in Tables 3 and 4 respectively. Within 24 hr. of the first use of DDT bait-boxes on 14 July fleas were reduced strikingly on both host species. The effect was less apparent on *Citellus lateralis* than on *Eutamias* spp. since, unfortunately, only one *C. lateralis* was caught immediately prior to establishment of the bait-box stations. Fleas remained low on both host species during the 12 days bait stations were in use. By 6–7 August, less than 2 weeks after removal of the bait-boxes, *Eutamias* fleas had increased to 1·2 per host. An apparent increase in *C. lateralis* fleas was largely due to the capture of one non-resident animal bearing 17 fleas. By 11–12 August *Eutamias* fleas had increased to the pre-DDT level of 2·4 per host, while *C. lateralis* fleas were still lower than in Grid 2.

With the second application of DDT in bait boxes on 12 August a 24-hr knock-down effect was observed again. Fleas remained low on both host species during the 28 days bait-box stations were in use, even though they were baited only twice weekly. Animals were observed to visit unbaited stations frequently during this

Table 4. *Effect of* 10 % *DDT dust in bait-boxes on the incidence of fleas* parasitizing the ground squirrel,* Citellus lateralis, *during two exposure periods;* 14–26 *July and* 12 *Aug.*–8 *Sept.* 1959.

Treated plot (Grid 1)				Check plot (Grid 2)			
Dates	No. hosts/ no. fleas	Mean fleas	% hosts infested	Dates	No. hosts/ no. fleas	Mean fleas	% hosts infested
30–31 May	18/33	1·8	61	—	—	—	—
18–19 June	20/21	1·0	48	—	—	—	—
30 June–1 July	15/43	2·9	73	2–3 July	13/14	1·0	61
14 July	1/18	—	—	—	—	—	—
15–16 July	16/8	0·5	31	—	—	—	—
17 July	18/3	0·2	11	—	—	—	—
20–21 July	26/2	0·08	8	13–22 July	73/77	1·0	49
26–27 July	20/15	0·8	15	29–31 July	25/42	1·7	65
6–7 Aug.	20/35	1·8†	45	—	—	—	—
11–13 Aug.	19/15	0·8	58	7–15 Aug.	33/55	1·7	61
20–21 Aug.	28/0	0	0	—	—	—	—
26–27 Aug.	16/2	0·1	12	19–29 Aug.	25/19	0·8	44
8–11 Sept.	33/3	0·09	6	6–7 Sept.	11/8	—	—
23 Sept.	16/5	0·3	25	22 Sept.	3/9	—	—
15 Oct.	3/1	—	—	15 Oct.	5/5	—	—

* The identification and abundance of flea species are shown in Table 2.

† One non-resident host had 17 fleas; if these are deleted the mean is 0·9 and the percentage infested is 40.

time. It was noted that *C. lateralis* became much more thoroughly covered with DDT dust than *Eutamias* because of its habit of repeatedly switching its tail while sitting erect at the edge of a bait-box. This may explain the apparently longer residual effect of DDT on *C. lateralis* fleas after the first experiment. Trappings on 23 September and 15 October indicated a residual control period of at least 42 days for *Eutamias* fleas.

The increased residual effect, after a longer exposure of the rodents to DDT dust in the bait-boxes, may be partially explained on the basis of experience with cricetid rodents (Kartman, 1958, 1960). In the latter case, direct evidence of flea control in *Microtus* nests was shown, and in the present instance the insecticide undoubtedly was transported to the rodent nests in a similar manner and thus may account for a more prolonged effect on the flea population.

Early in September it became difficult to capture *C. lateralis* often enough to provide adequate flea data. Apparently these animals had begun their winter hibernation by that time, even though some individuals were caught as late as

15 October. Tevis (1955) has shown that *C. lateralis* may hibernate as early as late August near Quincy, Plumas County, California.

Results of the extension of Grid 1 on 8–11 September appear in Fig. 1. Only chipmunks were caught in sufficient numbers to include in these data which suggest that the DDT bait-boxes influenced flea numbers on *Eutamias* spp. at least 400 ft. from the grid. At 500 ft., flea numbers increased sharply, presumably because fewer animals were caught whose home ranges extended into the DDT area. This indication of linear distances travelled by *Eutamias* closely approximates

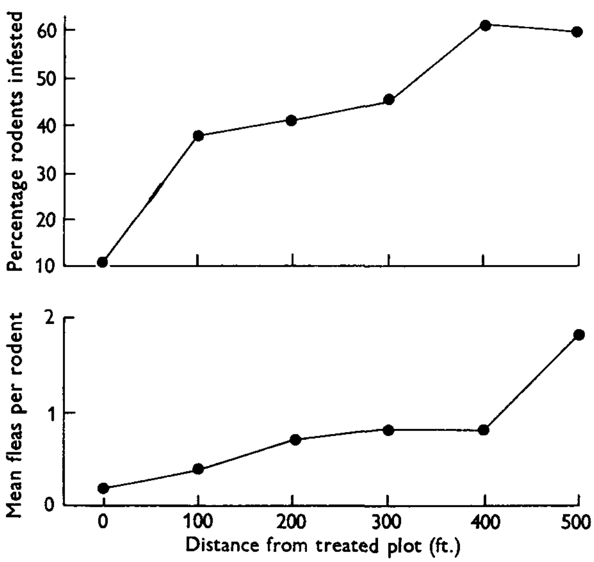

Fig. 1. The abundance of fleas on chipmunks, *Eutamias* spp., in relation to distance of capture from DDT-treated bait-boxes in Grid 1 (results of trappings between 8 and 11 Sept. 1959).

results from the mark and release home range study done concurrently (D. R. Roberts, unpublished). In view of the rather extensive home ranges of these particular animals, 200 ft. spacing of DDT bait-box stations should be as effective as the arbitrary 100 ft. spacing used throughout the study. In situations where other small mammals are involved, e.g. voles (Kartman, 1958), spacing of the bait-boxes would have to be adjusted to account for their smaller home ranges.

CONCLUSIONS

The results of these tests show that fleas on *Eutamias amoenus*, *E. speciosus* and *Citellus lateralis* can be rapidly and economically controlled in the field with 10% DDT dust in bait-boxes. When baited twice weekly for 28 days, good residual control was obtained. The insecticide bait-boxes are easily constructed and are simple to use, requiring no special knowledge or techniques. In the case of colonial burrowing rodents, burrow dusting may be a more efficient means of flea control. Where non-colonial rodents are involved, area insecticiding is another alternative. The use of bait-boxes has distinct advantages over area treatment in that they allow direct contact of the insecticide with the rodent and its nest, the action is selective, thus posing little if any threat to wildlife, and very little insecticide per acre is required (less than 400 g. of 10% DDT).

It has been stated that control of wild rodent plague should be considered an emergency measure with limited objectives (Kartman, 1956). Control measures, when needed, should be rapid and effective. With the development of efficient, economical techniques for wild rodent flea control, emphasis could shift from control of the reservoirs of wild rodent plague to control of its vectors. It would be too bold an assumption to suppose that ectoparasite control can or should supplant rodent control in all cases. Nevertheless, the control of wild rodent fleas has distinct advantages over wild rodent control. Effective control of vectors immediately reduces the hazard to man and interrupts the natural transmission cycle of the disease. It is generally more economical and far less hazardous to man and wildlife than rodent poisoning campaigns. Moreover, where disease hazards occur and rodent control is indicated, the immediate hazard to man is most readily reduced by supplemental ectoparasite control. Rodent control without control of ectoparasite vectors may temporarily increase, rather than decrease, the hazard to man by leaving the controlled area with hungry, potentially infective, vectors without natural hosts to feed upon. Insecticide bait-boxes, as described and used here, offer a rapid, effective, and economical means of wild rodent flea control for use in mountain recreation areas in the western United States.

SUMMARY

Trials were conducted in the Sierra Nevada Mountains of California to test the effectiveness of 10% DDT dust in insecticide bait-box stations against the fleas of native diurnal rodents. The principle host species involved were the chipmunks *Eutamias amoenus* and *E. speciosus*, and the golden-mantled ground squirrel, *Citellus lateralis*. The important flea species were *Monopsyllus eumolpi* and *M. ciliatus* on chipmunks, and *Diamanus montanus* and *Oropsylla idahoensis* on ground squirrels. When baited daily for 12 days and furnished with 50 g. of 10% DDT dust, the bait-box stations reduced fleas strikingly within 24 hr., but very little residual control was obtained. A second application in which boxes were baited only twice weekly but for 28 days, also resulted in rapid knockdown and a residual control still effective 42 days after removal of the bait-boxes. The effect of the DDT was apparent at a distance of 400 ft. from the nearest bait-box due to the relatively extensive home ranges of the hosts. Although, in these trials, bait-box stations were spaced 100 ft. apart, 200 ft. spacing probably would be as effective with these hosts.

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