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WILD-RODENT-FLEA CONTROL IN RURAL AREAS OF AN ENZOOTIC PLAGUE REGION IN HAWAII

A Preliminary Investigation of Methods

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SYNOPSIS

Preliminary field tests were carried out to develop methods for controlling fleas on wild rodents in the enzootic plague region of the Island of Hawaii. Among several designs, a metal hood-type DDT bait-box was developed which was simple in design, low in cost, easy to transport to and maintain in the field, protected the insecticide from the elements, and attracted all species of field rats inhabiting a gulch in the Hamakua District. These rats—*Rattus rattus* (and its subspecies), *R. norvegicus*, and *R. hawaiiensis*—readily fed in the DDT bait-boxes and were dusted with 10% DDT powder (in pyrophyllite) on contacting hanging cloth sacks, containing the insecticide, when entering and leaving the bait-boxes. The results indicate that a reduction of the plague-vector fleas, *Xenopsylla cheopis* and *X. vexabilis hawaiiensis*, may be obtained both on rats and within their burrows and nests, by the use of DDT bait-boxes. It is suggested that the use of such bait-boxes for wild-rodent-flea control may constitute a valuable method in the prevention of epizootics of plague in the Hamakua District, Hawaii.

The history and epidemiology of plague in the Hamakua District, Island of Hawaii, have been elucidated in the basic study by Eskey,[6] and more recent accounts of plague work are given by Gross & Bonnet.[10, 11]

As an addition to the programme of the Bureau of Rodent Control, Territorial Department of Health, Honolulu, studies were initiated during 1952 to develop suitable techniques for the control of wild-rodent fleas in rural (wild) situations of the district. This activity was established as a co-operative project between the Territorial Department of Health and the Communicable Disease Center of the US Public Health Service.

That flea control is an important measure in combating human plague appears to be a well-established principle.[7] As recently noted by Wagle & Seal,[24] the first successful field application of DDT in the control of plague was made by United States military personnel at Dakar, French West Africa, in 1944.[13] The experimental basis for the use of DDT in the 1944 plague epidemic at Dakar was established during the early part of that year by field tests with the common " house and body " flea, *Synosternus pallidus*.[12] Successful plague control during which the use of anti-flea measures was emphasized has been recorded from Peru,[14] Palestine,[15] and India.[24] Furthermore, the use of the newer synthetic organic insecticides in plague prophylaxis appears promising.[16] The control of wild-rodent fleas has been approached on the basis of direct applications of insecticides to rodent burrows [1, 21] or by area dusting,[17] depending upon conditions. It is of interest that a publication issued for lay consumption emphasized the importance of flea-control measures prior to rat destruction during outbreaks of flea-borne diseases.[18]

The Hamakua District, Hawaii

The Hamakua District on the Island of Hawaii is a portion of the north-west slope of Mauna Kea (an inactive volcano) which rises to an altitude of 13,825 feet (4,210 m). The district has a coast line approximately 20 miles (32 km) in length, and is bounded on the north-west by the Waipio Valley and on the south-east by the North Hilo District. The plague endemic area extends throughout the entire length of the region from the Waipio Valley to the village of Ookala, but the infection apparently resides in a very narrow coastal strip not over 5 miles (8 km) in width. There seems to be no evidence of plague above an altitude of 2,000 feet (600 m).

The four species of rodents found in the Hamakua District are : *Rattus rattus* (and its subspecies), *R. norvegicus*, *R. hawaiiensis*, and *Mus musculus*. The commensal species live both in human habitations and in the field, but the native Hawaiian rat, *R. hawaiiensis*, is a true wild rodent and is rarely captured in habitations. It is of interest that the Hawaiian rat is thought to be a race of *R. exulans exulans*, a species in the Malayan *concolor* group, many of whose members are generally regarded as having house-frequenting habits.[5]

The species of fleas found in the district are as follows : *Xenopsylla cheopis*, *X. vexabilis hawaiiensis*, *Nosopsyllus fasciatus*, *Leptopsylla segnis*, *Echidnophaga gallinacea*, *Ctenocephalides felis*, and *Pulex irritans*. The two *Xenopsylla* species are considered to be the ones primarily concerned in plague transmission. Although neither of the *Xenopsylla* species from the Hamakua District has been tested, the plague-vector efficiency of *X. cheopis* is generally well known, whereas that of *X. v. hawaiiensis* remains to be determined. The predominant rat-mites encountered are *Echinolaelaps echidninus* and *Laelaps nuttalli.* Rat lice captured are mainly *Polyplax spinulosa* and a species of *Hoplopleura.*

Plague in urban areas is now fairly easy to control by modern methods of rat-proofing, rodenticidal operations, and application of DDT or other pulicides. Furthermore, prophylactic vaccination and the newer chemotherapeutics against plague are available to the local population.

The district is primarily agricultural, the chief crop being sugar-cane. The bulk of the population of about 6,000 lives in small villages and plantation camps below the 1,500-foot (450-m) level and quite often in direct contact with cane-fields, wooded areas, and gulches, which are heavily infested with rodents. Approximately 20,000 acres (800 ha) are planted in sugar-cane, and these fields border upon both inhabited and wild areas. The gulches range from a few score to several hundred feet in depth and, together with the sugar-cane, provide harbourage for rodents all the year round (see fig. 4, page 56).

The enzootic plague area lies within the low phase of vegetation—" zone D " according to the classification of Ripperton & Hosaka.[20] This region is characterized by an annual mean temperature of 73°F (23°C) and a minimum rainfall of about 60 inches (1,500 mm) at sea level. The trade winds are generally brisk but seldom strong, and are responsible for the rainfall, which is less variable than in other zones. The high rainfall has resulted in extensive erosion, creating the numerous deeply-cut gorges so characteristic of the region.

The most common shrub is guava; and the gulches abound with Kukui trees, banana, mango, some papaya, various berries, many species of fern, and a variety of grasses, sedges, and herbs. The rodents living in the wild areas have an extremely stable food-supply throughout the year, and significant rodent migrations appear to be unknown. At sugar-cane harvest-time they migrate to adjacent gulches, grassy fields, or maturing cane-fields, since their harbourage is destroyed by the bulldozers used in the harvesting.

The wild type of plague is difficult to control because methods of attacking the flea vectors have not been developed for field application. In spite of many years of rodenticidal operations there seems to be no indication that enzootic plague among field rodents of the district is following a curve of recession. Periods of quiescence have consistently been broken by epizootic incidents, usually heralded by the finding of dead rats.[6, 11]

The use of DDT or other insecticides for the control of fleas on wild rodents in the Hamakua District is beset with serious obstacles. Indiscriminate use of these insecticides would threaten the many beneficial entomophagous parasites which have been introduced, at great expense, to combat sugar-cane pests. Also, it is not known whether an insecticide might become part of the raw sugar product if it were to be spread in the fields. Moreover, while the spreading of insecticides in certain areas might be feasible during periods of prolonged dry weather, owing to the frequent and intensive rainfall, insecticides spread in the open along rodent trails or on rock piles would be rapidly rendered ineffective. Because of the lush vegetation and the impenetrability of cane-fields, an extremely small percentage of rat burrows could be located for direct dusting with residual insecticides; even in shallow gulches or in grassy fields preliminary clearing would be necessary for this type of operation.[2]

Thus the first step in formulating methods of flea control was to consider the problem in relation to the peculiarities of the Hamakua District. It appeared that the use of insecticides in the field should be developed on the basis of utilizing the rat itself as the contactor and disseminator of the insecticide, and, at the same time, safeguarding the insecticide from adverse conditions and indiscriminate spread. The investigation described below has been conducted with this principle in view.

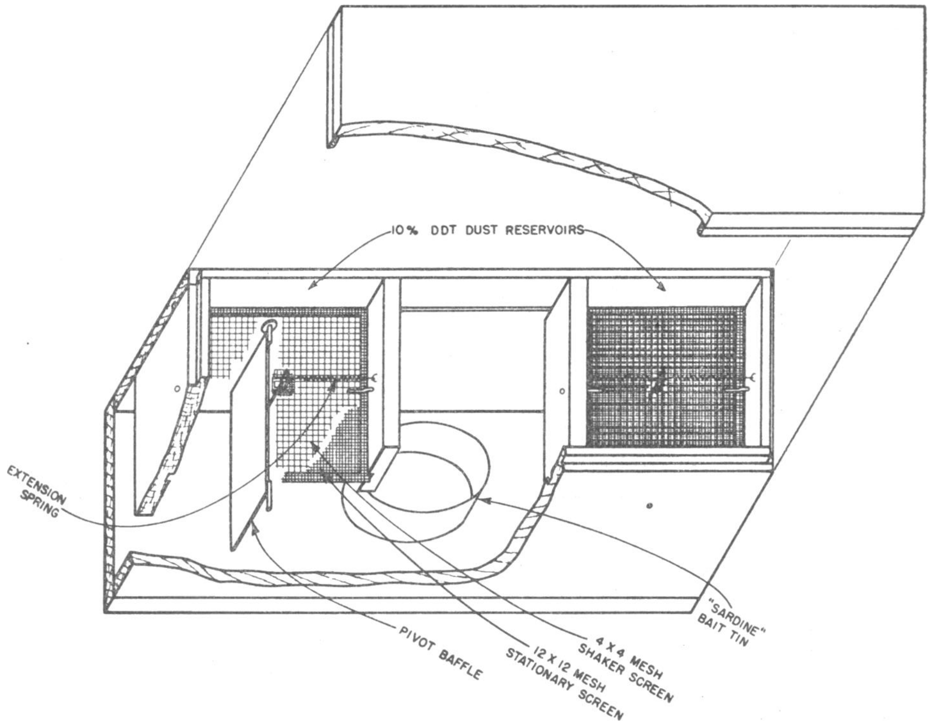
Methods and Materials

Several types of DDT bait-box were designed for the purposes of this study. However, only the two types which constituted the source of most of the experimental data will be described here.

The wooden DDT bait-box, shown in fig. 1, was designed in San Francisco by one of the writers (R.P.L.) prior to initiation of the field studies in Hawaii. The box operates as follows : the rodent enters at either end opening; to reach the bait in the middle compartment, it pushes the baffle forward; this moves the shaker screen across the stationary screen and a shower of DDT powder is sifted down over the full cross-section of the entrance compartment; as the rodent passes by, the baffle comes back to its normal position, and the reverse of the above takes place when the rodent leaves the box, thus giving it two " showers " of DDT at each visit. The coating of DDT on the floor of the box also serves to coat the underside of the rodents.

The metal hood-type DDT bait-box is shown in fig. 2 and 3. This box was designed to simulate the hood type of feeding station commonly used on plantations for rat control,[3] and utilizes hanging cloth sacks for dispensing the DDT powder.[8] The box is much lighter than the wooden type, and an even further reduction in weight can be attained by the use of aluminium instead of galvanized iron for its construction. Estimates by local firms of the cost to build from 1,000 to 10,000 such units were quoted at about $1.15 each in galvanized iron, and about $1.10 each in aluminium. For orders of over 10,000, the quotations were, respectively, $1.00 and $0.95.

FIG. 1 DIAGRAM OF WOODEN DDT BAIT-BOX



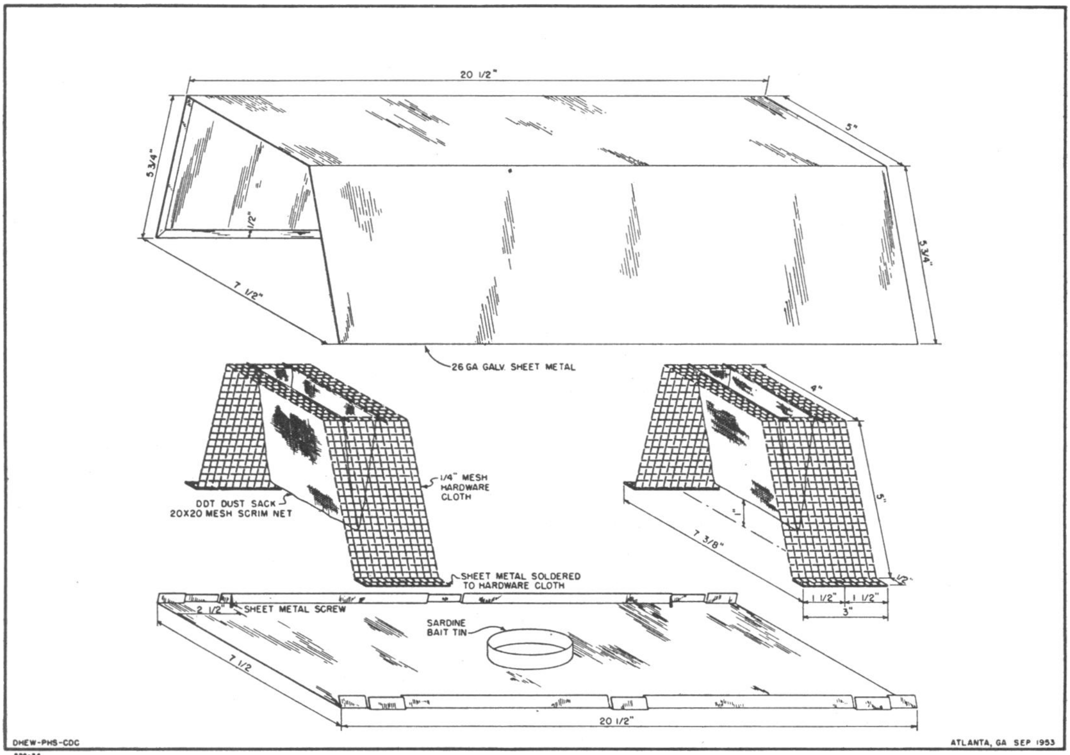
Materials : wood : " all-heart " redwood ; metal : non-ferrous or ferrous with rust-resistant coating
Dimensions : height, 8½ inches ; width, 9¼ inches ; length, 26 inches
Weight : 14 pounds
Size of openings : 2½ inches × 7¾ inches
Capacity of reservoirs : 1½ pounds of DDT powder
Capacity of bait container : 200 grams (rolled oats)
Distance between bottom edge of baffle and floor : 1 inch
The two ends of the box are identical.

Operation of the hood-type box is generally similar to that of the wooden one, but is somewhat simpler. The DDT powder is sifted upon the rat when it brushes past the cloth sacks both on entering and leaving the box. In both types of box, the capacity of the bait container can be increased to about 1 pound (450 g) (rolled oats) if desired.

Part of the investigation was conducted from 6 February through 24 March 1952 in Field 1 of the Paauhau Sugar Plantation Company. This field consisted of approximately 103 acres (50 ha) of mature plant cane (variety 31-1389) and extended from 200 feet (60 m) to 900 feet (270 m) in elevation. An area of about 40-50 acres (16-20 ha) around the periphery of the field was covered with 200 live-type cage traps placed at 35-foot (10-m) intervals (the traps are designated locally as " Japanese " and " Marine " types). These were baited with small coconut squares during the afternoon, and were visited the following morning. Captured rats were anaesthetized with ether or chloroform, combed for ectoparasites, checked for certain physical data, marked by toe amputations, and released at the point of capture. Rats from certain portions of the field were dusted with from 0.1 g to 0.6 g of 10% DDT powder in pyrophyllite each time they were captured; the amount of DDT applied was dependent upon the size of the animal. All other trapped rats were used as controls and did not receive the DDT application. An individual record card was kept for every animal captured.

From May 1952 to May 1953, the work was conducted in Kaunamano Gulch, which is approximately 6 miles (9 km) east of the town of Honokaa and about 2 miles (3 km) west of the town of Paauilo. This gulch is bordered mainly by sugar-cane fields, grassy slopes with many guava bushes, and a small area of cultivated and inhabited farm land.

FIG. 2. DIAGRAM OF METAL HOOD-TYPE DDT BAIT-BOX



Weight: 3 pounds. Capacity of sacks: 80 grams of DDT powder. Capacity of bait container: 200 grams (rolled oats). The box can be simplified by eliminating the sack hangers and suspending the sacks from the hood by wire pins inserted in holes bored in the sides of the hood ; the sacks are then filled through a (corked) hole bored through the top of the hood.

A total of 80 experimental stations was established in the gulch, extending over a distance of about 4,000 feet (1,200 m) in length and from approximately 400 feet (120 m) to 750 feet (230 m) in elevation. Meteorological records were obtained from two sets of instruments owned by the Hamakua Mill Company, one located at an altitude of 765 feet (233 m) and 2.2 miles (3.5 km) from the gulch, and the other at 250 feet (76 m) elevation and 0.5 mile (0.8 km) from the gulch.

Each station was supplied with a live-type cage trap, and 17 wooden DDT bait-boxes were placed at intervals of five stations. The stations were 50 feet (15 m) apart, thus making the DDT bait-boxes about 250 feet (76 m) from each other and distributed throughout a representative area of the gulch in a more or less linear arrangement. In other tests, the metal hood-type DDT bait-boxes were substituted for the wooden bait-boxes at desired stations.

The bait-boxes were supplied with unpoisoned or with warfarin-treated rolled oats as desired, and each box was given a supply of DDT powder as needed. Bait consumption was estimated by weighing the bait before placement in the boxes and then weighing the residue after suitable time-intervals. During some of the tests, rodent activity also was measured by counting all faecal pellets in the boxes at each visit.

In order to facilitate observations on the species of rats feeding in the DDT bait-boxes, each bait-box station was supplied with two live-type cage traps; one was set adjacent to the bait-box and another was attached to one end of the wooden bait-box by galvanized metal brackets, so that a rat was compelled to go through the bait-box in order to secure the bait in the trap. The cage traps were baited either with coconut or with a mixture of commercial dog-food and rolled oats. Two cage traps were also set adjacent to the metal hood-type bait-boxes, but none was attached to the bait-box. In this case, rolled oats stained with Du Pont " Oil Red " (No. 49875) at the rate of 1 g to 1,500 g of bait were used to indicate rodent activity in the bait-boxes. Faecal pellets, retained by waxed paper placed under the cage traps, were subjected to a few drops of xylene, which produced a red colour in positive cases. The stain is insoluble in water.

All rats captured were processed as indicated above. Rats were taken from control areas in the gulch and in adjacent fields for comparison with animals presumably affected by the DDT bait-boxes. Where feasible, burrows and nests of rats, both in the DDT bait-box zone and in the control areas, were excavated for observations on flea populations.

It should be noted that *Rattus rattus* and subspecies, and *R. hawaiiensis* were the predominant populations in the test area during this study. Data on *R. norvegicus* have been included merely for completeness.

It will be seen, in the data presented below, that the number of fleas on the infested rats was very low and fairly uniform : about 1 or 2 fleas per rat. Thus the results could not be presented as percentage control since, even though the difference may be significant, the small sample sizes would result in the variances of the percentage control being very large. Accordingly, the tests of significance used were : (1) the p-q test with the addition of Yates's " correction for continuity "; and (2) Fisher's " exact test " for comparisons involving less than 5 rats in the smallest group.

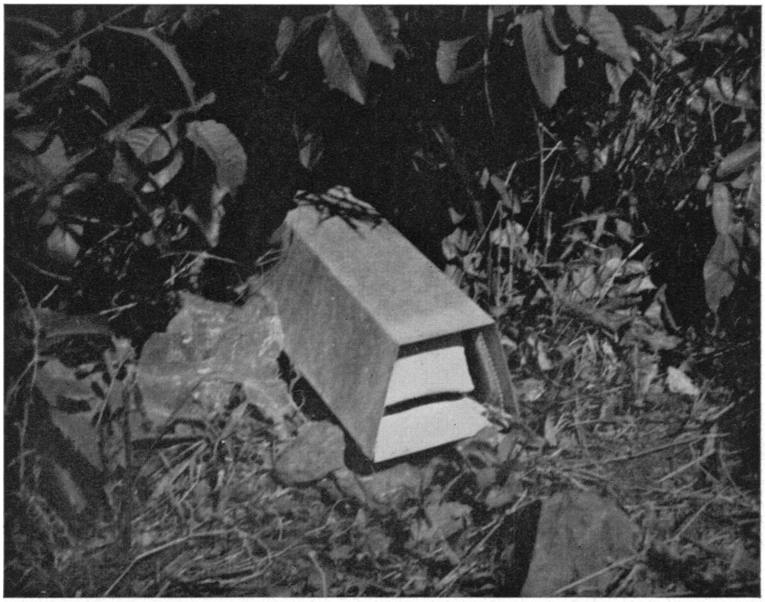
Data and Discussion

The generally low *Xenopsylla* indices on wild rats in the Hamakua District during the period under consideration should be noted in view of the fact that these studies are concerned with flea control (fig. 5). Eskey [6] presented data which showed that rat-flea indices can be correlated with the distance from habitations of the host habitat. Nevertheless, the *Xenopsylla* index on rats is apparently very sensitive to meteorological fluctuations, especially rainfall. This phenomenon, which was noted by Eskey,[6] is illustrated in fig. 5 in relation to the Hawaiian rat and flea. Thus tests on flea control in the field must be carried out over a long enough period to include significant changes in the flea index on rats.

The plague epizootic, indicated in fig. 5, occurred in another area of the plague region, but has been included to delineate the apparent relation of a dry period to a following rise in the flea index and an epizootic episode. It is of interest to note that the authors gave warning of a possible epizootic, on the basis of rising *Xenopsylla* indices in Kaunamano Gulch, over a month before the first plague-infected rat was found by the Territorial Plague Station in an area several miles away. Whether or not this constituted a mere coincidence is not known, since data on rat-flea indices in the epizootic area were not available to the writers. Furthermore, the general validity of observations on the relation of vector-flea indices to plague incidence remains a moot question.[19] At any rate, low numbers of fleas on wild rodents, although discouraging from the standpoint of flea-control analysis, may nevertheless be of critical importance to the ability of plague to transform from the enzootic to the epizootic form. If this is true in the Hamakua District, the first aim of a flea-control study should be to determine the feasibility of reducing the flea indices (or the indices of infective fleas) on wild rats to a level sufficiently low to prevent an epizootic.

The application of an average of about 0.3 g of 10% DDT powder directly to rats captured in Field 1 resulted in a difference from untreated rats of 9% for the *R. rattus* group, and of 18% for *R. hawaiiensis* with respect to the percentage of rats infested with the fleas, *X. vexabilis hawaiiensis* and *X. cheopis*. With respect to the mean number of fleas per rat, the indices for the controls and treated rats were respectively : *R. rattus* group, 0.20 and 0.13; *R. hawaiiensis*, 0.30 and 0.08. No data are available for *R. norvegicus* since none of these rats in the DDT test zone was captured more than once.

FIG. 3. METAL HOOD-TYPE DDT BAIT-BOX



A. End view of box in actual use

B. Box with hood removed, showing full DDT sacks and bait container with rolled oats.

FIG. 4. VEGETATION OF HAMAKUA DISTRICT, HAWAII

A. Typical deep gulch with dense vegetation

B. Shallow gulch with grassy slopes, trees, and volunteer sugar-cane

FIG. 4. VEGETATION OF HAMAKUA DISTRICT, HAWAII (continued)

C. Close-up of mature sugar-cane, showing difficulty of penetration

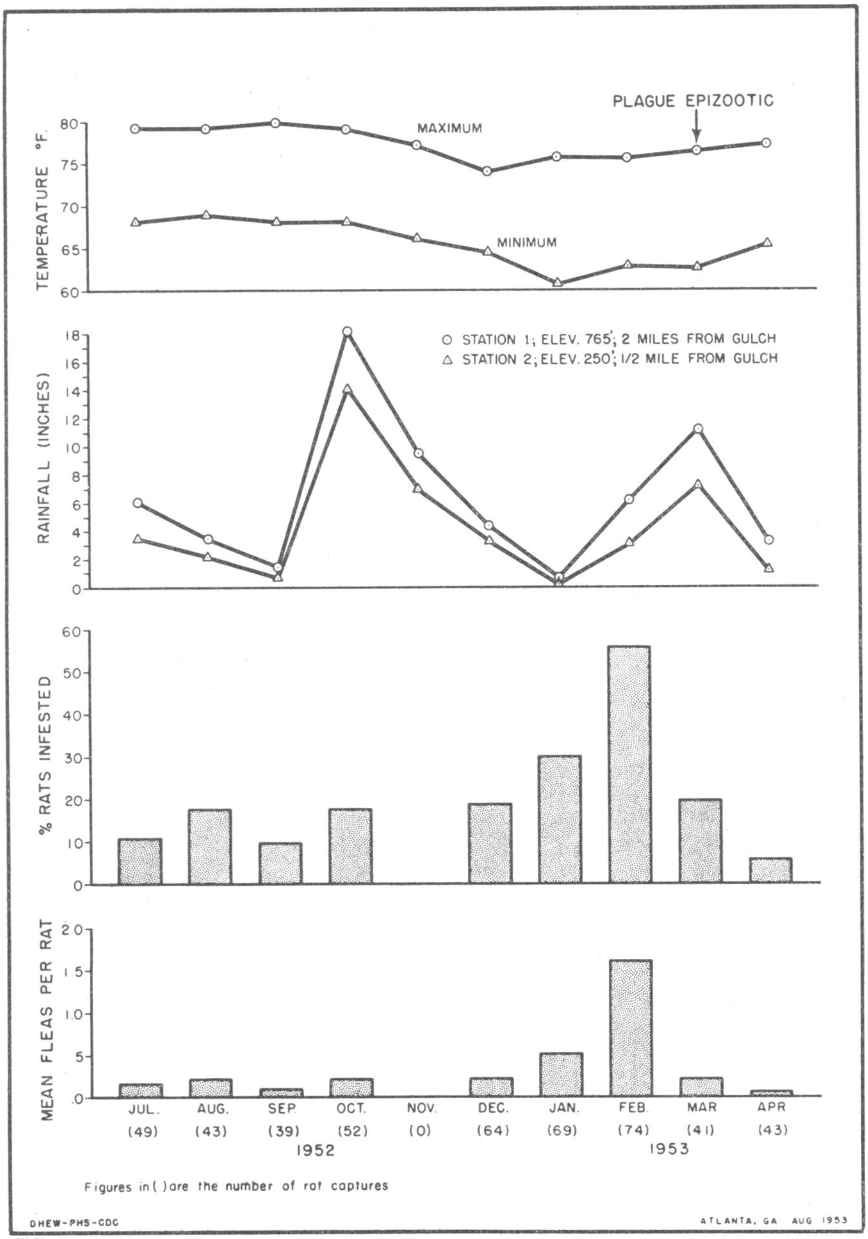
D. Bottom of deep gulch, showing areas exposed to and shielded from sunlight

FIG. 4. VEGETATION OF HAMAKUA DISTRICT, HAWAII (concluded)

E. Field of 6-month-old sugar-cane with ocean in background and mango trees along Kaunamano Gulch on the right

F. Avenue through maturing sugar-cane for lateral irrigation

FIG. 5. RELATION OF METEOROLOGICAL CONDITIONS TO INDICES OF XENOPSYLLA VEXABILIS HAWAIIENSIS ON RATTUS HAWAIIENSIS IN KAUNAMANO GULCH, HAMAKUA DISTRICT, HAWAII



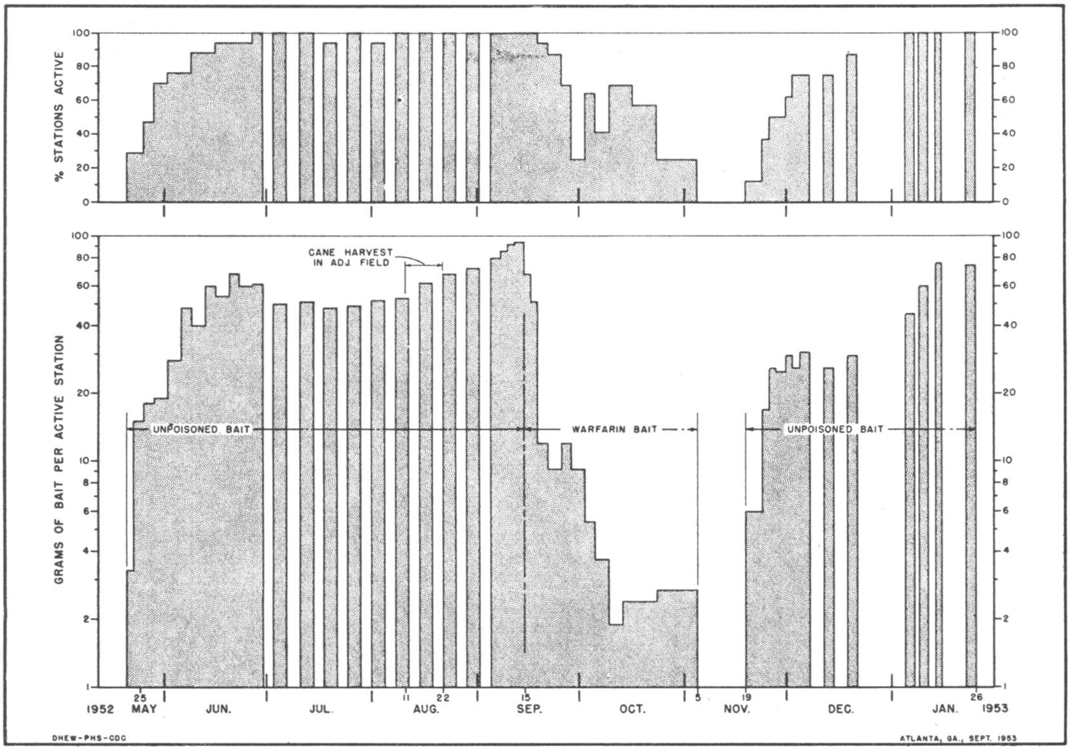
The observations in the gulch were made at an altitude of from 400 feet to 750 feet. The epizootic was detected in a field several miles from the gulch (see text on opposite page).

These results, although statistically not significant, suggested that the use of a bait-box combined with an insecticide-dusting device might prove of value in the field.

Field tests with the wooden DDT bait-box indicated that a high bait-consumption level was attained, but the commensal rat species were apparently the predominant populations feeding. These data are shown in fig. 6 and table I and are also confirmed by data on numbers of faecal pellets, which gave a rising curve directly correlated with bait consumption.

The Hawaiian rat is reputed to be a very timid species,[22] and artificial decimation of the competing commensal rat population has been reported to result in an increase in the number of snap-trapped Hawaiian rats.[9] Accordingly, warfarin-treated rolled oats, according to Doty's formula,[4] were substituted for the unpoisoned rolled oats, and this produced a sharp drop in the commensal rat population as indicated by a rapid decline in

FIG. 6. CONSUMPTION OF ROLLED OATS BY RATS AT WOODEN DDT BAIT-BOXES IN KAUNAMANO GULCH, HAMAKUA DISTRICT, HAWAII, SHOWING EFFECTS OF SUGAR-CANE HARVEST AND OF WARFARIN ON RAT POPULATION



The rats were mainly *Rattus rattus alexandrinus* and other subspecies of *R. rattus* ; 17 bait-boxes were used from 21 May to 5 November 1952, and 8 boxes were used from 19 November 1952 to 26 January 1953.

TABLE I. RATS CAPTURED IN KAUNAMANO GULCH FROM 1 JULY TO 23 OCTOBER 1952 IN RELATION TO WOODEN DDT BAIT-BOXES

Rat species	Total captures	At bait box (%)	Intermediate to bait box (%)
R. rattus group	104	69.2 (28.8)*	30.8
R. norvegicus	13	53.8 (15.3)	46.2
R. hawaiiensis	182	15.3 (2.1)	84.7

* Figures in parentheses show the percentage of rats captured in traps attached to the bait-boxes (see text, page 59).

bait consumption (fig. 6) and the finding of dead rats. However, this did not result in any significant increase in the numbers of Hawaiian rats feeding in the DDT bait-boxes. The withdrawal of the poisoned bait resulted in an increase of the commensal rat population almost to the pre-poisoning levels within a period of 2 months (fig. 6).

The control of rat fleas, as effected by the wooden DDT bait-boxes, also indicated that certain of the commensal species mainly were involved. As a matter of fact, flea control on the native rat was completely negative (table II). It should be noted that a statistically significant difference

TABLE II. FLEA* CONTROL ON RATS IN KAUNAMANO GULCH FROM 1 JULY TO 23 OCTOBER 1952 IN RELATION TO WOODEN DDT BAIT-BOXES

Rat species	Infested rats/ total rats		Fleas/total rats		P at 5% level **
	controls	treated	controls	treated	
R. rattus group	11/142	0/104	11/142	0/104	0.01 (significant)
R. norvegicus	18/56	1/13	22/56	1/13	0.14 (not significant)
R. hawaiiensis	48/331	29/182	60/331	36/182	0.76 (not significant)

* *X. vexabilis hawaiiensis* and *X. cheopis* are the only species considered in any of the tables.
** Comparison of infested rats to total rats

occurred with the *R. rattus* group but not with *R. norvegicus*. It is quite possible, however, that the data for the Norway rat would have been significant had the sample been larger.

The metal hood-type DDT bait-box proved to be promising when the bait consumption and rat captures were tabulated (tables III and IV). These data indicate that the hood-type bait-box attracted significant numbers of Hawaiian rats together with the commensal species. The effect of the hood-type DDT bait-box on wild-rat flea indices substantiates the

TABLE III. CONSUMPTION OF UNPOISONED ROLLED OATS IN TWO TYPES OF DDT BAIT-BOX IN KAUNAMANO GULCH

Date	Box type	Number of stations	Number of station nights	Grams of bait per station night
24.11.52 to 9.2.53	wooden (w/DDT)	8	344	42.6
24.11.52 to 9.2.53	control (no DDT)*	7	301	62.2
6.3.53 to 26.4.53	hood (w/DDT)	11	562	48.3
6.3.53 to 26.4.53	control (no DDT)*	7	364	61.5

* Conventional hood feeding-station.[3] In calculating the bait consumption at these control stations, the figures were adjusted by subtracting an average of 75 g per station night, since a study showed this to be the average of the daytime consumption attributed mainly to the Japanese hill robin, *Leiothrix lutea* (Scopoli). Evidence of food consumption by animals other than rodents in the DDT bait-boxes was not obtained.

impression that Hawaiian rats had fed and had been DDT dusted, since the control on this species was better than that on the commensal species (table V). When all species of rats are combined, there is a significant difference in the numbers of flea-infested rats in the controls and treated groups ($P = > 0.01$). However, this is obviously the result of the relatively large numbers of *R. hawaiiensis* in the treated group. Although, from the statistical standpoint, there appears to be a contradiction in the flea-control data for the *R. rattus* group as effected by the wooden box (table II) and the hood-type box (table V), it is suggested that the data on rat captures and bait consumption show this to be a mathematical inference rather than

TABLE IV. RATS CAPTURED IN KAUNAMANO GULCH FROM 3 MARCH TO 24 APRIL 1953 IN RELATION TO HOOD-TYPE DDT BAIT-BOXES

Rat species	Total captures	At bait box (%)	Intermediate to bait box (%)
R. rattus group	48	85.4	14.6
R. norvegicus	17	100.0	0
R. hawaiiensis	167	52.0	48.0
		With stained faeces *	
R. rattus group	22	95.4	4.6
R. norvegicus	12	100.0	0
R. hawaiiensis	53	75.4	24.6

* Stain added to bait before being placed in bait-boxes

TABLE V. FLEA CONTROL ON RATS IN KAUNAMANO GULCH FROM 3 MARCH TO 24 APRIL 1953 IN RELATION TO HOOD-TYPE DDT BAIT-BOXES *

Rat species	Infested rats/ total rats		Fleas/total rats		P at 5% level **
	controls	treated	controls	treated	
R. rattus group	11/109	1/48 (0/22)	12/109	2/48 (0/22)	0.16 (not significant) (0.24) (not significant)
R. norvegicus	14/40	2/19 (1/12)	16/40	2/19 (1/12)	0.09 (not significant) (0.15) (not significant)
R. hawaiiensis	11/84	7/167 (0/53)	13/84	8/167 (0/53)	0.02 (significant) (<0.01) (significant)

* Figures in parentheses refer to rats with stained faeces, i.e., to rats definitely known to have fed in the DDT bait-boxes.
** Comparison of infested rats to total rats

a biological one. The degree of flea control achieved in less than two months suggests that it may be possible to reduce the indices of *Xenopsylla* fleas well below the level deemed necessary for the spread of rodent plague in the field.[6]

Owing to the physical difficulties of excavating rat burrows in the gulch, only 20 of 67 burrows opened yielded intact nest material. However, some data were obtained which suggest that fleas were controlled in rat burrows within the zone affected by the hood-type DDT bait-boxes (table VI). In this connexion, it is of interest that many individuals of all rat species, recaptured after periods of one month or more, were still free of fleas. The home ranges of these rat species (to be reported upon elsewhere*) were apparently sufficiently restricted for a major portion of the population in the experimental area to contact the DDT bait-boxes, or the DDT spread from them, at some time or other. It is of interest to note that one nest, containing two *Rattus hawaiiensis* (see table VI), was found to contain the following by chemical analysis :

Nest material	112.6 g
Total DDT	0.720 mg
Total DDE	0.014 mg

The contents of other nests were not analysed.

The data presented here are preliminary and cannot be given conclusive interpretation. They suggest that a DDT bait-box, constructed along lines similar to the metal hood-type box described in this paper, may be of value in the field control of flea vectors of plague affecting all three species of rats in the Hamakua District, Island of Hawaii. Although no data have been presented here, there is some indication that fleas on the mouse, *Mus musculus*, can be controlled in the field with the DDT bait-box, since this species readily entered the boxes. Although the house mouse has been

* Kartman, L. & Lonergan, R. P. (1955) *Publ. Hlth Rep. (Wash.)*, 70 (in press).

TABLE VI. RAT ECTOPARASITES[a] FOUND IN BURROWS AND NESTS IN KAUNAMANO GULCH FROM 4 MARCH TO 17 MAY 1953 IN RELATION TO HOOD-TYPE DDT BAIT-BOXES

Rat species	Number of burrows [b]	Fleas		Mites		Rats found in burrows		
		mean number	nests infested (%)	mean number	nests infested (%)	number	with mean number of fleas	with mean number of mites
DDT bait-box test area								
R. rattus group	2	0	0	21.5	100	0	—	—
R. norvegicus	3[c]	0	0	8.0	100	2	0	3.0
R. hawaiiensis	4[c]	0	0	47.2	100	2[d]	0	0
Control area								
R. rattus group	1	29	100	40	100	2	0.5	10.0
R. norvegicus	2	19.5	100	36.0	100	4	2.2	1.0
R. hawaiiensis	11	27.0	100	44.0	100	11	2.0	4.5

[a] Fleas were predominantly *X. vexabilis hawaiiensis* with the exception of a pure culture of *Leptopsylla segnis* found in the nest of a Hawaiian rat in the control area and consisting of 47 adults, 7 pupae, 19 larvae, and 10 eggs. Mites were almost exclusively *Echinolaelaps echidninus* and *Laelaps nuttalli*.

[b] Most of the ectoparasites were taken from nest material in the burrows ; nests of the *R. rattus* group were taken from Kukui trees, *Aleurites moluccana*.

[c] One nest of a *norvegicus* and one of a *hawaiiensis* contained stained faeces.

[d] Marked individuals ; DDT found in nest (see text on preceding page).

found to be naturally infected with plague in the district, its epizootiological role is not known. It also should be noted that control of the rat mites, *Echinolaelaps echidninus* and *Laelaps nuttalli*, and the rat louse, *Polyplax spinulosa*, compared favourably with other control studies of these parasites.[23]

It is suggested that further testing of the DDT bait-box should be carried out by means of a large-scale demonstration in typical niches of the plague region; the investigation should be continued for at least one year, or for a period sufficient to include significant fluctuations in meteorological conditions and flea indices on field rats. Some of the tests should be conducted in wild areas known to be enzootic plague foci because of repeated epizootic outbreaks in the past, and it seems essential that concurrent checks for the presence of plague in wild rodents and their fleas must be a part of flea-control studies in any particular area chosen.

Some of the field tests reported here also have suggested that the DDT bait-box may be used for the control of commensal rat species by means of warfarin-treated baits. Thus the possibilities of utilizing such a bait-box in a combined operation of rat control and rat-ectoparasite control appear obvious and should be tested.

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RÉSUMÉ

En marge du programme d'étude d'épidémiologie de la peste à Hawaï, des recherches ont été entreprises en 1952 sur les techniques applicables à la lutte contre la peste des rongeurs sauvages, dans le district d'Hamakua.

La peste sévit dans une zone côtière de quelque 30 km de longueur et de 8 km de largeur. Elle est transmise principalement par deux espèces de *Xenopsylla* (*X. cheopis* et *X. vexabilis hawaiiensis*). On rencontre dans ce district quatre espèces de rongeurs : *Rattus rattus*, *R. norvegicus*, *R. hawaiiensis* et *Mus musculus*.

La zone d'enzootie pesteuse est située dans une région de végétation basse et dense et de champs de canne à sucre, où il est très difficile de repérer les terriers de rats pour y effectuer des fumigations ou des pulvérisations.

La méthode de lutte contre les puces, décrite ci-après, a été élaborée sur le principe suivant : mettre le rat en contact avec l'insecticide en pulvérisant sur sa fourrure du DDT dont il ira ensuite imprégner son terrier. Des boîtes à appâts, en bois ou en métal, ont été construites à cet effet. En y pénétrant, le rat déclenche un mécanisme par lequel la poudre de DDT, contenue dans un sac, est projetée sur son dos. Au sortir de la boîte, par un mécanisme analogue, il reçoit une seconde aspersion. Le DDT déposé sur le fond de la boîte imprègne au passage la fourrure du ventre et des flancs. L'appât est constitué par des morceaux de noix de coco ou des flocons d'orge.

Le nombre de puces trouvées sur les rats est très faible dans cette région. Il est cependans suffisant pour que l'enzootie pesteuse évolue en épizootie lorsque les conditions météorologiques s'y prêtent. Pour mettre au point une lutte contre les puces, il s'agit d'établir s'il est possible de réduire l'indice pulicidien à un niveau assez bas pour empêcher une épizootie.

La comparaison a porté sur le nombre de rats — témoins et traités — infestés par les deux espèces de *Xenopsylla* précédemment mentionnées et sur l'indice pulicidien. On a constaté une différence de 9% entre l'infestation des *rattus* témoins et celle des *rattus* traités, et de 18% entre celle des *hawaiiensis* témoins et traités. Quant au nombre de puces par rat, il était de 0,20 pour les *rattus* témoins et de 0,13 pour les traités ; ces chiffres étaient respectivement 0,30 et 0,08 chez les *hawaiiensis*. Ces résultats, bien que n'étant pas statistiquement significatifs, indiquent pourtant que l'emploi d'une boîte à appâts avec dispositif pour la pulvérisation de DDT peut avoir une valeur appréciable dans la lutte contre les puces. La diminution du nombre des *Xenopsylla* dans la zone expérimentale, après une action de deux mois, permet d'espérer que l'on pourra abaisser l'indice pulicidien à un niveau inférieur à celui qui est nécessaire à la propagation de la peste des rongeurs sauvages.

Les auteurs proposent que ce procédé de destruction soit appliqué pendant une année au moins dans d'autres endroits de la région où des poussées épizootiques ont été maintes fois signalées. D'autre part, en munissant les boîtes d'appâts empoisonnés à la warfarine, on pourrait combiner la destruction des rongeurs commensaux à celle de leurs ectoparasites.

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