PLAGUE IN PARADISE

A STUDY OF PLAGUE ON HAWAIIAN SUGARCANE PLANTATIONS

by

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The third pandemic of bubonic plague menaced the whole globe for more than a century and claimed the lives of more than thirteen million people. In the twentieth century, plague reached America for the first time, arriving on the Hawaiian archipelago in 1899. By 1910, a rural form of plague known as sylvatic plague, characterized by persistent enzootic infections and intermittent human contraction, became firmly established in the Hamakua District of Hawaii's Big Island. This area's economy and society was dominated by sugarcane plantations, which worked closely with public health authorities in combating the plague pestilence. Plantation doctors participated in administering evolving plague treatments, while other leaders tried various methods of vector and reservoir control. These efforts largely amounted to a massive anti-rodent campaign, waged in the fields of the sugarcane plantations. Rat control experts tried trapping, poisoning, and other methods, but most attempts proved to be ineffective in halting plague entirely. The last case of human plague in Hamakua occurred in 1949, and enzootic plague disappeared somewhat mysteriously in 1959. In total 112 Hamakua residents caught the disease, 109 of whom perished.

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Introduction

Bubonic Plague claimed its first Hawaiian victim when You Chong, a Chinese bookkeeper, died on December 12, 1899 in Honolulu.[1] The pestilence continued to ravage the territory's capital and the island of Oahu, spreading to the local plantation villages of Aiea and Waialua in 1902. While the last case of plague on that island occurred in 1910, the disease had already spread to the neighboring islands of Kauai, Maui, and Hawaii. The latter is also known as the Big Island, as it is physically the largest and second in importance. Plague first arrived there at the port city of Hilo on the windward side of the island. By 1912 Hilo had experienced 25 confirmed cases of plague, and the peripheral Olaa, Papaikau, and Pepeekeo sugar plantations reported an additional 16 cases by then. As in Honolulu, however, plague disappeared from the urban center of Hilo without explanation, the last case occurring in 1913. But plague arrived and remained virulent 65 km north of Hilo in the rural Hamakua District. Honokaa, the chief village of that sector, had reported its first case in 1910. Among the sugarcane plantations of Hamakua, plague found a home. From 1910 to 1949, 112 people caught the disease, 109 of whom succumbed to it.[2]

Plague is primarily a disease of rodents, and only rarely jumps to the human population. Historically, on three violent occasions plague has made the jump and caused epic death in pandemic form. The Plague of Justinian in the sixth century, the Black Death of the fourteenth, and finally the longest and most deadly Third Pandemic that struck Hawaii. This last pandemic originated in Southeast Asia in the latter part of

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[1] James Mohr, *Plague and Fire: Battling Black Death and the 1900 Burning of Honolulu's Chinatown* (New York: Oxford University Press, 2005), 38.
[2] Quentin P. Tomich, and others, "Evidence for the Extinction of Plague in Hawaii," *American Journal of Epidemiology* 119, no. 2 (1984): 264.

the nineteenth century, and spread across the Pacific from there. In contrast to the first two pandemics, this third pandemic spanned a whole century, relentlessly attacking cities all over the globe. It was the first time the disease reached North America, and by the end of it all, more than thirteen million died.[3] Between the three major pandemics, human plague was mostly dormant, although occasional epidemics broke the quiescence. In reality, plague was always present, living actively in enzootic animal populations. The bacteria *Yersinia pestis* causes plague, which comes in three forms: bubonic, pneumonic, and septicemic. Bubonic is by far the most common form. Bubonic plague occurs in humans only after a flea bites a diseased animal, ingests the bacteria, and then bites a human, thus spreading the infection. This is the root cause of all plague epidemics, as the pneumonic and septicemic forms typically spawn from some bubonic cases.

The Hamakua District of Hawaii was perfectly suited to become an enzootic plague focus. Ample food sources and dense harboring vegetation supported an abundant reservoir rat population. These Hamakua rats were also infested with the necessary large and diverse flea population. When plague is found in rural areas like Hamakua, only occasionally spreading to humans, it is known as sylvatic plague, but it is in no way physiologically different from the urban variety. The term meaning 'woods' or 'wild country' "was adopted to differentiate plague in the filed rodents from which few human cases are contracted, an that from domestic rats from which a greater number of human cases have been and are apt to be contracted."[4] Hamakua was perfectly rural, dominated almost entirely by the large sugar plantations that controlled nearly all the land and commerce. The plantations owned the stores, constructed the village camps, supplied the

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[3] Charles T. Gregg, *Plague!: The Shocking Story of a Dread Disease in America Today* (New York: Charles Scribner's Sons, 1978), 12.
[4] N.E. Wayson, "Plague," *American Journal of Nursing* 42, no. 3 (1942): 289.

education, and provided for all the area's healthcare needs. These businesses therefore carried the responsibility to protect themselves and their employees when plague struck. A few managers ran the operations, and the majority of the population consisted of laborers working on the plantations. As a service to the residents, and to maintain their labor supply, the plantations owned and operated local hospitals, staffed with their own plantation physicians. As plague persisted in Hamakua in the twentieth century even after disappearing everywhere else on the islands, these doctors became the only people for thousands of miles around gaining any experience in treating the dreaded disease. Hawaii was uniquely isolated and so leaders constantly had to solve their own problems. The Territorial Board of Health helped carry some of the burden. Plantations and governments worked together in forging anti-plague campaigns.

This paper seeks to describe the conditions under which plague developed in Hamakua, and evaluate the methods that concerned authorities used to fight it. Essentially these people faced excessive challenges in combating plague, and so it persisted for four decades there. Different attempts to treat plague on all biological levels succeeded and failed to varying degrees, and in the end, a combination of these factors seems to have finally eliminated the disease in 1949. Much of the research is based on contemporary epidemiological studies and articles explaining methods of rat control. Some secondary sources are cited, as well as primary local Hawaiian newspapers. This paper would not have been possible without the use of the Hawaiian Sugar Planters' Association (HSPA) Archives, which are located in the University of Hawaii at Manoa's Hawaiian Collection.

Living With The Plague

Hamakua: Ripe for Infestation

The Hamakua District on the island of Hawaii[5] is one of nine such separations on that island. Within the district, the plantation village of Honokaa was the major plague focus. The "infection is postulated to have come via steel cable landings along this rugged coast" from Hilo, which lies 65 kilometers southeast.[6] Spreading out from this locality, both wild mammal and human cases of plague were found along the coastal region of Hamakua in different plantation camps and fields. The area where plague surveillance activities occurred was "approximately 3 to 5 miles wide, extending from the village of Ookala, located 32 miles northwest of the port of Hilo, to Waipio Valley 20 miles beyond Ookala."[7] Essentially plague conveniently remained confined to the physical borders of the Hamakua district proper, as the district boundary near Laupahoehoe served as a virtual plague border to the south and the Waipio Valley was a barrier to plague movement in the north. While plague moved freely in its narrow corridor, it was "unable to spread to wetter lands toward Hilo, to high elevations, or to the rugged Kohala Mountain region beyond the Waipio Valley."[8] This narrow strip was bordered by the Pacific Ocean to the east, and the slopes of Mauna Kea on the west. Concerning the 112 total Hamakua cases of human plague, "108, or 96.4 percent, occurred below an elevation of 1,500 feet where approximately 90 percent of the people in this region reside or work. The remainder (3.6 percent) occurred at elevations between 1,500 and 2,000 feet." Similar numbers exist for rodent plague in Hamakua, where of the

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[5] See Appendix A.
[6] Tomich 264.
[7] Bertram Gross and David D. Bonnet, "Plague in the Territory of Hawaii I: Present Status of Plague Infection, Island of Hawaii," *Public Health Reports* 66, no. 6 (1951): 211.
[8] Tomich 272.

1,145 known cases, 1,120 (97.8 percent) occurred below 1,500 feet and the remaining 25 or 2.2 percent were found below 2,000 feet.[9] This area and elevation coincided with the bulk of Hamakua's human population, meaning that the location ripe for sylvatic plague also had at-risk humans. The mean annual temperature in this region is 73°F. The fact that the slope of Mauna Kea is so steep accounts for the narrowness of the plague zone. The slopes come down sharply to near vertical cliffs, and many gorges and gulches twist down to the water. In addition to the common guava shrub, "the gulches abound with Kukui trees, banana, mango, some papaya, various berries, many species of fern, and a variety of grasses, sedges, and herbs."[10] These gulches were difficult to access, and afforded rodents with ample food and harborage year round. Gulches became especially important in providing rat refuge at harvest time, when they instantly fled the barren fields.

Every district of the Big Island has its own unique climate, and it was partially these distinctive weather conditions that led to plague prevalence in Hamakua. On the windward side of the easternmost island, Hamakua boasts heavy enough rainfall to allow for dense vegetation and therefore rat abundance. The fleas, however, seemed to prefer dryer weather, so those districts receiving excessive rain never became plague foci. C.E. Pemberton proposed a theory stating that districts with frequent heavy rains and irrigated plantations have a tendency to drown litters of young rats. However, he believed rat abundance to be more related to the availability of safe harboring in "gulches, rock piles, permanent waste areas and grass, weeds, shrubs, cover crops, etc.," as well as

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[9] Gross 213.

[10] Leo Kartman and Richard P. Lonergan, "Wild-Rodent-Flea Control in Rurual Areas of an Enzootic Plague Region in Hawaii," *Bulletin of the World Health Organization* 13 (1955): 51.

corresponding proteid food availability.[11] Difficultly existed in determining exactly what the relationships were between climate, rodent, flea, and plague prevalence. Clearly, the Hamakua District had the right combination to become a plague focus. The rain of Hamakua facilitated a general abundance of rats, and the flea population occasionally swelled during periods of dry spells. In a March 20, 1926 letter written to the parent company on Oahu in regards to three recent plague deaths, P. Bartels, Assistant Manager of the Honokaa Sugar Company, demonstrated contemporary knowledge of this phenomena: "These cases did not surprise us, as with continued dry weather the plague condition in the Hamakua District is always aggravated." Two days later in response, Owner Frederick A. Schaefer hoped for much needed rain to alleviate the problem.[12] With progressing contemporary knowledge of the correlations between precipitation and plague, plantation officials in Hamakua were able to anticipate outbreaks, and therefore respond more efficiently. Likely, such constant vigilance and comprehensive responses helped stop a general epidemic.

In 1934, C.R. Eskey of the United States Public Health Service (USPHS) conducted a detailed epidemiological examination of plague in Hawaii. As part of this study, Eskey published the seasonal prevalence of plague for every focus. He found that 40 percent of all Hamakua plague cases occurred during the months of July, August, and September. Furthermore, he showed that "77 percent of infected rodents found in the Hamakua district were discovered during the summer and fall months." Such information was of course valuable to plague fighting authorities, who then knew when to

[11] C.E. Pemberton, "The Field Rat in Hawaii and Its Control," *Bulletin of the Experiment Station of the Hawaiian Sugar Planters' Association: Entomological Series*, no. 17 (1925): 14.
[12] Hawaiian Sugar Planters' Association (HSPA) Plantation Archives, University of Hawaii at Manoa Library Hawaiian Collection, HSC 11/2 F.A. Schaefer & Co. In & Out - 1926.

increase their vigilance. Nevertheless, rainfall in Hawaii was rather consistent throughout the seasons, facilitating inconsistency yet constant presence of plague. Therefore, although plague appeared more commonly in the dryer summer months, it occurred in all other seasons as well. The Hilo, Kohala, and Puna districts had too much rainfall to allow sylvatic plague. "The persistent rural type of plague found in Hamakua has not been discovered in sections of this district having an average annual rainfall in excess of 100 inches, nor in any of the other foci on the island of Hawaii, all of which have a precipitation exceeding this figure," Eskey stated.[13] Climatic conditions made the Hamakua District a prime location for enzootic plague.

The Victims: Facing Death

In the 39 years that plague afflicted the Hamakua District, from 1910 to 1949, there were 112 reported cases with 109 deaths. A simple calculation reveals the reported mortality rate therefore to have been over 97 percent. Unfortunately, because little has been written on plague in Hamakua, and because no comprehensive examination has been conducted to date, these victims lost to the dreaded scourge remain largely anonymous. Dr. Clarence Lamar Carter was a plantation physician for the Honokaa Sugar Company and the Paauhau Sugar Plantation for 35 years, and he personally attended to more of these cases than anyone else did.[14] Dr. Carter believed that the plague mortality rate was not actually so high. He felt that some cases that recovered could not meet the Territory's rigorous plague confirmation standards. These cases went unreported as official. He complained, "I have had quite a number of cases that were clinically typically plague but in which I was unable to get a biopsy of the glands, so that

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[13] Eskey, C.R. "Epidemiological Study of Plague in the Hawaiian Islands." *Public Health Bulletin* no. 213 (October 1934): 10.

[14] Mamiya Medical Heritage Center, *Clarence Lamar Carter*, http://hml.org/mmhc/mdindex/cartercl.html.

the Board of Health could not accept them as bubonic plague."[15] Board of Health regulations required positive results (death) of a guinea pig inoculated with serum taken from the suspected plague victim. Dr. Carter did not disagree with these methods as a means to prevent misdiagnosis, but as a prominent de facto plague expert he best understood the reality of the plague situation in Hamakua. Additionally, some plague cases where death occurred were likely not officially recorded because of lab inoculation errors, physician misdiagnosis, or deaths occurring outside of a physician's care. Therefore, in actuality more than 112 people caught plague in Hamakua, and the official mortality rate was probably too high. Regardless, the stories of these victims deserve to be heard.

The search to find names of the victims and personalize the plague deaths was not an easy task. The hunt began at the Hawaiian Sugar Plantation Association Archives at the University of Hawaii at Manoa Library, where documents from the Honokaa Sugar Company shed some light on the victims' stories. Communication between the plantations and the parent company, as well as correspondence with Board of Health officials documented plague cases and revealed reactions, as did some newspaper stories.

Board of Health plague reports often merely stated the date and maybe the location of the death. Then at other times information such as gender, occupation, age, nationality, and type of plague were disclosed. The reports were inconsistent in their information, and only occasionally listed the name of the plague patient. A typical example of one of the more complete reports read, "Sep. 23, 1919, Kukaiau Plantation, Kunyoki Camp Japanese Male, Stableman, Kukaiau Stables, Bubonic."[16] That report

[15] C.L. Carter, "Bubonic Plague on the Island of Hawaii," *Hawaii Medical Journal* 2, no. 6 (1943): 298.
[16] HSPA Archives, HSC 22/14 T-Z Correspondence - 1910-1919.

came in a letter from D.S. Bowman, Chief Sanitary Inspector, Island of Hawaii, addressed to Mr. W.P. Naquin, Manager of the Honokaa Sugar Company. Unfortunately, these busy men often did not choose to record more biographical detail, or even to disclose names. They merely chose to reveal basic demographical statistics. Possibly, the predominantly non-white laborers were production assets more than respected individuals. Especially in the earlier years of the plague epidemic, when cases were common and treatments essentially nonexistent, only details relevant to the future prevention of cases were recorded. Perhaps naming the victims or listing surviving kin simply were not essential to plantation business.

Newspapers published in Hilo and Honolulu also revealed some information that personalized these plague deaths. Even newspaper articles, however, often failed reveal more personalizing information. An article titled "Big Isle Girl Dies of Bubonic Plague," stated, "Jan. 27 – A 12 year old girl died of bubonic plague in the Hamakua district, Dr.. Leo Bernstein, health officer, has announced."[17] Another article reported, "The plague claimed the life of a 14-year-old boy of Japanese descent May 3, Dr. Haralson [Territorial Commissioner of Public Health] said."[18] In these two instances, personal information such as names may have been withheld because the victims were minors. Nevertheless, such information was frequently absent, indicating a general indifference for mourning the deceased in favor of focusing on future public health prophylaxis.

Nevertheless, to give some order to this epidemic, here are the known dead:

Date Deceased (became ill)	**Name**
July 4, 1922	Dan Kapela
July 7, 1922	Kichigi Miwa
August 1, 1922	Isau Murakami

[17] *Honolulu Star-Bulletin*, "Big Isle Girl Dies of Bubonic Plague," January 27, 1944, pg. 7.
[18] *Hilo Tribune-Herald*, "Hamakua Has 4th Plague Death," May 11, 1943, pg.1.

September 2, 1922	Bernaldo Bolongon
September 9, 1922	Pilipe Bolongon
October 20, 1922	Antone Pedro Benevedes
September 27, 1924	Pedro Monton
July 26, 1929	Pastor Molina
July 27, 1929	Sabastian Gargarin
July 30, 1929	Eugenio Gargarin
August 4, 1929	Victoriano Alpara (recovered)
February 13, 1932	Victoriano Domingo Apaoa
February 24, 1932	Francisco Abon
March 5, 1943	Seigo Matsunaga
April 11, 1943	Nancy Kauai
April 23, 1945	Anacleto Realin (recovered)

Even when the victims were named, officials rarely gave much more insightful information besides mere demographic data. A letter from Assistant Chief Sanitary Inspector Joseph S. Caceres to Naquin told of perhaps the youngest plague victim, Isau Murakami, Japanese female, who was only 2 years, 7 months, and 18 days old on the date of her death.[19]

The case of Pedro Monton received considerably more attention than the average in one Territorial Board of Health plague report letter. C. Charlock, Chief Sanitary Inspector wrote the notification on October 2, 1924. Mr. Charlock reported the death of the 38-year-old Filipino male "with regret," and included details of the case. Pedro Monton had come to the Territory about ten years prior to his death. Mr. Charlock reported the case:

> He worked in a cane field mauka[20] of the Government Road, about one mile West of Paauilo Village from September 1st to September 7th. On September 8th to September 19th he worked in the mill, Hamakua Mill Co. On September 20th he complained of feeling "a little sick" with headaches and aches all over his body. Dr. Christensen was called on September 24th. The next day the patient was found to have beginning pneumonia. On September 26th, pneumonia had developed; an indurated swelling was noticed on the inner aspect of the right thigh, just above the knee. Also a

[19] HSPA Archives, HSC 23/3 General Correspondence In & Out – 1921-1922.
[20] Mauka – Towards the mountain.

> small indurated swelling had appeared underneath the right eye-brow. On September 27th he was removed to the Hamakua Mill Co.'s hospital and isolated. The swelling on the right thigh had increased in size to about that of a hen's egg and showed signs of softening. The swelling of the forehead had increased in size, but was still indurated. There were perceptible enlargement of the glands of the right side of the neck and palpable glandular enlargement in both groins.

Mr. Charlock went on to describe how Dr. Christensen informed District Inspector W. P. Jelf of the plague possibility by telephone at 11:05 A.M. on September 27th. He moved the case to Paauilo Hospital for isolation, and then sent specimens on the 2:30 train bound for the Hilo plague laboratory. The blood smears were examined and proved morphologically positive for plague, and two guinea pigs were inoculated with the specimens; one cutaneously and the other subcutaneously, each with 2 cc of blood emulsified in normal saline solution. Then, as was typical with plague suspicion, District Inspector Jelf ordered immediate prophylaxis, including the employment of up to four additional rat catchers in the suspected plague focus. Pedro Monton died that same day at 11 P.M., and the lab used post mortem specimens to inoculate another guinea pig, which died of plague five days later on the date of Mr. Charlock's letter.[21] Although Board of Health officials described this case in greater detail than most, we have no reason to assume that Pedro Monton's was otherwise atypical. Mr. Monton was an immigrant plantation laborer like the majority of victims, so his experience was representative.

The archives at the Hawaiian Sugar Planters Association are full of similar correspondence regarding plague, especially in the 1920s. The letters are primarily between plantation management and Board of Health officials. Because Honokaa was the largest village and primary plague focus, the Honokaa Sugar Company (including the Pacific Sugar Mill subsidy) folders contain the richest documents regarding plague in

[21] HSPA Archives, HSC 23/8 General Correspondence In & out – 1924.

Hamakua. W.P. Naquin, Manager; P.H. Bartels, Assistant Manager; J.W. Waldron, President, and others from parent company F.A. Schaefer & Co.; and Dr. C.L. Carter, plantation physician, composed this company's correspondences regarding plague. They wrote such letters typically in response to communication from different Board of Health administrative officers and bureaus such as the Bureau of Sanitation and the Bureau of Rodent Control. Officers included Dr. F.E. Trotter, President; D.S. Bowman and C.Charlock, Chief Sanitary Inspectors; B.J. McMorrow, Administrative Officer, Island of Hawaii; and Joseph S. Caceres, Assistant Chief Sanitary Inspector. In the correspondence, the Board of Health made general notifications of plague rats trapped and found dead, and of cases of human plague, anywhere in the Hamakua district. The Board also enforced sanitation policy and conducted plague control campaigns, which left a paper trail found in plantation correspondence archives as well. The Board of Health sent such records of their activities to numerous interested parties. In the above-mentioned letter concerning Pedro Monton, Mr. Charlock lists the various recipients. These included the *Hilo Tribune-Herald*, four plantation physicians, the Hilo Shippers Warf Committee, five plantation businessmen, and District Inspector Jelf.

In order to make sense of the plague situation and to satisfy epidemiological curiosity, the Board of Health searched for connections between plague cases. Following the case of Pedro Monton, President F.E. Trotter of the Board of Health personally went searching through incidences of confirmed rodent plague in the area. "In looking for a possible source of infection in this case, I find on September 6th, there was a rat trapped in field 17, about ¾ of a mile makai of the Government Road, 1,000 feet makai[22] of the

[22] Makai – Towards the ocean.

seashore and about ½ mile west of the Hamakua Mill."[23] Considering the two weeks between these instances and the short incubation period of plague, it is not likely that Mr. Monton died from direct contact with that plague rat, but rather from a related case of rodent plague in that epizootic.

In July of 1929, an interesting little epidemic allowed for the drawing of epidemiological conclusions. The epidemic involved a series of three related cases. The first case was Pastor Molina, who died on July 26, and whose death was confirmed to be bubonic plague after an autopsy and after a guinea pig that had been inoculated with postmortem material died on August 1. The following day Sabastian Gagarin succumbed to plague, and three days later, on July 30, Eugenio Gagarin died. C. Charlock reported both cases to be bubonic and confirmed plague by animal inoculation (in a letter to Naquin dated August 3, 1929). While we can infer that the latter two victims were kin, we unfortunately do not know just how, as the documents fail to say. Although it was rare for the Board of Health to write greater than two letters regarding a given plague case (generally one to report suspicion of plague and a second to confirm diagnosis via animal inoculation), this case warranted an additional supplement. From Charlock's July 29 supplement: "I wish to state that shortly after the Filipino in question (Pastor Molina) was considered suspicious three more of the inmates of Camp 2K developed temperatures and were promptly isolated in the Hamakua Mill Co. hospital at Paauilo." The two Gagarins were among the three suspicious Pastor Molina contacts, while the third case remains anonymous but was not plague. Sabastian Gagarin was a 21-year-old Filipino male, but similar demographics of his probable relative Eugenio were not disclosed.[24] Of

[23] HSPA Archives, HSC 23/8 General Correspondence In & out – 1924.
[24] HSPA Archives, HSC 29/1 Miscellaneous Letters In & Out – 1929-1930.

course as with all epidemics of bubonic plague, it is nearly impossible to tell exactly how these three deaths were related. Because it was impossible for the bacteria to spread directly from Pastor Molina to either Sabastian or Eugenio Gagarin without the presence of a flea vector (all three cases were bubonic), it is equally likely that the latter two victims caught the plague after an encounter with a plague carrying rodent. Regardless, this epidemic was recorded and closely monitored by public health authorities, who considered it important and worked to effectively halt its spread.

However, known cases of plague normally were not linked with one another. Primarily because of the watchful vigilance of the Board of Health, coupled with quick sanitation efforts to stomp out epizootic plague outbreaks, but also because of the sylvatic nature of Hamakua plague, outbreaks in the human population were necessarily sporadic. Immediate quarantines and house-to-house inspections for new cases effectively halted epidemics. The infrequent and somewhat unpredictable occurrences, even after long spells of quiescence, served to confuse and frustrate plague authorities. J.W. Waldron, F.A. Schaefer & Co. President, expressed this confusion well on March 20, 1927:

> We regret very much to learn that you have had a fatal case of bubonic plague at Honokaa, - a Portuguese being taken ill with it on Saturday night and succumbing to the disease on Tuesday night. The way the Hamakua district, - from Waipio Valley to say Ookala, - remains an area of infection for this sickness is certainly a mystery. In some way the plague seems to hide itself for months and then, from its concealed hiding place, suddenly strike someone down. It is very difficult to explain (in fact impossible to do so) why we have been able to rid Honolulu, Kahului and Hilo of this dread disease and yet have been unable to rid the Hamakua district of it.[25]

Such feelings are understandable, because human effort to halt plague was equally (sometimes more) intense in these compared locations. Everywhere in Hawaii where plague appeared, it eventually disappeared without a wholly reasonable explanation,

[25] HSPA Archives, HSC 11/9 F.A. Schaefer & Co. In & Out – 1927.

including eventually in Hamakua. G.E. Schaefer, Vice-President and Treasurer for F.A. Schaefer & Co., expressed a calmer attitude in regards to the surprise appearance of one case. "It seems to the writer that this is the first case in quite some time, and we presume it is just another of those that seem to crop up every so often without any special reason, and that there is no unusual circumstances surrounding this particular case," Schaefer stated in a March 3, 1932 letter.[26] While some allowed the elusive nature of plague to bother them more than others, the intermittent problem was carefully and consistently addressed over the course of four decades.

Leave it to the Experts: Treatment and Prevention

Plantations played a primary role in the treatment of plague cases. In the Hamakua District, the plantations essentially held a monopoly on healthcare, as their hospitals served as the only medical institutions. Essentially each plantation built their own small, well-equipped hospital that they staffed with a plantation physician. In 1936 there were 26 such hospitals serving 48,200 plantation employees.[27] Medical benefits for plantation employees (a majority of the district's population) were very generous, as these services cost little to nothing. A 1911 newspaper article commending plantation health efforts revealed, "Practically every plantation in the islands [has] a physician whose services are free to the laborers."[28] In fact, the plantation doctors, working on salary, provided free services up until the general strike of 1946. After this year, negotiations between the HSPA and the International Longshoremen's and

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[26] HSPA Archives, HSC 15/12 F.A. Schaefer & Co. In & Out – 1932.
[27] Charles S. Judd Jr., "Plantation Health," *Hawaii Medical Journal* 41, no. 4 (1982): 118.
[28] *Hilo Tribune*, "Plantation Men Are Complimented," December 12, 1911, pg.1.

Warehousemen's Union (ILWU) occurred on a plantation-by-plantation basis.[29] The typical healthcare arrangement provided that employees earning less than $100 per month automatically received free care, while those earning more were charged discounted fees on a progressive scale. Plantations extended healthcare rights to families of employees also.[30] Furthermore, in regards to the plague situation specifically, those in power (territorial authorities and plantation management) certainly found it in their best interest to treat the disease thoroughly and completely. Because of the public health element, plague patients received the best possible care without having to worry about the bill (morbidly, most patients did not live to see the bill anyway).

The year 1922, with twelve plague deaths, constituted the worst plague year of any in the endemic period. Plague victims received increased attention after that catastrophic year. Vowing not to repeat the same plague-facilitating mistakes, President F.E. Trotter ordered an increase in plague vigilance. In a letter to Dr. Carter dated August 13, 1923, Trotter instructed the plantation physician to be on a special lookout for the disease. He ordered that all suspicious cases be isolated in the plantation hospital, and "Any case that might be considered suspicious of plague which is not connected with the plantation should be placed in the hospital and a bill rendered to this office through the Chief Sanitary Inspector, Hilo."[31] It was assumed that cases involving plantation employees would be covered by the plantations.

Treatments for bubonic plague evolved throughout the endemic plague era in question. Upon suspicion of plague, the first step taken was always to isolate the case,

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[29] Lela M. Goodell, "Plantation Medicine in Hawaii 1840 to 1964: A Patient's Perspective," *Hawaii Medical Journal* 54, no. 11 (1995): 787.
[30] "Plantation News," *Hawaii Medical Journal* 1, no. 1 (1941): 41.
[31] HSPA Archives, HSC 33/10 Rat Poison Correspondence – 1922-1927.

and increase preventive efforts. Certainly, prevention of plague was the most valued tool at authorities' disposal. In the early years of the plague infections, victims had little resources for treatment or hope for recovery. With extremely high death rates, doctors may have seemed and felt almost as helpless as their medieval counterparts, but in actuality the third pandemic was an era of dynamic change in the treatment of plague. For this pandemic, for the first time in the devastating history of plague, health authorities had the advantage of new epidemiological knowledge. With the identification of the *Yersinia pestis* bacteria, along with an understanding of the corresponding rodent reservoirs and flea vectors, public health authorities took prophylactic steps to limit the number of cases. For the unfortunate victims, early recognition and treatment were crucial to possible recovery, although treatments lacked hardly and efficacy for many years. Plague serums and vaccines existed soon after bacteriological isolation of plague, and these treatment forms evolved with continued research. The treatment of plague, nevertheless, remained limited (essentially hopeless) until the introduction of antibiotics in the 1940s.

Yersin's serum was an early treatment measure available to Hamakua doctors, which has limited efficacy. Developed by Alexandre Yersin, discoverer of the plague bacillus (he of course shares the honor with Shibasaburo Kitasato), this serum constituted the first attempt at treatment at the bacteriological level. The archives of Honokaa Sugar contain a confidential report dated December 21, 1918 by the Bureau of Medicine and Surgery, Department of the Navy, offering instructions to their medical officers regarding plague treatment. The naval doctors claimed that when used early and in large amounts, Yersin's serum could reduce the case fatality rate by about 15 percent. "The serum is strong in bactericidal action but weak in antitoxic properties. The bacillus produces an endotoxin, which is only liberated when the organism has been destroyed. The serum therefore destroys the plague bacilli, liberating a large amount of toxin, against which it exerts but relatively light antitoxic action."[32] Although Hawaiian physicians used Yersin's serum, the high mortality rate indicated the general ineffectiveness.

Nevertheless, the serum was part of the great bacteriological revolution, giving more hope to patients and providing a foundation for future success. Yersin's serum was prepared by repeated inoculations of a horse with living plague bacilli, at set intervals, from six months to a year. The preparer then bled the horse, and separated the serum from the clot. Lastly, inoculation of a mouse confirmed that no living bacilli remained.[33] Allegedly, when given to a patient soon after infection, the serum could confer temporary immunity, perhaps up to 10 days. Robert Lindsay, Manager for the Hamakua Mill Company wrote a letter to the Messrs Board of Directors regarding the treatment of a plague case, dated October 19, 1922. The company employed the Portuguese man in locomotive repair work, and found him infected during a house-to-house inspection campaign that was instituted after a plague rat was found. Mr. Lindsay reported, "100 c.c. of Plague Serum was injected into him Tuesday morning, 60 c.c. yesterday and today we are glad to report that his temperature is down from 104 to 100 and his pulse is steadier and we are hopeful now of his recovery if this is so."[34] Although the effects of Yersin's serum were limited, they were an important improvement and played a role in treating cases of plague in Hamakua.

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[32] HSPA Archives, HSC 33/10 Rat Poison Correspondence – 1922-1927.
[33] *Encyclopedia Britannica*, 11th ed., s.v. "Plague."
[34] HSPA Archives, LSC 23/1 HMC, C, Hospital Correspondence – 1921-1923.

While plague serum aided in cases of contracted plague, a prophylactic vaccine existed that was somewhat more effective. Russian microbiologist Waldemar Haffkine developed the vaccine in 1897, and so Hawaiian physicians knew the concoction as Haffkine's vaccine. It was prepared by growing bacilli in animal broth with clarified butter on top. The bacilli grew to from stalactites projecting downward into the broth. After about four weeks, the culture was heated to kill the bacilli, and mixed with carbolic acid to prevent growth of other organisms. After a vigorous shaking, the plague vaccine was ready for use.[35] The above-mentioned Navy document recommended the vaccine for persons knowingly entering a plague focus. The patient received the vaccine in two stages of injections, ten days apart. Apparently, this immunity lasted for a few months.[36] Of course, this could not provide a permanent solution to the plague situation in Hamakua. The vaccine involved painful reactions, with fevers rising to dangerous levels up to 104° F. Furthermore, it was expensive and impractical to administer to a general population that probably did not want or need it. Some officials believed Haffkine's vaccine constituted an inappropriate response to the infrequent plague outbreaks of Hawaii, while others saw it as useful. Dr. N.E. Wayson, Medical Director for the U.S. Public Health Service Plague Suppressive Measures recognized the difference of opinions. He stated that because "the favorable reports are not generally accepted, it seems unwise to rely upon the efficiency of available preparations to procure protection, but they may be used as an adjunct."[37] In Dr. Carter's overview of plague on the islands, he recommended the Haffkine prophylaxis because he believed its efficacy to last for a

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[35] Louis C. Parkes and Henry R. Kenwood, *Hygiene and Public Health* 3rd ed., (Philadelphia: P. Blackiston's Son & Co., 1907), 461.
[36] HSPA Archives, HSC 33/10 Rat Poison Correspondence – 1922-1927.
[37] Wayson 288.

year, and because of the success Haffkine had in British India.[38] Like the plague serum, the early vaccines had their place in Hawaiian medicine, but were not advanced enough to provide effective control alone.

The 1940s saw dramatic improvements in the treatment of plague. In particular, improved vaccinations finally became effective enough for general public use. Dr. Karl F. Meyer at the Cutter Laboratory of the Hooper Foundation, University of California developed the Cutter vaccine in 1944. Laboratory tests showed that this preparation confirmed 90 percent immunity, and caused only mild reactions at the injection site. For example, on the island of Hawaii, "out of the 104 health department personnel immunized, only two complained of a sore arm."[39] In Hawaii, the Board of Health eagerly sought the Cutter vaccine for use in the plague districts of Makawao (Maui) and Hamakua, especially considering the unexpected epidemic of 1943 that claimed ten lives in the territory, seven in the Hamakua District. After that year, the Board of Health formed a new plague committee to administer vaccinations free of charge to the general population in these areas. The people of the Big Island responded with like enthusiasm, "Dr. Bergin reported that on the first day the vaccine was offered 700 people requested it and on the second day 900."[40] As of January 1945, 6,000 Hamakua residents, or 85 percent of the population there, had accepted the vaccination.[41] One of these people was Anacleto Realin, a plantation carpenter. When he contracted plague in April of 1945, he recovered. "It may be possible that the immunization has saved his life," reported Dr.

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[38] Carter 298.
[39] C.L. Wilbar, Jr., "Plague Vaccination—A Field Test," *Plantation Health* 4, no. 1 (1945): 18.
[40] Nils P. Larsen, "Tropical Disease Dangers in Hawaii," *Hawaii Medical Journal* 4, no. 1 (1944): 12.
[41] Wilbar 17.

James R. Enright.[42] The Cutter vaccine represented an exciting new era of plague suppressive measures for the plantations and corresponding employees of the Hamakua District. Nevertheless, as is the problem with plague vaccinations even today, immunity did not last for life. From a letter written by vaccine creator Dr. Meyer to the Territorial Board of Health President Dr. Charles Wilbar: "Particularly in an endemic area the immunity must be constantly renewed since the protection conferred by any vaccine—dead or living—will decline after the third month. For this reason I highly recommend re-vaccination with the new type of vaccine which will be prepared for you and the plantation people."[43] While the Cutter vaccine was an effective force in eliminating plague in Hawaii, it was not a magic bullet.

Probably the most important progress in the treatment of plague, was the development of antibiotics. Antibiotics today remain the best (only) cure for plague and other bacteriological infections. In Hawaii, at the end of the plague era, sulfonamides such as Prontosil (an early broad effect antibiotic by Bayer) and sulfadiazine were most important.[44] In 1944, Dr. Wayson at the plague laboratory in San Francisco conducted experiments with sulfadiazine on guinea pigs with favorable results. One of the pigs, however, died of sulfadiazine crystalluria, a seemingly rare occurrence but nevertheless important.[45] Dr. Carter, for 27 years the primary plantation physician of the main plague focus, at about 100 cases, received perhaps the most personal experience in treating human plague of any American doctor at the beginning of the antibiotic era.[46] He had the

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[42] *Honolulu Advertiser*, "Victory Won In Hamakua Bubonic Case," May 26, 1945, pg. 7.
[43] Karl F. Meyer, "Bullets from the Field," *Plantation Health* 8, no. 3 (1944): 35.
[44] Carter 298.
[45] N.E. Wayson and M.C. McMahon, "Sulfadiazine Treatment of Guinea Pigs Infected by Artificial Methods or by Flea Transmission," *Public Health Reports* 59, no. 12 (1944): 385.
[46] Tomich 261.

privilege of administering these new sulfa drugs before their effects were conclusively known. He also experimented with injecting patients with 100 cc of 1 percent merbromin, an antiseptic.[47] Dr. Meyer noted the importance of administering antibiotics in large quantities, and stated that it was imperative for sulfa treatment to begin immediately and to continue "for at least ten to fifteen days after the patient is afebrile."[48] When properly administered, these new antibiotics greatly increased a patient's chances for survival. It is notable that the 1945 recovery of Anacleto Realin could be attributed to sulfa drugs, although he did receive the Cutter immunization as well.[49]

In 1945, Dr. Carter published the details and treatment methods of the case of one little girl, only named as "M.H." "At the time of our examination, the little girl was running a temperature of 104°, a pulse of about 130, and she had a typical bubo in her left inguinal region," which Dr. Carter's biopsy revealed to be plague positive. Immediately the following morning he administered "intravenously 10 cc. of sodium sulphadiazine (25% solution). From that time on she was also given one tablet of sodium sulphadiazine by mouth every four hours." Unfortunately, she was bothered with frequent vomiting, which prevented full drug absorption, and she passed on March 10, 1945. Interestingly, although *Y. pesits* was recovered and Dr. Carter made an obvious diagnosis of bubonic plague with pneumonic complications, inoculated guinea pigs failed to die of plague. Dr. Carter explains, "it is quite possible that the intravenous sulphadiazine medication cleared the girl's system of all live pestis bacilli...This is the first time following any post mortem on a human plague case that we have not been able to recover the plague germs either from the liver, lungs, or spleen." In the same article, Dr. Carter explains that a

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[47] Carter 297.
[48] Meyer 35.
[49] *Honolulu Advertiser*, "Victory Won In Hamakua Bubonic Case," May 26, 1945, pg. 7.

second patient, J.T.F., recovered after treatment with sulfa drugs. Patient number two's sulfa-treated serum also failed to kill any guinea pigs, and so like the first case went undocumented as official with the Territorial Board of Health.[50] Cases such as these, and the formerly mentioned anonymous case of recovery reported by Mr. Lindsay demonstrate why Dr. Carter felt that the plague mortality rate of Hawaii was inflated.

Besides vaccination for prevention and using antibiotics, the general treatment of plague cases in the 1940s consisted of supportive therapy. Dr. Carter reported giving an injection of a quarter grain of morphine sulphate to alleviate the pain of a septicemic plague patient.[51] Sometimes treatment came down to simply making the patient as comfortable as possible, in order to allow the body to fight the infection on its own. Naturally, the body required nourishment to perform this task. For the little girl who died on March 10, Dr. Carter supplemented her diet with "two 500 cc. injections of human blood plasma and 10% glucose in saline, 1000 cc. on three successive days."[52] These treatment methods were aspects of modern supportive therapy systems, in sharp contrast to the depletive therapies of the past. Dr. Carter also described local bubo treatment, which consisted of aspiration and incision for drainage if necessary. "A mixture of camphor and thymol may be injected into it through a drainage tube, or a 1 per cent solution of iodine in potassium iodide solution may be employed for the same purpose," he wrote.[53] Treating cases of plague was mostly ineffective throughout the majority of the plague period. Treatments in the final decade of human plague in Hawaii (the 1940s), however, proved to be somewhat successful.

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[50] C.L. Carter, "Post Mortem Plague Report," *Plantation Health* 4, no. 1 (1945): 15-16.
[51] C.L. Carter, "Bubonic Plague on the Island of Hawaii," *Hawaii Medical Journal* 2, no. 6 (1943): 297.
[52] C.L. Carter, "Post Mortem Plague Report," *Plantation Health* 4, no. 1 (1945): 15.
[53] C.L. Carter, "Bubonic Plague on the Island of Hawaii," *Hawaii Medical Journal* 2, no. 6 (1943): 298.

What Can We Do? Prevention and Sanitation

In contrast to the responsive treatments of plague, which were quite limited, especially up until the 1940s, preventive actions played a major role in combating plague in Hawaii. Since plague is a fast-acting disease with a high mortality rate, it makes sense that public health and plantation authorities invested their efforts in preventing cases before they occurred. In reality, if one wishes to end the presence of an endemic disease, prevention is the only option. Because of the dangerous nature of plague, and its history of pandemic outbreaks, the Hamakua District had the aid of many interested people. While plantations carried out much of the "dirty work" in preventing plague, the Territorial Board of Health immensely guided and aided their efforts. In fact, it was the public health authorities who pushed the issue, and whose primary concern was halting the dreaded disease. In matters of funding and research, federal authorities also played a role. With knowledge of the epidemiology of plague, prevention essentially boiled down to a war on rodents and fleas, coupled with sanitary campaigns. As plague ravaged the region for decades until finally leaving in mysterious fashion, it is difficult to claim that any single effort had a profound effect. Nevertheless, these labors combined helped check the malady.

The effort to combat plague necessitated cooperation between the Territorial Board of Health and plantation management. Unfortunately, these parties' relations were occasionally unfriendly. On September 1, 1922, Manager of the Honokaa Sugar Company W.P. Naquin wrote a letter to President Trotter of the Board of Heath in response to sanitation recommendations by the latter. Mr. Naquin responded with annoyance: "The work outlined by you is practically the same as we have been doing for the past 10 years."[54] Even so, Naquin complied and the tone of his disagreements remained subtle. Tensions existed between the Board of Health and the plantations because of the frustrations plague deaths caused and the futility of combating it. Sometimes territorial officials placed undue pressure on plantations. Nevertheless, both parties shared the common goal of plague relief.

Associations seemed to improve with time as plague presence and the corresponding efforts became institutional. In an intracompany letter dated May 27, 1927, President J.W. Waldron revealed, "We are also pleased to know that the relations between the Board of Health and the plantations are much more friendly than they were some time ago."[55] These men appeared to be rational and genuinely concerned with the grave health issue at hand. Dr. Trotter expressed his appreciation to Mr. Naquin for his "interest and cooperation" in the plague work at Honokaa, "It certainly is most gratifying to know that absolute harmony and assistance are being shown by all in this rodent plague outbreak."[56] As always, Waldron received a copy of this letter, and on this occasion chose to reply, expressing his thanks and his honest worries concerning plague. He wrote, "There must, of necessity, be co-operation and harmony between the plantations and your honorable Board at all times and when plague or any such dread disease threatens, we must co-operate for the common good."[57] With the vast majority of land, capital, and human resources under plantation control, public health authorities found the alliance essential to their efforts. The cooperation did not waver, but strengthened with time. Health Administrative Officer B.J. McMorrow told Mr. Naquin

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[54] HSPA Archives, HSC 8/9 F.A. Schaefer & Co. In & Out – 1922.
[55] HSPA Archives, HSC 11/9 F.A. Schaefer & Co. In & Out – 1927.
[56] HSPA Archives, HSC 23/3 General Correspondence In & Out – 1921-1922.
[57] HSPA Archives, HSC 8/9 F.A. Schaefer & Co. In & Out – 1922.

of his sincere appreciation for cooperation in 1939, "The wholehearted aid given by the plantations in the plague area is of tremendous value to the campaign."[58] If the plantations had not been compliant, plague may have spread beyond control. Fortunately, they recognized that aiding the Board was in their best interests.

Hawaii was (and remains) an important American port to and from Asia. With numerous ships traversing Hawaiian waters en route to various global destinations, the presence of a dangerous pestilence such as plague became an issue that concerned higher authorities. Dr. M.F. Haralson, Territorial Commissioner of Public Health, addressed this issue saying, "As an island outpost between the Orient and continental America, Hawaii's health department will continue to protect the people of the islands and of the United States mainland from the scourge of plague."[59] Public Health Reports periodically published data concerning plague deaths and resulting activities. Experts from the USPHS supplemented territorial evaluations in 1912, 1932-1933, and from 1952-1953.[60] This latter federal plague control team consisted of Dr. Leo Kartman and Richard Lonergan, who left somewhat abruptly "because of alleged lack of full cooperation from Territorial officials."[61] This claim, however, seemed out of place amidst the generally collaborative efforts. The team had arrived after the last case of human plague (1949) anyway, and rodent plague ceased soon afterwards. Even still, federal relations resumed, and that government stationed a plague research unit on Hawaii from 1958 to 1968, which the National Institutes of Health helped fund.[62] The fact that this team failed to

[58] HSPA Archives, HSC 30/7 Miscellaneous Letters In & Out – 1939.
[59] M.F. Haralson, "Territory of Hawaii is Plague Control Frontier," *Science News Letter* (November 1, 1941): 285.
[60] Tomich 264.
[61] *Honolulu Star-Bulletin*, "Federal Plague Control Team Scheduled to Leave Honokaa," March 27, 1953, sec. B8.
[62] Tomich 264.

find any plague bacteria confirmed its disappearance. Public health authorities on the mainland worried about the possible pandemic spread of plague, and took steps to aid in the fight against plague on the Big Island. For example, the USPHS stationed inspectors at the Hilo port to examine all cargo and vessels for evidence of rat infestation. These inspectors luckily did not have to do much enforcing, as watchful eyes helped at many steps in the exportation process, and because the chief export, raw sugar, was not very susceptible to rat infestation.[63] The USPHS supplemented the Board of Health's plague budget, which in 1941 annually totaled about $140,000.[64]

Broad concern over plague included local business such as the plantations and others. During 1911, "the Shippers' Wharf Committee of Hilo placed at the disposal of the Board of Health, for better sanitation and prevention of disease on the Island of Hawaii, the sum of $2,564.99"[65] Public Health Committees on the Honolulu and Hilo Chambers of Commerce aided local anti-plague organization. The aid offered by the plantations and individual Hamakua residents helped immensely. Clearly, sanitation on Hawaii was a mass organized, heavily enforced, and well-funded operation.

Observance was the constant element and first step in any Board of Health anti-plague campaign. These officials required knowledge of the course and location of plague in the Hamakua District, so that they could focus their attentions appropriately. The BOH searched for plague cases, both in the human and rodent populations. They also received suspicious rats that were found dead by community members. The Board encouraged this cooperative behavior, enlisting the help of the threatened residents. Remaining vigilant and aware, the plantations aided the Board. The public health

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[63] Eskey 69.
[64] Haralson, 285.
[65] *Hilo Tribune*, "Plantation Men Are Complimented," December 12, 1911, pg.1.

officials also engaged in active trapping activities, which served to help control the reservoir plague population, but primarily helped locate plague foci.[66] The employed trappers came across many plague-killed rats in the fields.

The Board of Health retained two plague laboratories to determine infections: one in Hilo and one in Honokaa. The Territory founded the second lab because of the difficult distance (about 42 miles) from the Hamakua cases to the Hilo lab. This occurred in May 1911 with Dr. F.W. Taylor in charge.[67] Every time the laboratory officials confirmed a case of plague in a rodent, they made a numbered card labeling the rat's species, sex, and location. They compiled this data to make epidemiological observations of plague foci, and plan prophylactic poisoning, trapping, sanitation, and educational measures. The archives of the Honokaa Sugar Co. contain a map created by McMorrow's staff, "showing the location of all cases of rodent plague found on your plantation during the fiscal year July 1, 1938 to June 30, 1939."[68] The Board of Health notified plantation management and other concerned local businesspeople of every known case of plague, both human and rodent. Upon discovery of plague foci, the Board of Health and the plantations took swift steps to stamp it out. Efforts included campaigns against rats and fleas, increased sanitation, and public education.

Because information was an important commodity in the fight against plague, the Board of Health engaged in educational activities. They informed residents of all ages: "In the schools in the region there has been an educational program, teaching the children

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[66] Hawaiian Sugar Planters' Association, *Report of Committee in Charge of the Experiment Station* (1922): 28.
[67] *Hilo Tribune*, "Plantation Men Are Complimented," December 12, 1911, pg.1.
[68] HSPA Archives, HSC 30/7 Miscellaneous Letters In & Out – 1939. See Appendix B.

the meaning of disease and disease prevention."[69] The Board educated the average resident; Dr. Haralson reported, "Much of the work done within urban communities of the Territory is the education of householders in methods of eradication—rat proofing, poisoning and trapping."[70] After Rat A-96 proved positive for plague, the Board set up warning place cards around the Kukaiau Village of the Hamakua Mill Company, updating residents there on the present situation.[71] It is particularly notable that the Board of Health worked with the plantations on issues of sanitation, because that was where the majority of plague cases occurred. Dr. George Walter McCoy was a federal plague expert, who was in charge of the plague laboratory in San Francisco from 1908 to 1911, when he began his new post in Hawaii as federal advisor.[72] He and his team "agreed that a campaign of education among the laborers on the plantations and explanations of just what results would follow their modes of living would have good effects."[73] In order to give information, officials first needed it themselves, and so the line of communication went both ways. Dr. Carter advised citizens in their role on bubonic plague, "To keep up on eternal vigilance against rats, fleas, rat harbors around your home; report any dead rats to the board of health immediately but do not touch them at any time; report any illness that might appear to you to be similar to plague."[74] Knowledge was a simple yet crucial component to the plague campaign.

Sugar plantation archives are full of hundreds of the notifications of plague that the Board of Health sent out over the years. The Board notified plantations of every

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[69] Larsen 12.
[70] Haralson 285.
[71] HSPA Archives, HSC 29/1 Miscellaneous Letters In & Out – 1929-1930.
[72] Mamiya Medical Heritage Center, *George Walter McCoy*, http://hml.org/mmhc/mdindex/mccoyg.html.
[73] *Hilo Tribune*, "McCoy Reports on Health Conditions," December 26, 1911, pg.1.
[74] Dr. Clarence L. Carter, "Battle Against Bubonic Plague," *Honolulu Star-Bulletin*, March 31, 1944, pg. 4.

plague rat found in their vicinity. Every year, trapping, hunting (shooting rats in tree nests), and searching efforts provided thousands of rats for the laboratories to autopsy for plague. Sometimes the lab examined individual rats for skin lesions and then tested the rat's serum for bacilli. Later they used a more efficient method developed by Surgeon C.R. Eskey of the USPHS plague laboratory in San Francisco. This method called for combing the rodents for fleas, grinding the fleas up in a salt solution, and then inoculating a guinea pig. Known as mass flea inoculation, it was effective because "plague cannot exist among rodents without the infection being present in the fleas they harbor."[75] Furthermore, this method had the advantage of speed, as harvested fleas could be instantly tested for plague, whereas previously the laboratory had to wait for the animal to develop reactions. The numbers of plague rats found varied greatly throughout seasons and years, correlating with the sporadic nature of the disease. For instance, of the 401 total plague rats found in the 1940s, as many as 122 were found in 1942, and yet authorities did not find a single plague rat in 1950. In many years authorities reported only a few plague rats, and then in adjacent years epizootics killed many more. The majority of plague rats were found dead rather than being trapped or killed.[76] A typical plague notification letter read:

> Please be advised that Rat D-141-Kukaiau was examined at our rat laboratory on August 14, 1929 and deemed suspicious for plague. A guinea pig was cutaneously inoculated at 2.40 P.M. of the same date. Rat D-141-Kukaiau was killed in the Japanese school section of camp 2-K, Hamakua Mill Co. This rat was apparently ill, and was noticed by the plantation inspector, during the work of prophylactic measures being carried on in Camp 2K and was killed.[77]

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[75] "New Method of Determining Plague Infection in Rodents," *Public Health Reports* 51, no. 24 (1936): 786-787.

[76] Bertram Gross and David D. Bonnet, "Plague in the Territory of Hawaii II: Plague Surveillance, Hamakua District, Island of Hawaii," *Public Health Reports* 66, no. 47 (1951): 1546.

[77] HSPA Archives, HSC 29/1 Miscellaneous Letters In & Out – 1929-1930.

The inspector conducted the prophylactic measures in question after a previous rat established Camp 2-K as a plague focus. Typically, orders or summaries of prophylaxis followed notification.

Plantation sanitation efforts took many forms, all contributing to the health of their employees and the prevention of pestilence. The always present and most important step taken after the discovery of a plague focus was an anti-rodent campaign. This consisted of trapping, poisoning, and other methods, which will be discussed later in detail. Various sanitary measures helped prevent the contraction of new cases. In cases of rodent plague, the operations affected a broad area, and while sanitation efforts occurred in all locations where residents lived or worked, in cases of human plague particular attention was given to locations the patient frequented. P. Bartels described the responsive measures taken after a painter succumbed to plague: "The local Board of Health has taken charge of the disinfecting of the man's living quarters and the camps in which he has been working lately."[78] Additionally, it was common to quarantine anyone who knowingly had contact with the patient. Sometimes the quarantined received prophylactic vaccinations. In all cases, house-to-house inspections for additional cases began immediately following plague suspicion.

While no area of the Hamakua District was ever completely safe from the plague threat, some unsanitary plantation locations became somewhat notorious for rat harborage. Acknowledging this, Dr. Trotter emphasized, "The importance of maintaining all camps, stables, warehouses and stores in a thoroughly clean condition and free from

[78] HSPA Archives, HSC 11/9 F.A. Schaefer & Co. In & Out – 1927.

rubbish of any description."[79] Among this list, stables were frequently of concern. Plantation workers learned to remove rubbish that would otherwise serve as rodent housing and food, and to clean plantation camps with power spray pumps frequently. The journal *Plantation Health*[80] reported the importance of keeping garbage in metal containers, stacking wood at least 24 inches above the ground, keeping animal pens sanitary, never leaving running water unattended, and keeping camps' grass cut short and free of rat harboring plants. Regulations allowed families only one dog each, and officials in the 1920s killed all stray dogs and cats, because they were at risk for carrying the plague flea.[81]

Some work required more time and effort, such as the wrecking of buildings and rebuilding with rat proof construction. Still, plantations implemented these measures as best they could, "Plantation managers have torn down old camps, thinned out crowded ones, built new camps, some of them much better than the ordinary dwellings of the poor, installed drainage and sewerage lines…," D.S. Bowman reported.[82] Although rat campaigns constituted the main prophylaxis in the fields, sanitary improvements had tremendous effects in and around plantation structures. That sanitation on plantations had a marked effect in reducing the numbers of plague, may be partially proven by a temporary lapse in sanitation. The year 1943 saw a sudden occurrence of seven cases of human plague after three years of peace. An article from that year concerning a legislature request for additional territorial plague funds cites lacking plantation housing. The article reads, "Mr. Tay admitted that the condition of plantation dwellings in certain

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[79] HSPA Archives, HSC 33/10 Rat Poison Correspondence – 1922-1927.
[80] *Plantation Health* was a publication of the HSPA from 1936 to 1964.
[81] W. B. Patterson, "Sanitation on a Plantation," *Plantation Health* 4, no. 1 (1945): 20.
[82] *Hilo Tribune*, "Plantation Men Are Complimented," December 12, 1911, pg.1.

camps on Hawaii was such as to provide harboring places for rats. He said that the plantations have made improvements to eliminate this situation but that the lack of money and wartime conditions had interrupted their building plans."[83] Dr. McCoy toured the Hamakua District in 1911; he expressed surprise and the amount of plantation sanitation improvement: "It is astonishing to look over what has been done in the last two years." Interestingly, during those same two years (in 1910) plague first struck the region.

With the adoption of prophylactic measures, plague in Hamakua was contained to the district, and many cases were likely averted. The funding for these campaigns came largely from plantation coffers, such as the additional $3,000 budgeted by the Honokaa Sugar Company in response to pressure from Dr. Trotter, even in the face of general financial cutbacks.[84] The Board of Health helped with their own sanitation employees, and the USPHS provided additional funding.[85] Hawaiian health authorities regarded plague as a preventable disease. An article in *Plantation Health* listed plague along with smallpox, diphtheria, and yellow fever as "examples of what can be done by the proper application and education concerning preventive measures."[86] In addition to the multitude of sanitation steps taken in the name of public health, Dr. Carter made recommendations for the general public. He advised, "While working in the fields it may be well to wear leggings or something to protect your lower extremities and wear gloves to protect your hands; call upon the board of health to spray under your home or around

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[83] *Honolulu Advertiser*, "Legislators Will Ask Governor For Funds For Plague Control," September 18, 1943, pg.1

[84] HSPA Archives, HSC 8/9 F.A. Schaefer & Co. In & Out – 1922.

[85] HSPA Archives, HSC 30/7 Miscellaneous Letters In & Out – 1939.

[86] "The Present Status of Preventive Medicine," Editorial in *Plantation Health* 2, no. 1 (1937): I.

your premises in order to exterminate the fleas."[87] Dr. Carter viewed preventative measures as the greatest asset in the plague campaign. Individual vigilance was a way for every Hamakua resident to aid in the anti-plague fight. Sanitation efforts had the broad and penetrating support of those threatened most. Honokaa Sugar reported, "Laborers spend from half an hour to an hour in the evenings cleaning up and sprinkling around their dwellings – so as to lessen the chances of infection."[88] Naturally, one could consider the previously mentioned vaccines preventative health measures. Nevertheless, sanitation and the other preventative measures treated the problem more holistically, by inhibiting the bacteria from entering human bodies in the first place.

Fighting the War on Rats

A Rat Portrait

Controlling the rodent population was perhaps the most important preventative measure conducted along the Hamakua coastal plague region. While plague can be fought by attacking the bacilli, the vector flea, or the reservoir rodent; the latter method was the easiest because this component is physically the largest and least numerous of the organisms in the infections chain. Especially in the early part of the twentieth century, it was a difficult task fighting an enemy that was hard to see. Furthermore, plantation managers had a vested interest in controlling these creatures in addition to plague control: rats constituted a serious menace due to the destruction of sugarcane crops. Considering these factors, plantation managers and public health officials engaged in massive campaigns to kill rats.

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[87] Dr. Clarence L. Carter, "Battle Against Bubonic Plague," *Honolulu Star-Bulletin,* March 31, 1944, pg. 4.
[88] HSPA Archives, HSC 8/9 F.A. Schaefer & Co. In & Out – 1922.

Hawaiian rodents consisted of three species of rats and one mouse species, all plague carriers. The rats of the genus *Rattus* consisted of the Norway rat *Rattus norvegicus*, the common black rat *Rattus rattus* (broken into its subspecies *R. r. alexandrinus* and *R. r. rattus*), and the native Hawaiian rat *R. hawaiiensis* (sometimes labeled as the general Polynesian rat, *R. exalans*).[89] The house mouse, *Mus musculus*, was common almost wherever rats were. The first two invasive rats arrived with the first Europeans, while the native rat came centuries earlier on Polynesian canoes.[90] The Norway and black rats were much larger than their Hawaiian counterpart was, and would bully and cannibalize the smaller Hawaiian rat. Omnivorous rats usually fed on an abundance of vegetation in the lush Hamakua District (being especially fond of Hamakua's sugarcane and causing significant damage), but they frequently found protein nutrition in shorter supply. Due to the fear of cannibalism, sick rats isolate themselves. "When rats get the plague they crawl into their nests and die there," indicating that the actual occurrence of rodent plague was much higher than observed. The Norway rat (also known as the brown rat) is especially large. All rats are prolific, making them difficult to control. The black and Norway rats also have a greater predilection to live near human homes. While all three species lived in the field, "The native rat, *R. hawaiiensis*, is the only truly wild rodent in Hawaii—it lives only in the field and never in human habitation."[91] Therefore, in urban areas, the European rats traditionally caused plague epidemics. In the fields of the Hamakua District, however, where the plague was sylvatic, rodent control experts had to pay special attention to the weaker species. Eskey

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[89] Eskey 13.
[90] David H. Johnson, "Geographical Affinities of the Mammals of the Hawaiian Island and of New Zealand," *Journal of Mammalogy* 25, no. 4 (1944): 334.
[91] Leo Kartman and Richard P. Lonergan, "Observations on Rats in an Enzootic Plague Region of Hawaii," *Public Health Reports* 70, no. 6 (1955): 587.

pointed out, "*Rattus hawaiiensis*, being the natural host of Xenopsylla hawaiiensis, undoubtedly plays an important role in maintaining the endemic rural type of plague that has been present in the Hamakua district, Hawaii."[92] Combating plague largely boiled down to a war on these reservoir rodents. To achieve this, authorities employed trapping, poisoning, and using biotic controls.

Playing the Pied Piper: Trapping and Detection

The most basic and intuitive mode of rodent control, trapping, served two major functions. First, plague and plantation authorities implemented trapping for the somewhat obvious purpose of killing rats. Trapping for the outright purpose of killing rats was most efficient in smaller areas, where sufficient numbers of traps could be set to catch all the rats, such as in urban areas. Between 1915 and 1918, the Honokaa Sugar Co. captured 268,761 rats at a cost of $40,672 (not accounting for inflation). Even still, this vast and expensive campaign was pitifully ineffective. Rats damaged up to half of the cane stalks at a cost of more than $100,000 every year, and continued to do so despite the best trapping campaign.[93] The problem with trapping alone was the sheer acreage of cropland. Nevertheless, trapping remained a constant chore, employed by the Board of Health in order to find, study, and locate plague rats and foci. Even in this endeavor, trapping was not as useful as simply finding plague rats dead, yet catching any number of rats at all was important. Furthermore, it was the trappers themselves who found the majority of dead rats. Trapper presence also offered an outlet for local people to turn dead rats over to.[94] Even with all the close contact these people had with plague rats, Tomich points out, "Remarkably, only one rodent control worker, a plantation rat trapper,

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[92] Eskey 60.
[93] Hawaiian Sugar Planters' Association 27.
[94] Eskey 63.

was known to be a victim of plague."[95] Because trapping was effective when done intensely in a limited area, the Board of Health still used trapping for the outright death-dealing purpose on these confined foci. Trappers had a few different methods in their arsenal to achieve both these goals.

The most common trap type used in the rural field of Hamakua was the snap trap. By 1951, the Bureau of Rodent Control operated 5,000 snap traps daily, each with a painted number as identification. They treated these traps with a wood preservative to protect them from the moist elements. Trappers protected villages with one-third of the traps, and the remaining two-thirds went into the fields. Each trap contained a one-inch square piece of coconut bait, and had a square foot of clearance. Territorial-funded trappers began servicing the traps daily at 6 a.m., so as to beat the mongoose to the fresh meat. They evenly space the traps, provided service for maintain working conditions, reset sprung traps, and replaced missing or stale bait. It was the responsibility of snap trappers to begin the information collection process by forming a plague card for each rat found, which they tied to the animal's leg. It was very important for the trappers to take precaution in handling the removal of the possibly infected rodents, which they did without physical handling. Using caution, trappers freed the animals by picking the trap up by the base, releasing the striker, and allowing the rodent to fall into a receptacle. Gallon cans containing kerosene served to protect trappers and workers at the laboratory. However, "On days the rodents from a trapper's district are to be combed for fleas, the retrieved rodents are placed in a small paper bag in the field. One-quarter teaspoon of calcium cyanide is added to the bag, which is shaken and then tied tightly at the neck

[95] Tomich 272.

with string."[96] This trap method always killed the rodent, and should be distinguished from live trapping. Snap trapping was a prevalent and useful element of the anti-plague campaign.

A second method of trapping, utilized by the Bureau of Rodent Control, was barrel traps. A September 13, 1921 letter from continental expert Edward L. Baum to Experiment Station Director H.P. Agee discussed this method in detail. With this method, Mr. Baum saw catches of fifty or sixty rats in one barrel in one night. Mr. Baum described the trap:

> The scheme is very simple—being merely a barrel with a hinged top, the whole sunk in the ground so that the top is level with the surface of the ground. The top of the barrel is not properly hinged, but rather balanced on a rod, so that very slight weight on one side will cause it to tip. When this balance is attained, a small weight is put on one side, and a nail driven into the barrel to serve as a stop to hold the top level. The bait is put on the other (free) side of the top. When a rat goes after the bait, his weight, overbalancing the small counterweight, tips the lid, depositing the rat in the barrel. The counterweight then brings the lid back to the level, and the trap is ready for the next.[97]

Barrel trapping allowed the option of either killing the rats by filling the bottom of the barrel with water, or of preserving them alive (live trapping) by skipping this step. Occasionally Board of Health experts desired to have rats alive, such as for the purposes of lab experimentation or to conduct new extermination methods. When this was the object, the hole had to be dug deeper and wider in order to accommodate a pair of handles for barrel removal. Particularly in the earlier years of the endemic period, barrel traps served an important role along with snap traps.

Amid all the scrambling to find suitable plague-rat control measures, an interesting theory came into play. The fact that rats were so prolific caused many control

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[96] Gross 1543.

[97] HSPA Archives, HSC 23/3 General Correspondence In & Out – 1921-1922. See Appendix C.

problems. After an effective trapping campaign, for instance, rats would simply respond with a swell in population, reaching numbers often exceeding the original count and exacerbating the whole problem. Prolific rat populations rarely weakened due to the presence of plague or any other enzootic disease, but merely reproduce rapidly to replace victims. Furthermore, "from a bacteriological point of view their position was even stronger, since they might suffer from a chronic, non-fatal, but transmissible form of the disease," as they adapted, reported Dr. A.K. Chalmers, medical officer to the port of Glasgow. Reporting in the *British Medical Journal*, Dr. Chalmers discussed a method of controlling the rat population, originally developed by authorities in Copenhagen, which intended to circumvent these issues. The special method consisted of live trapping the rodents, then killing only the females and releasing the males. The idea was that the remaining males would fight amongst themselves to a great degree, and exterminate themselves. At Copenhagen results seemed successful, as they reduced the average rat catch from about 300,000 down to 90,000.[98] H.P. Agee, Director for the Experiment Station of the HSPA found Dr. Chalmers' article, and on October 1, 1921 he wrote to an E.W. Wilson of the Biological Survey of the U.S. Department of Agriculture inquiring for more information.

In C.E. Pemberton's 1925 report on rat control, he explored this method as it applied to Hawaii. Pemberton called the method the "Rodier Theory of Control," because William Rodier of Australia apparently championed the method heavily in those years. Rodier claimed to have successfully used the method to control the rabbit population there. Pemberton explained, "By upsetting the sex balance sufficiently, the remaining females are said to often become barren, be less fecund and the males perhaps

[98] HSPA Archives, HSC 23/3 General Correspondence In & Out – 1921-1922.

more cannibalistic on the young." Unfortunately, the vast cane fields and the sylvatic nature of plague in Hamakua once again proved too difficult to curb with methods that succeeded elsewhere. Mr. Pemberton further explains, "No satisfactory method is known whereby live field rats in Hawaii can be caught in sufficient quantity to apply this theory."[99]

Picking Their Poison

Public health and plantation scientists primarily used poison as a mainstay of rodent population control efforts. While poisoning and other rat control efforts began long before the arrival of plague in Hawaii to protect agricultural interests, methods and procedures were in a constant state of change. Poisoning rats as a means of plague reservoir control was conducted in conjunction with trapping, habitat destruction, general sanitation, and food supply disruption. The history of rat poison on Hawaiian sugar plantations is dynamic because of the progression of more efficient poisons and methods, as well as because of the necessity to out maneuver the adaptive rat species. During the plague era, no single rat poison or distribution method emerged as a dominant or wholly effective measure, although the Honokaa Sugar Company succeeded in reducing rat numbers. Moderate successes in poisoning facilitated a great reduction in rat-damaged sugar cane, but failed to end the persistence of plague. Poisoning efforts were laden with troubles, and as a result, rat populations continued to proliferate.

Individual poisons and distribution techniques have unique problems as will be described, but some general issues were ubiquitous. Scientists consistently faced the problem of how to keep their bait fresh and free from spoiling mold. While this would be

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[99] Pemberton 43.

an issue anywhere, it was a particularly difficult obstacle in the moist tropical sugarcane fields of Hawaii's Big Island. Chemical waterproofing and anti-molding agents either mixed in or wrapped around poisoned bait constituted a popular response to this problem. The introductions of increased chemicals, however, had the effect of increasing costs and often led to increased bait shyness. Simply replacing bait frequently could also be an effective alternative, but that option came with increased labor and supply costs. At the request of plantation management, and because of the special nature of the rat problem in the Hamakua area, the Hawaiian Sugar Planters' Association sent C.E. Pemberton, Associate Entomologist, on a two-year resident study of the rat problem at the Honokaa Sugar Company. Mr. Pemberton and associates at Honokaa made numerous poison field tests, adding to the body of applicable knowledge of poison in Hawaiian cane fields. Certainly other field tests were conducted by various plantations, as rats were a ubiquitous nuisance on the Hawaiian sugarcane plantation. Because of the bubonic plague in the Hamakua district, the special attention of Mr. Pemberton at Honokaa, and the zealousness of the Honokaa Sugar Co. plantation management in controlling the rat population, that plantation serves as an excellent poison case study in the 1920s. In addition to plantation field tests, by June 1925 there were 428 separate laboratory tests investigating various baits with barium carbonate, strychnine, arsenic, extract of squills, phosphorus, cyanide of potassium, and other poisons. While the laboratory tests found practical killing powers of various bait combinations, field tests researched practical distribution and implementation techniques.[100] Finding cost effective rat control methods was a perpetual concern in the sugarcane industry.

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[100] Pemberton 26.

An even greater problem faced by scientists was finding proper poison-to-bait ratios that were effective and sustainable. All too often, rats proved to be extremely adaptive, and even when poisons were thought to be odorless and tasteless, the rats began to refuse the poisoned baits over time. Agronomist R.E. Doty of the Hawaii Sugar Planters' Association stated, "Every control method or plan for poisoning field rats that has shown a reasonable efficacy when first tried has dropped in effectiveness with time."[101] Not only did Hawaiian field rodents prove to be adaptive in circumventing poisoning campaigns, but with ample natural food supplies in pineapple, sugarcane, miscellaneous fruiting trees, or any human scraps, rats were often initially suspicious of the new bait. This was often exacerbated by poison bait shyness, especially when exterminators used too high of a poison ratio. When excessive poisons were used costs were also higher, and there existed greater potential of accidental poisonings. With lower poison ratios, rats sometimes merely sampled and nibbled at the bait and did not ingest a lethal dosage. In these cases of low concentration the rodents often simply became very sick (sometimes even becoming hairless) and then certainly displayed increased bait shyness and may even have warned other rats.[102]

During Hawaii's plague era, numerous poison options existed, and these formulas grew as research progressed. Different poisons and implementation strategies were used simultaneously in varying locations. Arsenic was one simple and early choice of rat poison. Arsenic was relatively inexpensive and rather well received. It could be mixed with meal, barley, wheat flour, meat, or almost any other bait. Due to the cannibalistic instincts of rats, sick and dying members have a tendency to hide themselves from their

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[101] R.E. Doty, "The Prebaited Feeding-Station Method of Rat Control," *Hawaiian Planters' Record* 42, no. 39 (1938): 39.
[102] Doty 48.

peers. Rats poisoned with arsenic typically died 24 to 72 hours after ingestion, which was particularly desirable in fighting early urban plague epidemics because the rodents then had time to leave human centers before death.[103] In March of 1932, the Honokaa Sugar Company acquired 35 tons of 99% pure arsenic in 112-pound cases costing $3.09 each.[104] This poison was a standard choice in rat control work in many places, and Hawaiian sugar plantations found it useful in and around buildings. Combating rodents primarily in the field, however, Hawaii experts searched for better alternatives.

In 1936 experiments conducted on caged rats on Maui, arsenic was compared to thallium sulphate. The arsenic mixture consisted of mixtures of rolled barley, rice, or wheat with corn oil wrapped in wax paper with 10% arsenic. The thallium sulphate mixture required only a 0.4% poison ratio and was also mixed with wheat and wrapped in wax paper. The latter poison was more effective in killing the *Rattus hawaiiensis.*[105] Arsenic therefore was a popular and effective poison for combating urban plague during the third pandemic, but the sylvatic plague of the Hamakua sugarcane fields often had different poison needs. Field rats showed resistance to mixed arsenic bait as they did to most poison concoctions.

A more expensive and faster acting poison option was barium carbonate. In 1922, the Honokaa Sugar Company developed a new distribution technique with this poison. While the Territorial Board of Health in Hawaii actively fought plague in alliance with planters, the government focused their efforts more on urban centers such as plantation villages where more human life was concentrated. Plantations such as the one in

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[103] J.D. Long, "Choice of Rat Poison in Antiplauge Work," *Public Health Reports* 51, no. 20 (1936): 551.
[104] HSPA Archives, HSC 15/12 F.A. Schaefer & Co. In & Out – 1932.
[105] A.L. Dropmeyer, "Plague Eradicative Measures on the Island of Maui, Territory of Hawaii," *Public Health Reports* 51, no. 45 (1936): 1542.

Honokaa therefore took control of field rodents largely into their own hands. This company began to manufacture poisonous barium carbonate and flour dough cakes by the millions to distribute over their 10,000 acres of sugarcane fields.[106] In addition, the Honokaa Sugar Company was able to sell more cakes to neighboring plantation companies. These barium carbonate cakes (one inch in diameter and a quarter inch thick) were distributed in cane fields every ten feet by horseback. One man could cover 35 acres in a day at a cost of sixteen cents per acre. In order to solve the ever-present mold problem, the Honokaa Sugar Company coated their cakes with paraffin, allowing them to stay good for months. W.P. Naquin, Manager of the Honokaa Sugar Company and employee chemist F.R. Giddings developed the paraffin water proofing method.[107] Paraffin is an odorless and tasteless hydrocarbon, and was known as mineral oil in its liquid state.[108] The poison cakes had great initial success, reducing the monthly rat trappings by the board of health from 2,000 to fewer than 50. Nevertheless, this method also followed the inevitable trend of diminishing returns, but overall it was perhaps the most effective poison in the plantation arsenal.

Documents from the HSPA Archives revealed the barium carbonate cakes of the Honokaa Sugar Company were successful in limiting rat damage and became a popular choice for rat control worldwide. Honokaa Sugar was first successful in selecting proper baits. Omnivorous rats and mice needed both carbohydrates and proteins to survive and grow. "We have sufficient carbohydrates in the form of sugar cane to raise a billion rats and there is no doubt that the limiting factor in their increase lies in the proteid bodies, insects and bugs, such as mealy bugs, cut worms, etc.," stated W.P. Naquin in a letter to

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[106] "Plague Rats Menace Hawaii; But Poison Cakes Combat Them," *Science* 56, no. 1459 (1922): x.
[107] Pemberton 29.
[108] Wikipedia, *Paraffin*, http://en.wikipedia.org/wiki/Paraffin.

Mr. Pemberton.[109] Because protein was the limiting factor in the rat population growth in Hamakua, Naquin conceived of utilizing "poisons carried in proteid media such as grain, flour cakes, etc., [which] enables a poison campaign to succeed when the rat population is large."[110] One HSPA experiment station test in November of 1921 found that barium carbonate was a wise poison choice. Assistant Chemist Frederick Hansson found this poison to be most efficient, as it was odorless and tasteless, fast acting, and highly toxic to rodents. The poison, he found, attacked the stomach's lining and induced a thirst response, causing the rat to go in search of water and inducing death within about six hours.[111] Corporate records indicate that Naquin had tremendous success in his primary goal of reducing rat-damaged cane and increasing overall sugar yield using this poison, in combination with strychnine wheat torpedoes. On November 2, 1925, Naquin wrote to the Hawaiian Pineapple Co. about selling these poisons, and reported that using them the Honokaa "rat population has dropped tremendously, so that today rat damaged cane is practically nil."[112] Nevertheless, an effective reduction in bubonic plague incidences was harder to achieve. In 1922, Honokaa Sugar really began to mass-produce these cakes, making over 7.5 million of them to treat 10, 368 acres of their cane fields.[113] The formula was one part barium carbonate to three parts flour, mixed with water and kneaded into a stiff dough, rolled into ¼ inch thick cakes about ½ inch in diameter and dried thoroughly in an oven or by the sun.[114] Manager Naquin found that making poison combinations directly on the plantation was the most effective and cheapest way to do it.

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[109] HSPA Archives, HSC 23/3 General Correspondence In & Out – 1921-1922.
[110] Pemberton 5.
[111] HSPA Archives, HSC 23/3 General Correspondence In & Out – 1921-1922.
[112] HSPA Archives, HSC 33/10 Rat Poison Correspondence – 1922-1927.
[113] Hawaiian Sugar Planters' Association 28.
[114] Pemberton 29.

Homemade poisons were fresher, readily available in proper amounts, and could be sold to other firms with rat problems. These cakes became known as "Rat X cakes," as they were marketed to local and global buyers.

In combination with the rat cakes of barium carbonate, the Honokaa Sugar Company utilized strychnine torpedoes on their own fields and for sale to others. Experts at the experiment station of the HSPA such as Pemberton came to believe that the "almost complete disappearance of rats and the almost total cessation of rat injury to cane at Honokaa has been entirely owing to the thorough, systematic, persistent application of these poisons."[115] Plantation employees wrapped the poisoned wheat in paraffin paper to protect them from the elements. A dual poison attack system provided fuller coverage and helped to negate selective bait shyness. Strychnine, for instance, was particularly effective against the mice (*Mus musculus*) at Honokaa, which did not eat the poison cakes as readily as the rats. "The mice do no damage to the cane, but they are carriers of bubonic plague and their control should be considered an important point in a rodent campaign in Hamakua, where plague is so widespread," further reports the experiment station.[116] The strychnine wheat torpedoes consisted of one ounce each of powdered strychnine, baking soda and salt, one teaspoonful of saccharine for sweetening, a half cup of laundry starch, and 25 pounds whole wheat.[117] In many parts of the world, this was the preferred rat control poison.

As news of the successes of Pemberton and Naquin at Honokaa quickly spread throughout the islands and beyond, Honokaa Sugar began receiving a flood of letters requesting help. Some of these requests came from other local sugar companies, such as

[115] Hawaiian Sugar Planters' Association 28.
[116] Hawaiian Sugar Planters' Association 29.
[117] Pemberton 36.

one letter from Mr. Cruickshank of the Kealeku Sugar Company in Hana, Maui, dated March 12, 1927. Honokaa Sugar sold Rat X cakes and wheat torpedoes to plantations on the Big Island, Maui, Oahu, and Kauai. The Hawaiian Pineapple Company on Oahu wrote to Naquin two years earlier regarding poison formulas. Similar letters were found in the Honokaa Sugar records from the California Packing Company, Montefiore Hospital in New York, and Godchaux Sugars Inc. in New Orleans. Foreign orders came from places such as Alberta and Australia. In November of 1923, a Mr. C.E. Wood, Director of Agriculture in Nukalofa, Tonga wrote to Naquin asking for poison advice for use in the coconut groves there. Honokaa Sugar was very successful in marketing their homemade rat poisons, and were able to build a whole new sector of business based entirely on good news and recommendations. Customers came to them, as they read about successes in journals and magazines. On September 15, 1925, W.P. Naquin sent a thank you letter and $50 to Miss May E. Clapper of Canadaiguna, New York for a sketch of the Pied Piper she submitted for use as a poison label. In the same letter, he indicated that the company would begin marketing their poison products under the name of the "Pied Piper Poison Company."

While the quoted prices seemed to change slightly over the years, the torpedoes apparently sold for $400 per ton while the cakes went at about $275 per ton throughout the 1920s. Honokaa Sugar obtained their Barium Carbonate from the Board of Health at five cents per pound, one of the ways these entities cooperated for the common good. In this golden age of rat poison experimentation, it was standard procedure to send out sample poison packages to potential clients, and to offer detailed written troubleshooting. Honokaa Sugar, however, was primarily interested in the reduction of bubonic plague and rat-damaged sugarcane. Naquin told one potential Maui customer that, "We have been supplying this to a number of plantations, that is the prepared baits, at cost plus a small profit." To help them supply this large volume of product, Honokaa Sugar contacted various firms for quotes on automatic weighing and bag filling machines. A look at the 1925 income statement of the Honokaa Sugar Co. reveals a profit on poison of $1,288.57, after $4,275.37 in sales and $2,986.80 in expenses.[118]

Because they were first concerned with their own rat problem, however, the plantation continued to receive and entertain solicitations on all sorts of rat control concoctions in the hopes of finding something ultimately effective. These solicitations came from the Pacific Guano and Fertilizer co., the John F. Leinen Chemical Co. in San Francisco, the Bayer Company in New York, and a poison called "Rodine" made in Perth, Australia. Nevertheless, it does not appear that any of these private firms produced a more effective poison formula than the homemade versions, and generally they were based on the same usual suspects of poison types (thallium, strychnine, barium carbonate, etc.). Candid discourse with other poison manufacturers and sampling of their formulae revealed the Hamakua plantation to be primarily a consumer of rat poison, greatly concerned with the threatening rodent menaces. Honokaa Sugar desired first to solve their own rat problems, and then turned to helping others as necessity forced them to become experts in the field. This pressure was strengthened by the constant trapping and surveillance and other aiding activities of the Board of Health, as well as by the research aid provided in the form of Pemberton and the experiment station staff of the HSPA[119]

[118] HSPA Archives, HSC 11/2 F.A. Schaefer & Co. In & Out – 1926.
[119] HSPA Archives, HSC 33/10 Rat Poison Correspondence – 1922-1927.

W.P. Naquin correctly believed that the successes Honokaa Sugar experienced were due in large part to the extensive and thorough operations, which continued to be necessary for the control of bubonic plague. In the first year of the poisoning revolution in the 1920s, 12,000,000 separate baits (50 tons) were applied to 15,000 acres of cane land. Naquin expressed his disappointment that the intense poisoning operation failed to eliminate the plague threat in a letter to President F.E. Trotter, Territory of Hawaii Board of Health, on August 20, 1923. "We had hoped that the diminishing of the rat population would also have its effect on the plague conditions in Hamakua," said Naquin. Unfortunately it did not fully curb it, although we should assume that the situation might have been worse without the campaign. In reality, the plantation management had few other preventative options, and were honestly doing the best they could. He went on to say, "We are continuing our efforts along the lines of rat extermination, and hope that eventually this disease will be stamped out."[120] Poisoning rodents constituted the most basic and effective weapon in the war on rats. C.E. Pemberton praised poisoning operations:

> It is believed that the continuance of the rat poisoning at Honokaa will considerably alleviate the plague menace there, and the more widely the poisoning is extended in the district of Hamakua the better will become the chances for plague eradication there. The fewer rats present, the less chances occasional infected individual rats will have to pass the disease on in the particular locality where it may be. Infected foci will become reduced, for without rats present, almost immediately to pick up fleas from other rats sick or dying from plague, the disease must necessarily die out in those spots in a very short time, for the life of the flea is short without fresh blood for food, and the life of the plague bacillus is also comparatively short outside its living host.[121]

[120] HSPA Archives, HSC 33/10 Rat Poison Correspondence – 1922-1927.
[121] Pemberton 46.

Despite failing to wholly eliminate plague, poisoning was the most important anti-plague measure conducted by plantation management.

Of the various rat specious found in Hawaii, the native Hawaiian rat, *R. hawaiiensis* was believed to be the primary reservoir of plague in the wild.[122] Mice, mongooses, other small mammals, and of course all the other rat species also acted as reservoirs, but especially considering the rural behavior of the *R. hawaiiensis* it became important for Hamakua plantations to focus their rat control efforts on that species. This particular species is a descendent from the Polynesian rat, and is much smaller than the other rat species with which it competes.[123] One study found that 12 of 15 trapped plague infected rats were of the species *R. r. alexandrinus* or *R. rattus*, but postulated that their infection traveled up the trophic food chain as these invasive larger rats preyed on their smaller cousin.[124] In most areas of Hawaii, the Hawaiian rat is also the most prevalent rat species. Because cage tests showed thallium sulphate to be an effective measure against the Hawaiian rat, it was a popular poison choice in the 1930s. This poison mixed with bait, however, produced familiar results of diminishing efficacy. The study on Maui concluded that if a rat survived thallium sulphate poisoning three times, it became wholly aware and completely refused the bait thereafter. Throughout the majority of the plague period in Hawaii, scientists tried many poisons but none could act as a golden bullet, and multiple angles of attack remained necessary.

Considering all the problems associated with direct poison baiting methods such as waste due to spoiling, high labor costs, and diminishing efficacy; it became clear that new methods must be developed. In order to discover new rat control techniques, the

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[122] Kartman 590.
[123] Johnson 334.
[124] Dropmeyer 1540.

Hawaii Sugar Planters' Association employed scientists such as R.E. Doty. In 1939 this man revealed just such a different and more effective approach, known as the "prebaiting feeding station method."[125] Essentially this plan called for less, more central feeding stations that were stocked with non-poisoned grains for a period of at least six days. The initially suspicious rats acquired the habit of feeding at these stations, and whole field populations developed confidence in consuming this abundant food as their main nutritional source. Once a majority of the population gained such confidence, the rat control operator substituted the poison-free food with poisoned bait, which was then readily eaten and resulted in mass rat fatalities. Because the rats readily ate such large quantities of the poisoned rolled oats, operators administered lower concentrations of poison and still produced dead rats. C.E. Pemberton originally experimented with this method in 1936 at a Manoa experimental field on Oahu, but tests discontinued "following the unfortunate poisoning of three dogs that ate the rolled oat briquettes."[126]

Within the idea of prebaiting, Pemberton made continual improvements. In order to combat accidental poisoning and especially to prevent molding, experimenting produced the idea of using square tin feeding stations with arched galvanized iron covers. In the course of prebaiting experimentation, Pemberton found that rat preference for grain had the following order: sunflower seed, rolled oats, rolled barley, cornmeal, cracked corn, wholewheat, and finally milo maize. In 1937, an experiment conducted at the Pepeekeo Sugar Company on the Big Island found that sweetening the poison formula greatly increased its attractiveness to rats. The war on rats was necessarily a dynamic process, as it responded to the adaptive rodents.

[125] See Appendix D.
[126] Doty 41.

The prebaiting method had several unique advantages over the older direct poisoning "torpedo" model. Plantations could save on labor costs because they no longer had to wrap each individual torpedo by hand, although this was somewhat offset by increased visits to the field. Unpoisoned oats cost only 4.5 cents per pound, whereas poisoned oats cost as much as 17 cents per pound. Under the older torpedo method, untrustworthy rats nibbling at the bait wasted much of the precious expensive oats. With the newer method, plantations saved money as rats consumed nearly all of the expensive treated bait. Clever scientists even put the seemingly wasted unpoisoned bait to use by using it to survey rat populations, monitoring consumption levels and fecal pellets. The feeding stations with their galvanized iron coverings cost 18 cents each, and plantations placed four stations per acre. They created the base of the feeding stations using 7 by 7 by 1.25 inches baking tins that cost 7 cents each, and the iron in turn cost 11 cents. The poison of choice in this feeding method continued to be thallium sulphate, which was used under concentrations ranging from 1-100 to 1-250. Doty advised that the stations be placed every 90-100 feet (four per acre), and on level ground to prevent collection of rainwater. The total process took about ten days, and needed to be repeated every three months.

Even under this new model, methods of poison bait construction remained a debatable topic. Prebaiting was theoretically effective using a variety of poisons. Nevertheless, thallium sulphate continued to be the preferred poison, as it was efficient and well taken. It was also advisable to use some sort of attrahent (attractive scent) to help the rats find the stations and to mask the human smell, the best of which were found to be corn oil, raw linseed oil, sunflower oil, paraffin oil, and coconut oil.[127] Doty recommended rolled oats as the bait base of choice because of rat preference and the grain's ability to absorb poison. Although barley was an alternative option, rats always refused the hulls and so wasted both the food and its retaining poison. A 1931 report found the minimum lethal dose (M.L.D.) of thallium sulphate to be 31 mg per kilogram of rat.[128] Mass preparation of the bait contained the following formula by Doty's recommendation: 900 pounds rolled oats, 28.75 pounds brown sugar, 9 pounds corn syrup, 8 gallons water, and thallium sulphate. Doty further reports that H.J. Spencer of the Biological Survey found sodium sulphite to be an effective deterrent against mold and he advised its use. It was also possible to mix the familiar paraffin in with the oil attrahent to serve this same purpose. Spencer also conducted experiments to test the utility of sodium benzoate in this function, but they proved to be unsuccessful.

Throughout the 1940s, prebaiting feeding stations continued to proliferate on Hawaiian sugar plantations as the primary method of rodent control, until a somewhat revolutionary new rodenticide arrived: warfarin.[129] Warfarin is an anticoagulant that survives today for medicinal purposes to stop blood clots from forming in blood vessels.[130] This new rat poison was revolutionary because it was completely undetectable by the rodents (100% bait acceptance in lab tests), who consumed low doses of it in daily bait feedings. At lethal levels, warfarin acted to kill the rodents slowly and painlessly by internal hemorrhaging within about a week's time (6.2 day average). In a way, warfarin

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[127] R.E Doty, "The Use of Corn Oil for Thallium Wheat Torpedoes," *Hawaiian Planters' Record* 36, no.2 (1932): 125.
[128] James C. Munch, "The Pharmacology of Thallium and its Use in Rodent Control," *U.S.D.A. Technical Bulletin* 238 (1931): 28.
[129] See Appendix E.
[130] American Society of Health-System Pharmacists, *Wafarin*, http://www.nlm.nih.gov/medlineplus/druginfo/medmaster/a682277.html.

administration was a reversion to the direct poisoning methods, but it was also an adaptation of the feeding station method. Because the poison was so undetectable by rats, it could be kept in the field perpetually without the classic diminishing consumption level problem, so central feeding stations could remain in place. Allowing for at least four days for rats to find the food source, and allowing for outlying resistant rats that may take up to 11 or 12 days to die, Doty recommended that warfarin feeding stations remain in place for up to 16 days. The poison (originally known as Compound 42), was discovered by Dr. Karl Paul Link of the University of Wisconsin. Warfarin was mixed at very low levels (1-4000 or 0.025%), and required the rodents to eat an average of 36.3% of their body weight in treated oat mixture. The introduction of warfarin basically eliminated the need for prebaiting.[131]

When compared to the prebaiting feeding station method, warfarin poisoning was full of many advantages. Without the need to remove unpoisoned oats and to continually treat fields every three months, warfarin reduced the labor load. This was very useful in balancing the additional costs associated with the new and expensive drug. Additionally, not only was warfarin expensive, but because oats were perpetually treated and because warfarin was slow acting, plantations incurred these costs over more days. The additional time burden on feeding stations also caused a greater demand for new feeding stations. Nevertheless, new feeding stations were a one-time cost, and the overall cost of warfarin dropped with time. Furthermore, warfarin offered the distinct advantage of reducing the dangers of accidental poisoning to both humans and other animals as a greater quantity had to be consumed and Vitamin K existed as a known antidote. The

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[131] R.E. Doty, "Warfarin (Compound 42): A Promising New Rodenticide for Cane Fields," *Hawaiian Planters' Record* 54, no. 1 (1951): 1.

low toxicity also created a situation where there was very little danger of secondary poisoning when predators ate animals that died from warfarin. To illustrate this point, Dr. Link personally ate and served to his family some chickens killed using the new poison.[132]

Another valuable advantage was that warfarin was only slightly soluble in water, and so was ideally suited for use in the high moisture sugarcane fields of Hawaii. Nevertheless, para-nitrophenol (0.3 to 0.4%) was added to help prevent molding. Mineral oil was also added in the mixing process (one quart for every 15 pounds of rolled oats) to promote mixing of the powdered poison. Because all bait seemed to benefit from sweetening, Doty recommended the addition of 2% raw sugar crystals. The comparative costs for warfarin treatment were 50.7% higher than thallium sulphate and 78.3% higher than zinc phosphide.[133]

A field study produced on the Big Island the same year as Doty's report yielded an interesting finding regarding the native Hawaiian rat Curiously, the *R. Hawaiiensis* seemed to be slightly more resistant to warfarin than other rat species. The mean days until death after consumption for the Hawaiian rat was 7.9 days, while it was only 5.4 days for *R. norvegicus*, 5.8 days for *R. rattus*, and 6.8 days for *R. r. alexandrinus*.[134] The field study occurred on field 109 in plague zone 3A on the Honokaa Sugar Company lands in Hamakua. From February 9 to May 11, 1951, rats consumed 316 pounds of bait in 200 feeding stations there. Generally, results were positive and the numbers of most rat species declined, but curiously, the Hawaiian rat number actually increased. Because

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[132] Doty 2.
[133] Doty 12.
[134] David D. Bonnet, Edward S. C. Mau, and Bertram Gross, "Cage Tests With Warfarin on the Hawaiian Rat, *Rattus hawaiiensis* Stone, and the House Mouse, *Mus musculus* Linn., in Hawaii," *Public Health Reports* 66, no. 52 (1951): 1735.

it was known that the Hawaiian rat with its smaller stature suffered due to competition, the rise in their number could have been due to a sudden reduction in competition from the more poison-susceptible and aggressive rodents that were dying at higher rates. Simultaneous trapping occurred and autopsies of captured rats revealed that 59.8% of surviving *R. hawaiiensis* rats showed evidence of consuming warfarin treated oats. Therefore, the native rat did not have an objection to the poison, but merely chose to sufficiently supplement its diet with other natural foods. This reinforced the realization that poisoning efforts were not effective alone, but had to be paired with other strategies such as traditional food disruption. Nevertheless, this presented one severe limitation of warfarin, as the Hawaiian rat was known to be the primary reservoir of plague infection.

From barium carbonate to warfarin, poisoning was the best tool available to control the rats in Hamakua. Although this method was not psychologically as pleasing as trapping because there were fewer visible rat bodies, it was far more effective in its killing power. Plantations utilized poisoning for the dual purposes of plague control and reducing rat-damaged sugarcane. The Honokaa Sugar Company under Naquin was particularly involved in researching and developing poison techniques, and achieved economic success from their efforts. In the search to find the best poisons, the HSPA worked with Hamakua plantations. The Board of Health also aided the poisoning campaigns, because of the effects on plague, by providing discount poisons and free rat monitoring services. While no one poison or method decimated the rat population (with the disputable exception of warfarin), the consistent cooperative efforts effectively checked the rodent population and contained plague.

Killing the Natural Way

In order to control the rat population and therefore check bubonic plague, natural biotic stressors were sometimes employed in Hawaii. Inasmuch as rats have come to infest the entire world in many diverse localities, as smaller mammals they also have encountered equally diverse predators higher on the trophic chain. Cats, dogs, owls, hawks, snakes, and the mongoose are some of the natural enemies of the rat. In order to combat a rat infestation, one may choose to introduce such a predator and let nature take its course. Plantation management tried over the years to implement these stressors to varying degrees.

The use of natural rat enemies had only limited success on plantations. Dogs were an example of a domestic animal used by plantations and trained to kill rats. Dogs "killed many rats in cane fields at harvest time, but the percentage so killed, in comparison to the rodent population present is necessarily quite small."[135] Domestic dogs were not able to hunt for rats year round because of the same inhibiting factor of so many control agents; the rat was too good at hiding amongst the dense vegetation of Hamakua. Once a field was harvested, however, evacuating rats sought cover under the discarded cane, becoming easy targets for the dogs. While dogs could kill thousands of rats in this manner, the prolific rodents overall were hardly affected.

Cats were another common rat enemy employed in the war on rats on plantations like Honokaa. While cats were excellent predators, Pemberton reported, "Cats in large quantity are difficult to secure and practically impossible to keep within the desired bounds in fields because of their great domesticity." Attempts to develop or procure wild

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[135] Pemberton 42.

domestic cats were not successful on a large enough scale. Nevertheless, feral cats did exist, and like dogs, took a limited toll on the rat population. [136]

In many countries, snakes were used to control rats, but no snakes ever existed in Hawaii. Ecologically speaking, Hawaii is a unique island paradise, and the preservation of native species is generally encouraged. To this end, invasive species of all sorts should not be allowed within its borders. The same was felt to a lesser extent in the early twentieth century, and so quarantine regulations existed that prevented the importation of snakes to the islands.[137]

Birds of prey were of particular interest to plantation management. The archives of the Honokaa Sugar Co. have several pieces of literature on the subject, indicating their curiosity. Owls in particular were known to be excellent hunters and the barn or "monkey-faced" owl was commonly used in the continental United States. Owls had the advantage of sharing nocturnal habits with their prey, and unlike domestic animals they were fully independent. Archives revealed one excerpt on the subject, taken from the September 9, 1922 copy of the San Francisco *Argonaut*:

> In the dark a man cannot see the rat that scents and avoids him; but the rat can neither see nor hear the owl, which descends upon him with silent wings and carries death in its grip, for the owl's feather-shafts are rounded and the owl's claws in gripping pierce the heart. After a time the rat grows poison-shy and trap-shy...The rat may serve a purpose, though in the present state of our knowledge it is an unmitigated evil; in any event, its numbers and its habits constitute a national menace.[138]

In Hawaii the barn owl was not imported for this work, as a native Hawaiian owl, *Asio accipitrinus sandvicensis*, already existed. Additionally, there was the Hawaiian hawk,

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[136] Pemberton 42.
[137] C.C. Barnum, "Rat Control in Hawaii," *Hawaii Planters' Record* 34 (1931): 423.
[138] HSPA Archives, HSC 8/9 F.A. Schaefer & Co. In & Out – 1922.

Buteo solitarius, which was also a useful hunter of rats.[139] In his November 1921 report on rat control, HSPA Associate Chemist Frederick Hansson encouraged the protection of hawks, owls, and all natural rat enemies, which was carried out by the sugar plantations.[140] Nevertheless, because of the prolific numbers of rats and relatively small numbers of birds of prey, the effects of hawks and owls were also somewhat negligible.

The Indian mongoose (*Herpestes griseus*) was the most practically implemented biotic control in Hawaii, and therefore has the richest history. The mongoose was originally introduced to Hawaii in 1883 for the very purpose of rat control work. Because the mongoose had plenty of food supply and no carnivorous competition besides the above-mentioned birds and the occasional feral cat, mongooses fed extensively on rats in the Hamakua district. One study of the mongoose feeding habits revealed that 88.4% of their droppings contained rodent parts. These parts included bone, teeth, and hair of rodents. The only other thing that the mongoose fed on was insects, primarily cockroaches.[141] Perhaps the mongoose would have been a more effective rat killer, if it were not for the fact that rats are primarily nocturnal while the mongoose is a day feeder. Occasionally the mongoose became a nuisance to plague control employees. Sometimes attempts to live trap rats for various plague investigative reasons were foiled by mongooses that would kill and eat the defenseless trapped rodents.[142] Again, the rat population of Hamakua was so prolific, that no control measure could keep up. The mongoose, although an effective rat killer and an important force, was not prolific enough to keep down the huge rodent population. The effects of the mongoose on

[139] Pemberton 43.
[140] HSPA Archives, HSC 23/3 General Correspondence In & Out – 1921-1922.
[141] Harry T. Kami, "Foods of the Mongoose in the Hamakua District, Hawaii," *Zoonoses Research* 3, no. 3 (1964): 166.
[142] Dropmeyer 1544.

Hawaii Island can be inferred by comparison to the island of Kauai. Unlike Oahu, Maui, and Hawaii, Kauai never had the mongoose introduced, and the results showed a clear increase in the amount of rat-damaged sugarcane on that island versus its mongoose-inhabited counterparts.[143] Still, the mongoose had a noticeably positive influence, albeit slight, in controlling the rat population.

Nevertheless, the mongoose came to hinder the anti-plague campaign, and so its use for this endeavor was ironic. By the 1920s, scientists discovered that the mongoose could and often did pick up large number of plague-infected fleas from its meals, and then scattered the infected ectoparasites as it moved about. In addition to simply spreading infected fleas around, lab tests in 1910 first showed that the mongoose, when bitten by these fleas, was also susceptible to the *Yersinia pestis* bacteria. A jointly funded federal and state serological study in 1965 reported on these facts. The study showed that the mongoose may become infected either by the bite of a flea (traditional vector), or also possibly through the ingestion of infected rats.[144] On March 19, 1912, the *Hilo Tribune* reported on the return of three men from the Hamakua district, who had visited the area to check on the plague campaign there. The men were Chief Inspector Bowman and President Dr. Pratt of the Board of Health, and the plague expert Dr. George W. McCoy of the Marine Hospital Service. On that trip, they discovered the first ever naturally occurring plague mongoose. At the time, Dr. McCoy could not determine if it was a sporadic case or if the infection was becoming common among the mongoose. For the same reason that the mongoose failed to exterminate the rats fully, lacking numbers, it

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[143] Barnum 423.

[144] K.F. Meyer, D. McNeill, and C.M. Wheeler, "Results of a Preliminary Serological Survey of Small Mammal Populations for Plague on the Island of Hawaii," *Bulletin of the World Health Organization* 33 (1965): 814.

did not pose a large threat to human life.[145] Later serological surveys showed that plague infection amongst the mongoose was in fact rather common. Many mongooses showed resistance to plague inoculation, and had acquired plague antibodies.[146] The mongoose, therefore, while constituting the most effective biological control of the Hawaiian rat population, ironically failed to slow the spread of plague as it proved susceptible itself.

"Rat Virus" Experimentation

In the constant struggle to find more effective rat control measures, certain microorganisms were marketed as "rat viruses for the destruction of rats". Plantations administered these viruses much like poisons, by contaminating bait for rodent consumption. In the early part of the twentieth century, bacteriology was still a relatively young field. With unknown limitations, constant experimentation conducted by scientists and entrepreneurs tested for useful and profitable applications of microorganisms. Like introducing the mongoose or the owl, the introduction of fatal pathogens constituted an attempt to control rats via biological manipulation. Plantation managers received ample solicitations for the rat virus during the early 1920s. On December 18, 1922, Manager W.P. Naquin of the Honokaa Sugar Company received such a sales pitch from the Department of Animal Industry at the Parke, Davis & Company in Detroit, Michigan.[147] This large veterinary, biological, and medicinal product firm, which also boasted laboratories in Canada, England, and Australia, peddled a rat virus under the name of "Azoa." They claimed, "Azoa being a virus of a disease peculiar only to rats and mice

[145] *Hilo Tribune*, "Hamakua Health Campaign Work," March 19,1912.
[146] Harry H. Higa, William T. Matsuura, and Walter H. Watanabe, "Plague Antibody Response in the Mongoose," *Hawaii Medical Journal* 30, no. 2 (1971): 94.
[147] HSPA Archives HSC 33/10 Rat Poison Correspondence – 1922-1927.

has the advantage over cumbersome traps and dangerous poisons".[148] Undoubtedly, to optimistic plantation managers, the rat virus represented an exciting opportunity to capitalize on modernity. At the recommendation of President J. W. Waldron, Mr. Naquin ordered five dozen tins of a competing product for trial, known as the Liverpool rat virus.[149] At twenty shillings or about five dollars a dozen, the plantation management found a trial of that product to be a low-risk investment.

Optimism for the rat viruses waned rather quickly, however, as numerous such trials disproved the vendors' claims. In 1925, the United States Biological Survey reported that there were $500,000 in annual expenditures on bacterial rat viruses in the U.S.[150] Because there were so many competing brands, each seemingly produced under sound scientific logic, plantations only slowly realized their inefficiency over the course of a few years and after various experimentations. Honokaa Sugar Co. tried testing a rat virus known as "Ratin" in January of 1922, but found the results inconclusive due to a large and open testing area, and thus referred the testing to the HSPA Experiment Station under the direction of H.P. Agee.[151] During these years, agricultural organizations from all over the world conducted similar trials on various products. The persistence of rat viruses in the market revealed the eagerness to find a solution. In reference to Ratin, Mr. Agee remarked, "It is very doubtful if such preparations can be used to advantage, but by making a thorough trial of them we do no harm".[152] By the middle of 1925, HSPA entomologist C.E. Pemberton concluded: "Testimonials highly recommending [rat

[148] HSPA Archives, HSC 33/10 Rat Poison Correspondence – 1922-1927.
[149] HSPA Archives, HSC 10/1 F.A. Schaefer & Co. In & Out – 1925.
[150] Barnum 427.
[151] HSPA Archives, HSC 23/3 General Correspondence In & Out – 1921-1922.
[152] HSPA Archives, HSC 23/3 General Correspondence In & Out – 1921-1922.

viruses] have been frequent, and accounts of results have read well, but careful and continued investigations have usually shown them to be of little value".[153]

These so-called "viruses" were actually bacteriological in nature. They were microorganisms originally found in dead and diseased rodents, then harvested and exploited in the hope of destroying rats. These rodent pathogens offered the great potential benefit of selective preference. They advertised that they could kill their targets without accidentally harming humans or domestic animals. The exploited organisms were largely found in the paratyphoid-enteritidis group, specifically different varieties of *Bacillus enteritidis*.[154] F. Loeffler first isolated the most prevalent bacteria, *Bacillus typhi murium*, in 1889.[155] The rat virus products, therefore, were actually samples of naturally occurring rodent diseases. From a modern perspective it is easy to see that rodents lived with these bacteria for millennia, and were not likely to become extinct from their increased prevalence. Rats, furthermore, are highly resistant and adaptive, and these diseases were destined to fail because of the natural physiological responses of the rat. The fact that these bacteria were endemic in the rodent population already further doomed rat virus products, as many rat would have already developed or acquired immunity.

Public authorities and rat extermination specialists came to realize the flawed nature of rat viruses with the completion of experimentation. In the files of the Honokaa Sugar Co. there is a 1922 report from the Department of Veterinary Science, North Dakota Agricultural College as reported by California Department of Agriculture. This

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[153] C.E. Pemberton 25.
[154] William Hallack Park, *Microorganisms: A Practical Manual for Students, Physicians and Health Officers* (New York: Lea & Febiger, 1920): 398.
[155] C.E. Pemberton 25.

investigation used the freshest of virus material, held rats in close proximity to make certain of contact, and gave "the animals generous quantities of the material and at all times they ate freely and with relish". The study dealt with Reefer's Rat-Viro, Alexander Rat Killer, Pasteur's Liquid Rat and Mouse Virus, and Azea. The study concluded that these products had no qualities of contagium and did not "possess in any degree the efficiency and death-dealing qualities for rats as advertised and claimed by the manufacturers". The study agreed with similar investigations by the British government in India and the Italian Agricultural Society.[156] Honokaa Sugar also had a similar report by the Biological Survey of the United States Public Health Service, which concluded that there were four principal defects: The virulence was not great enough to sufficiently kill the rats, that the virulence of the viruses declined too rapidly with time, that the resulting diseases were not contagious between rats, and that they cost much more than poisons while requiring greater skill in their preparation.[157] Interestingly, plantations such as the one in Honokaa continued to try new rat virus brands even three years after receiving these reports, revealing the urgency of the rat problem in the early 1920s and the thoroughness with which the plantations tried to solve it. Additionally, rat viruses posed a threat to human health if they contaminated food, as the bacteria readily grew in various media. The created substances were poisonous to man, and so by 1931, two separate State Boards of Health completely banned their sale.[158] In the fight against plague reservoir rats, "viruses" constituted another dead end. Poisons remained preferable to rat viruses in the rat campaign.

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[156] HSPA Archives, HSC 23/3 General Correspondence In & Out – 1921-1922.
[157] HSPA Archives, HSC 23/3 General Correspondence In & Out – 1921-1922.
[158] Barnum 427.

Gassing

Another method tried for controlling the rat population was the use of gas for mass extermination. On the national scale, gassing and fumigation were critical components of rat control in the early twentieth century. A 1925 report of the USPHS activities on plague revealed that agency to have been very involved in monitoring ports and vessels for plague. They advocated proper trapping, rat identification, and animal inoculation to determine plague foci. With the discovery of plague, the USPHS recommended rat proofing and fumigating vessels. They experimented with hydrocyanic acid-cyanogen chloride and cyclone B, finding encouraging results using 80% liquid hydro-cyanic acid gas with 20% liquid cyanogens chloride.[159] These valued efforts certainly helped to halt the spread of plague to the United States, and helped limit plague to its enzootic region in Hamakua. Without such aid, perhaps plague would have spread frequently back into urban centers such as Hilo or Honolulu. The rat proofing and fumigation of buildings, both in urban areas and in plantation structures, were effective methods of rat control, but naturally did not affect the sylvatic plague in the cane fields.

Methods of gassing rodent burrows, however, did dominate rodent control efforts elsewhere. On the mainland, the gassing of prairie dog, ground squirrels, and similar rodents had great success. Popular gases were carbon disulfide, sulphur dioxide, and cyanogen. Java, another sugar-producing tropical island, was able to successfully utilize gassing in their rice fields, but natural problems existed in gassing the burrows in cane fields.[160] In 1921, Frederick Hansson, Assistant Chemist of the HSPA, conducted rat control experiments at the Honokaa Sugar Co. with the full cooperation of the

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[159] Public Health Service, *Annual report of the surgeon general on the Public Health Service of the United States for the fiscal year 1924-1925*, (Washington, DC: Government Printing Office, 1925): 135.
[160] Pemberton 7.

management there. In looking for burrow holes to gas, he and an associate took 45 minutes just to find two holes. The inherent problem with gassing in the cane fields was that far too much cane trash, tall grass, and other burrow-concealing factors restricted authorities' ability to find the burrows. Because each burrow may have multiple entrances, effectively finding occupied burrows, sealing them off, and then gassing them was nearly impossible. Only once the sugarcane is harvested and the field cleared of debris (usually by burning) could the numerous burrows easily be found. The Hawaiian field rodents, however, although not generally migratory, revealed their adaptive nature when food supplies were exhausted. Hansson gassed field burrows one day following firing, and found them all to be completely deserted. It became clear that as soon as a cane field was harvested, the occupying rodents instantly moved to new localities, including other cane fields, nearby rock piles, and neighboring gulches. The vegetation and climate of the Hamakua District again proved to provide suitable and sustainable resources for the rat population, undermining control efforts.[161]

Guy R. Stewart, Chemist for the HSPA, in a joint effort with Hansson, conducted a thorough experimentation of gassing in December of 1921. Using rats furnished by the Pathology Department, Stewart conducted his experiment on the toxicity of Aero Brand Gas Flakes at the Makiki Station on Oahu. Using knowledge of soil consistency and rat burrowing habits of Hamakua, the chemists recreated artificial burrows at their station. They made the burrows airtight with soil compaction, and placed a rat at one end of the burrow and the poison gas at the other, or about ten feet away. Stewart used various doses, from five grams up to seventy-five grams of gas flakes, but no trial showed enough efficiency to spread throughout the burrow and kill the rat, rendering the gas

[161] HSPA Archives, HSC 23/3 General Correspondence In & Out – 1921-1922.

flakes as useless. Testing the efficiency of other gases, Stewart tried using one-ounce liquid carbon bisulfide, which also failed to be fatal. When saturated carbon bisulfide was pumped into the burrow, however, the rat died in eight and a half minutes. Stewart also tried sulphur dioxide, but found that after using a full two pounds of this substance it still took twenty-seven minutes for the rat to die. He therefore concluded that any successful gas must be dense, insoluble in water, only slightly absorbed by the soil, and be able to be pumped into the burrow with moderate pressure. The carbon bisulfide came closer to these requirements than the gas flakes.[162] Given that for these results to be successfully applied in the field, it would have been necessary to find every burrow entrance, fill them in with soil, and pump them full of gas while the rats still remained inside, gassing was not a viable option in the overgrown cane fields of the Hamakua District.

Flea Control: Taking a Bite Out of Plague

By 1915, experts accepted that the transmission of plague occurred via a reservoir-vector relationship consisting of rodents and fleas. The progressive thinking and cooperative efforts of Hawaiian leaders facilitated effective use of this knowledge to control plague by controlling reservoir population. Efficient flea control methods however, did not arrive until the 1940s. In the chain of plague infection, treating the rat population had the advantage of fewer, more visible enemies, which were also agricultural nuisances. However, prolific rats proved difficult to control, so treating their ectoparasites was desirable. Dr. Carter's 1943 prophylaxis called for spraying under houses to kill fleas, "with such agents as Lysol, cresol, chloride of lime, 5 per cent

[162] HSPA Archives, HSC 23/3 General Correspondence In & Out – 1921-1922.

carbolic acid, or 2 per cent formalin solution."[163] Successful control, nonetheless, did not occur until the development of Dichloro-Diphenyl-Trichlorothane (DDT).

Even before the development of this chemical, Eskey conducted important biological experiments on the role of fleas in plague epidemiology. In his 1934 survey, he found seven separate species of fleas living on Hawaiian rats: *Pulex irritans*, *Ctenocephalides felis felis*, *Echidnophaga gallinacea*, *Leptopsylla segnis*, *Nosopsyllus fasciatus*, *Xenopsylla hawaiiensis*, and *Xenopsylla cheopis*.[164] Of that list, the last two species (those of the genus *Xenopsylla*) were particularly important in transmitting plague. While *X. cheopis* was the known plague flea across the globe, the *X. hawaiiensis* was native to the islands. The early urban epidemics in Honolulu and Hilo predominantly occurred via invasive rats and *X. cheopis*. The brown and black rats that lived near human habitation and their corresponding plague flea species spread the disease there. However, urban plague was short lived in Hawaii, disappearing within twelve years. By contrast, in the persistent plague foci of Hamakua, the disease lasted for four decades. Eskey postulates that plague could not survive in the urban centers because it lacked sufficient vector numbers, while "the only possible explanation of the endemic plague in Hamakua is the presence of a large number of rodent flea species."[165] The prevalence of the *X. hawaiiensis* flea greatly helps explain how sylvatic plague persisted there. It has already been established that the *R. hawaiiensis* was a critical reservoir in maintaining enzootic plague, and it was the adapted Hawaiian flea that transmitted it amongst these field rodents. Eskey further pointed out that the Hawaiian flea

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[163] C.L. Carter, "Bubonic Plague on the Island of Hawaii," *Hawaii Medical Journal* 2, no. 6 (1943): 298.
[164] Eskey 13.
[165] Eskey 51.

outnumbered *X. cheopis* 2 to 1 in Hamakua, and that the summer plague prevalence corresponded with summer *X. hawaiiensis* prevalence.[166]

The use of DDT in Hamakua became an important control measure in the 1940s. In West Africa, in 1944, the U.S. military first successfully applied DDT in the field.[167] Hamakua authorities desired a new method of plague control, as years of rat control showed few signs of reducing enzootic plague. However, the discovery of DDT and like insecticides did not instantly constitute a magical plague bullet in Hawaii. Authorities had to consider all the effects of the new chemical, and could not just spray insecticide indiscriminately, as they progressively realized the possible adverse effects. Mainlander Dr. Wilbar, on the other hand, advocated, "The plantation workers could certainly be kept free from fleas by treating their clothes and living quarters with D.D.T."[168] DDT use posed a threat to beneficial imported entomophagous parasites that combated sugarcane pests, it could be quickly rendered ineffective by Hamakua rains, and it was not known if absorption by the sugarcane posed a threat to human health.[169] In order to deal with these peculiarities of the Hamakua District, plague experts developed a means of using the rats themselves to disseminate DDT.

The effective dispersal of DDT in the late 1940s came in the form of DDT bait boxes.[170] These bait boxes contained any variety of bait from the typical barley and oats to coconut, pineapple, banana, or other available fruits. However, in instances where anticoagulant poisons like warfarin were mixed with the bait, it remained best to use

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[166] Eskey 52.
[167] Leo Kartman and Richard P. Lonergan, "Wild-Rodent-Flea Control in Rurual Areas of an Enzootic Plague Region in Hawaii," *Bulletin of the World Health Organization* 13 (1955): 50.
[168] Wilbar 36.
[169] Kartman 52.
[170] See Appendix F.

rolled oats. As a rat entered the box, it triggered a release that dusted it with DDT from above. For good measure, this happened again as the rat exited, and copious DDT dust on the floor treated the rat's underside. The three-compartment method with two entrances and a central bait box allowed the rat to enter from either direction. Upon moving through the DDT compartments, the rat moved a baffle, causing the DDT dust to sift down. Kartman reported on some DDT investigations conducted at the Paauhau Sugar Plantation Company in 1952. The study showed that that 10% DDT solution was an effective killing ratio. Plantations in Hamakua purchased thousands of these bait boxes, made from galvanized iron or aluminum, at the cost of just over one dollar each.[171] Kartman reported on the results, finding that DDT effectively curbed both *X. cheopis* and *X. hawaiiensis* plague-vector populations. Because the DDT-dusted rats returned to their burrows, taking the insecticide with them, more fleas were killed than just those that entered the box with the rat. A reduction in vector fleas was not only important in reducing the risk to human life directly, but also in decreasing the probability that enzootic plague would turn into an epizootic.

As the work occurred very late in the plague era, only becoming an established plague control method after the last case of human plague, it is difficult to praise it as an important control activity during the period of interest. However, it may be true that DDT use was critical to the final removal of enzootic plague in the 1950s, turning a normal quiescence period into total extinction. Therefore DDT, along with the medical miracles (vaccines and antibiotics) that emerged around World War 2, was important in the final removal of plague.

[171] Kartman 52.

Conclusion

In three separate pandemics, the plague ravaged humankind with sudden and violent fervor. Accounts of the relentless pestilence creating endless numbers of corpses during the first two pandemics forever burned fears into human history. While Europe survived the Black Death, the infamous legacy it left haunted humans for generations. The fear was well founded, because the mysterious disease disappears as suddenly as it comes, only to arise again without warning. Plague of course did not disappear, but has always existed in permanent enzootic foci. Plague only appeared dormant to humans, until the nineteenth century, when an enzootic area in China once again bloomed into an epizootic that spread to the human population that launched the deadly third pandemic. For the first time plague reached the New World, spreading globally across the Pacific via new steam technology.

The dawn of the twentieth century brought plague to the western United States and Hawaii, where the disease found additional enzootic plague foci. Conditions in the Hamakua District of the Big Island seemed especially suitable to allow plague to thrive in the local rodent population. New epidemiological knowledge with time began to limit the threat of epidemics, particularly in combating urban scourges. With the interests of many people aiding the campaign in a limited geographical area, dense cities could control reservoir rat populations. Vast rural fields without sufficient combating capital created an entirely different situation, as the enzootic problem remained difficult to manage. Although primarily a problem of the animals, the presence of plague continued to pose a threat to humans, who steadily contracted the disease. This form of plague became known as sylvatic plague, and was particularly worrisome on the island of Hawaii. On the one hand, Hawaii's isolation made the presence of any epidemic disease frightening, so authorities struggled against the sylvatic plague that stood between them and archipelago-wide plague eradication. On the other hand Hawaii was an important port, and a possible source of infection to any other port lining the Pacific in either Asia or the Americas. Of course the victims, their families, and the remaining fearful residents of the Hamakua District had the most to fear.

Private plantations, the Territorial Board of Health, and U.S. Marine Hospital Service (USPHS) worked cooperatively to combat plague in the endemic Hamakua District. Plantation physicians and their hospitals provided healthcare to all Hamakua residents. While all healthcare was generally free for plantation employees, cases of plague were always attended to by plantations, and if needed the Board of Health covered the bill. However, the majority of plague cases afflicted plantation ranks anyways. Although physicians could offer only limited treatments in the early days, isolation and supportive care were important in aiding a few survivors and in protecting others in the name of public health. Later, when suphadiazine and vaccines became reliable treatments, plantations and the Board of Health continued to cooperate in treating humans.

As the twentieth century gave rise to increased bacteriological understanding, specifically the rodent-flea reservoir-vector relationships, anti-plague activities amounted to a campaign against rats. Although empirical knowledge should have led to this conclusion in the past (and to some extent did), the certainty and intensity with which plantations fought rats was novel in plague control. These efforts consisted of combined government and private business efforts, as everyone saw the advantage of eliminating plague. As plantations controlled the majority of land and capital, and stood to lose greatly if a large epidemic broke out, their cooperation was essential. Plantations also had an interest in controlling rats because of the threat they posed to sugarcane production. The Board of Health worked diligently to trap, catalogue, and lab test rodents to determine plague foci. They employed many trappers, who worked with communities and plantations to uncover major threatening plague-rat populations and destroy them. The Board of Health maintained two plague laboratories on the Big Island to achieve their goals. The federal government meanwhile contributed funds, expert personnel, and knowledge from their mainland plague laboratories. They also helped control the spread of plague to and from the islands via inspectors set up in ports.

Plantations were the primary enforcers of the best plague control operation: poisoning. The HSPA assisted them in this endeavor by providing expert research in their experiment station on Oahu, and by sending experts like Mr. C.E. Pemberton out into the field. The plantations were interested in protecting both their labor force and their product. To achieve their goals, plantation managers constantly researched the most efficient poisons and distribution methods. Along the way they attempted many ineffective strategies, and sometimes they proceeded even with knowledge that the method was likely futile, demonstrating their commitment and frustrations. This was the case with the "rat viruses." Some other failed attempts at rat control included gassing burrows and sex specified trap-and-release programs. Poisoning evolved to become increasingly efficient, and accommodated for rats that became bait-shy with time. They made advances in poison types (warfarin) and distribution methods (prebaiting). The archives of the HSPA revealed a good deal about the rat campaigns of one particular Hamakua plantation, the Honokaa Sugar Company. While all Hawaiian plantations felt threatened by rats, Honokaa felt particularly vulnerable because of the increased plague threat. They worked closely with government authorities on the plague campaigns, and received special attention for their personal experimentations in rat poisons.

In the 1940s real improvements arrived to help combat plague. For the first time ever, pharmacology exerted an influence in the fight against plague at the patient level, working on the bacteriological battlefield. New antibiotics could finally cure plague patients. Mainland plague authorities developed the Cutter Vaccine, which was a vast improvement over the weak and precarious immunity provided previously by the Haffkine counterpart. Plantations and Board of Heath employees worked to administer these new treatments to Hamakua residents. The 1940s also brought the newer anticoagulant poisons, which became efficient rat killing tools. Then, with the arrival of DDT, authorities began fighting plague at the vector level by eliminating fleas.

From 1910 to 1949, plague posed a consistent menace to the residents of Hamakua, afflicting at least 112 people and killing 109 during those years. Meanwhile thousands of rats succumbed to the pestilence, some of which public health officials recovered and studied. Plague remained an enzootic disease until the last recorded case of rodent plague in 1957. Although the plague showed periodic times of quiescence, eventually the quiet became permanent.

The disappearance could have been a product of the cooperative combating efforts previously described, or it may have simply died out naturally as vector populations dwindled and reservoirs developed resistance. Plague extinction was likely a product of all these reasons. Nevertheless, the infection could be flying under the human radar even today, lying dormant on the Hawaiian Islands. Without a source for reinfection, the isolated islands have likely remained plague free for many years now, but they still must keep a watchful eye. As there remains no permanent solution for treating enzootic plague, it still poses a remote threat to any former foci that still have resident rats and vector fleas. Plantations and public health authorities must continue to remain vigilant as their predecessors.

Appendix A: Maps

EXTINCTION OF PLAGUE IN HAWAII 263

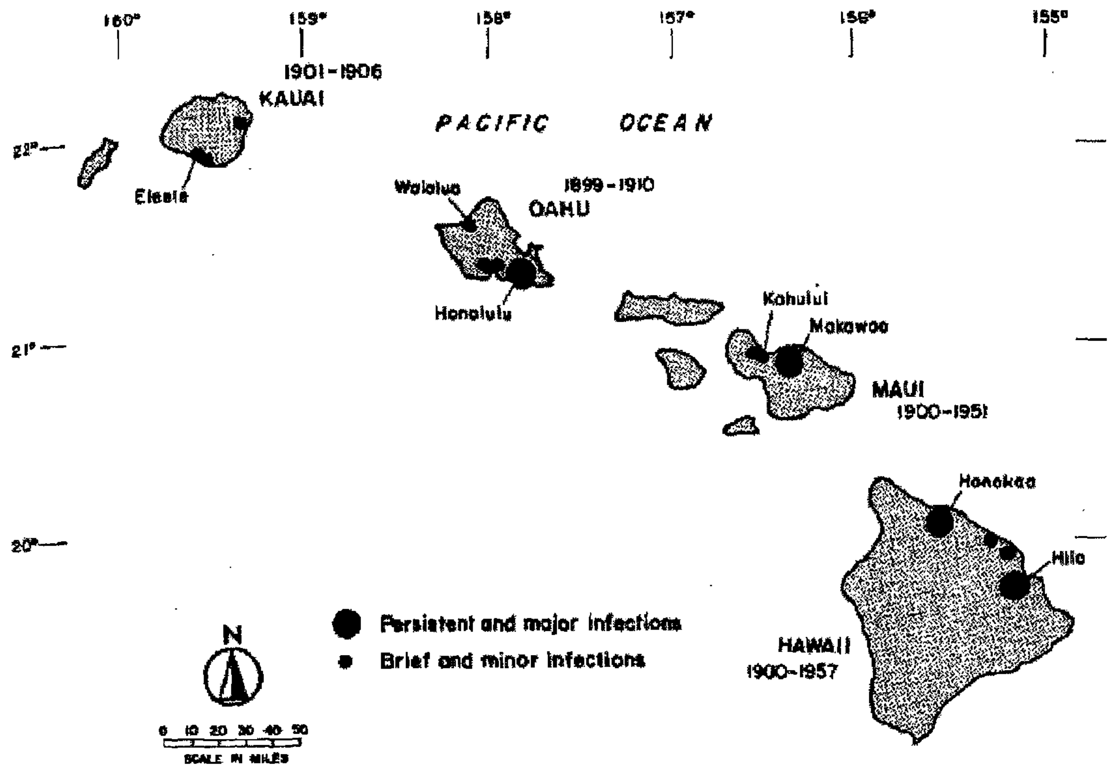
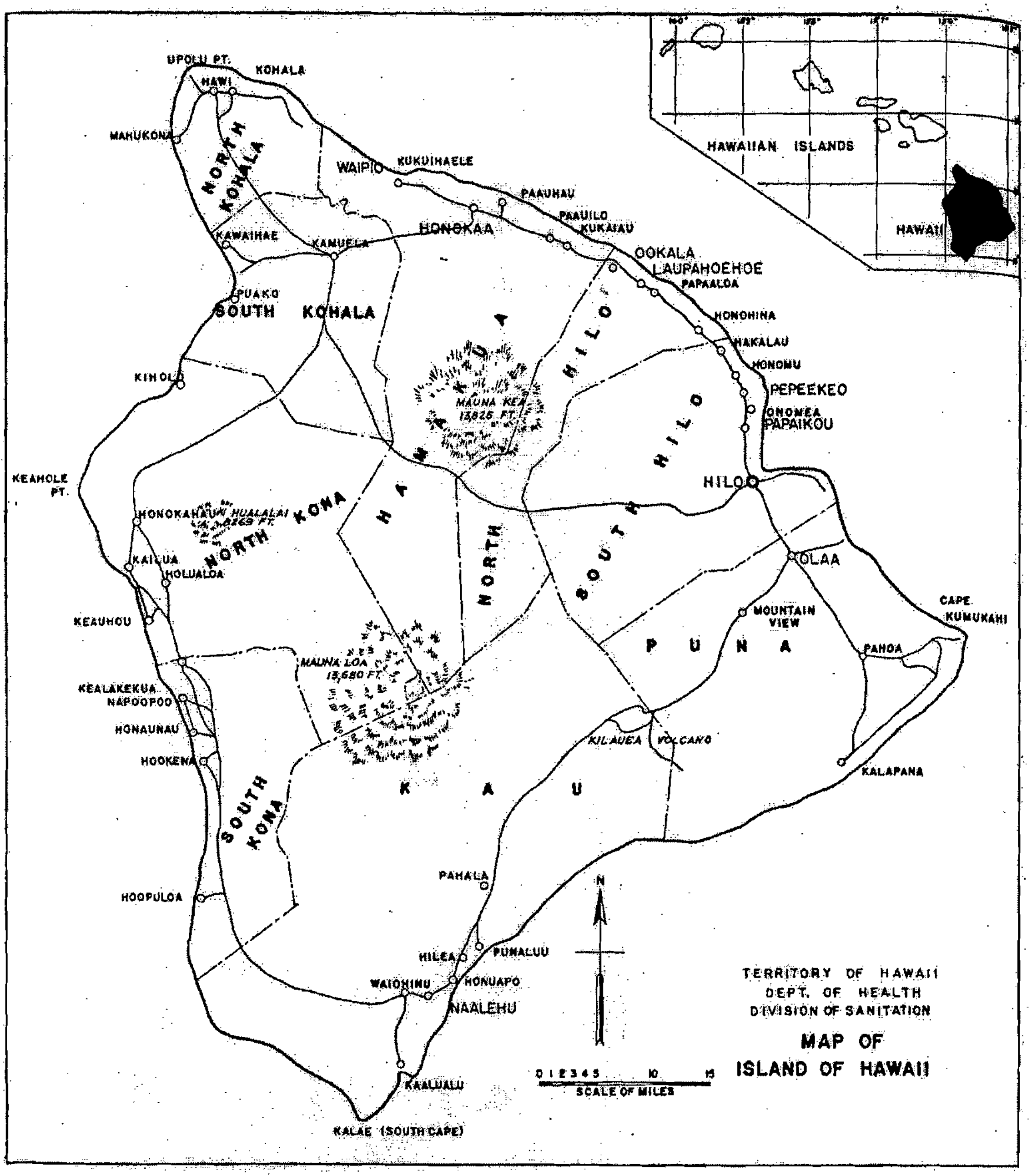


FIGURE 1. Map of the Hawaiian Islands showing the course of plague infection from that first detected at Honolulu in 1899 through the last trace of the disease near Honokaa in 1957. Inclusive dates span individual periods of infection for each island.

Source: Tomich 263.



Source: Gross 210.

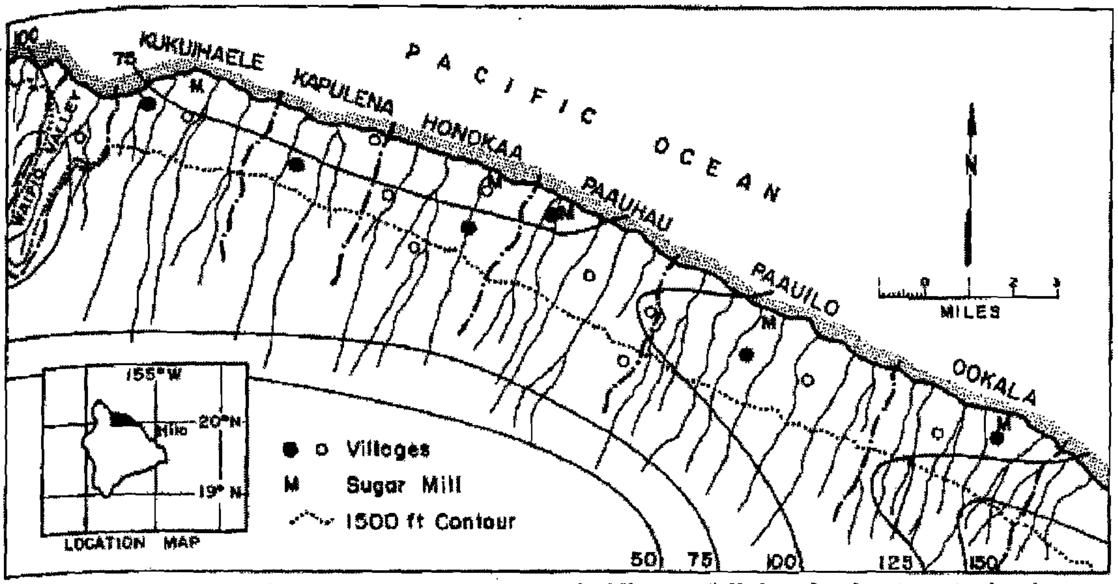
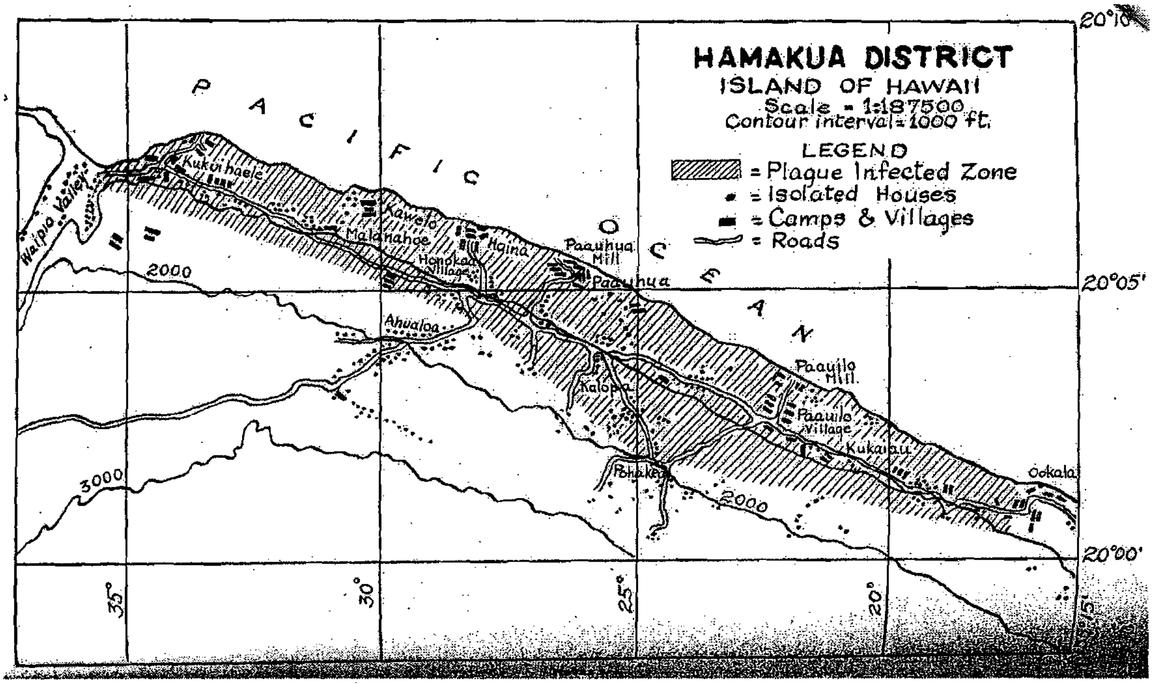


FIGURE 2. Map of the Hamakua plague region, island of Hawaii. Filled circles denote major local population centers; open circles indicate smaller, outlying communities. The 1500-foot contour approximates 460 m. Isohyets for mean annual rainfall in inches are from United States Weather Bureau records overlaid on a geological survey quadrangle. Rainfall of 75 inches equals 1890 mm.

Source: Tomich 265.



Source: Eskey 6.

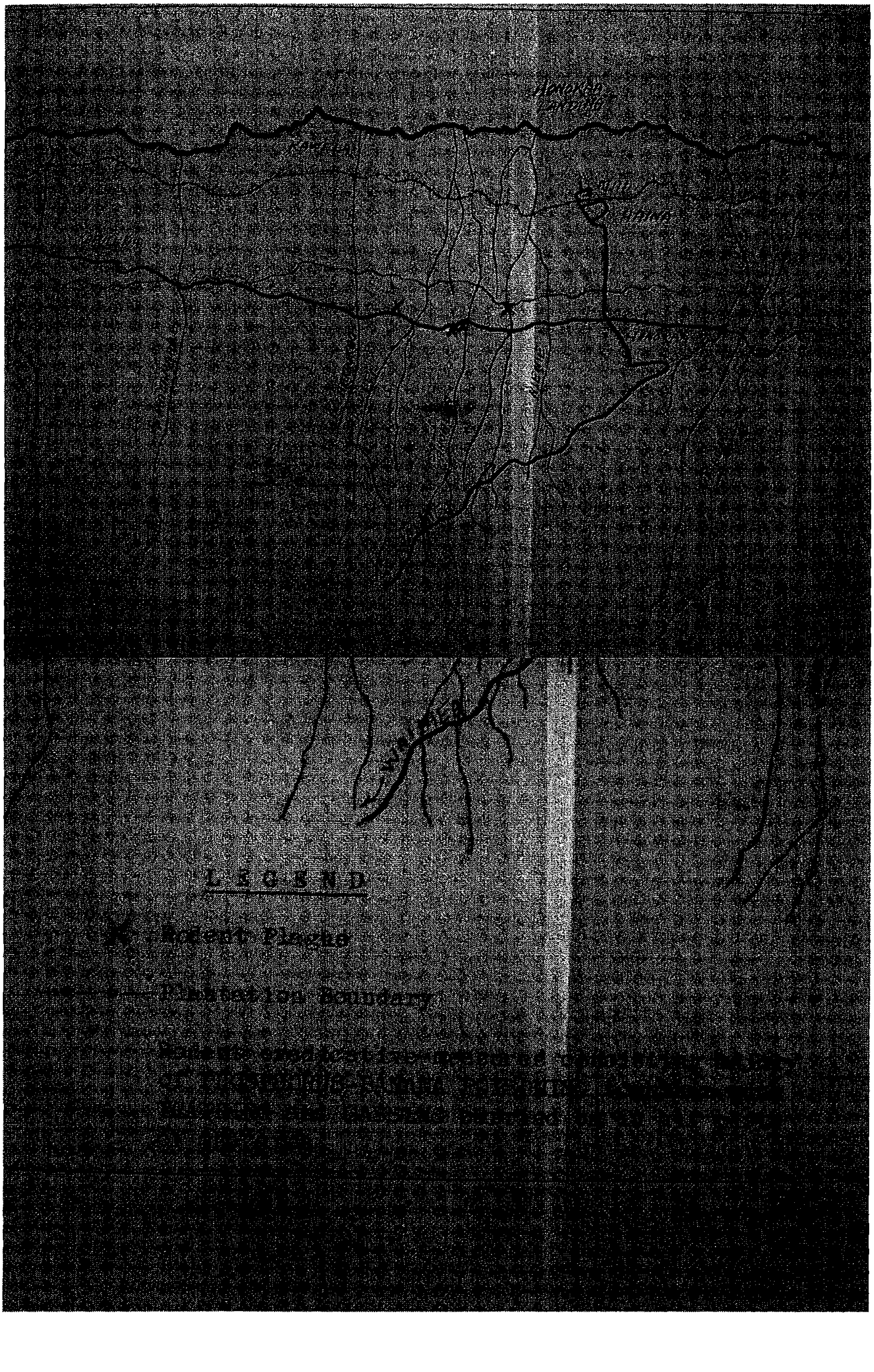
Appendix B: 1939 Board of Health Plague Summary

[illegible]

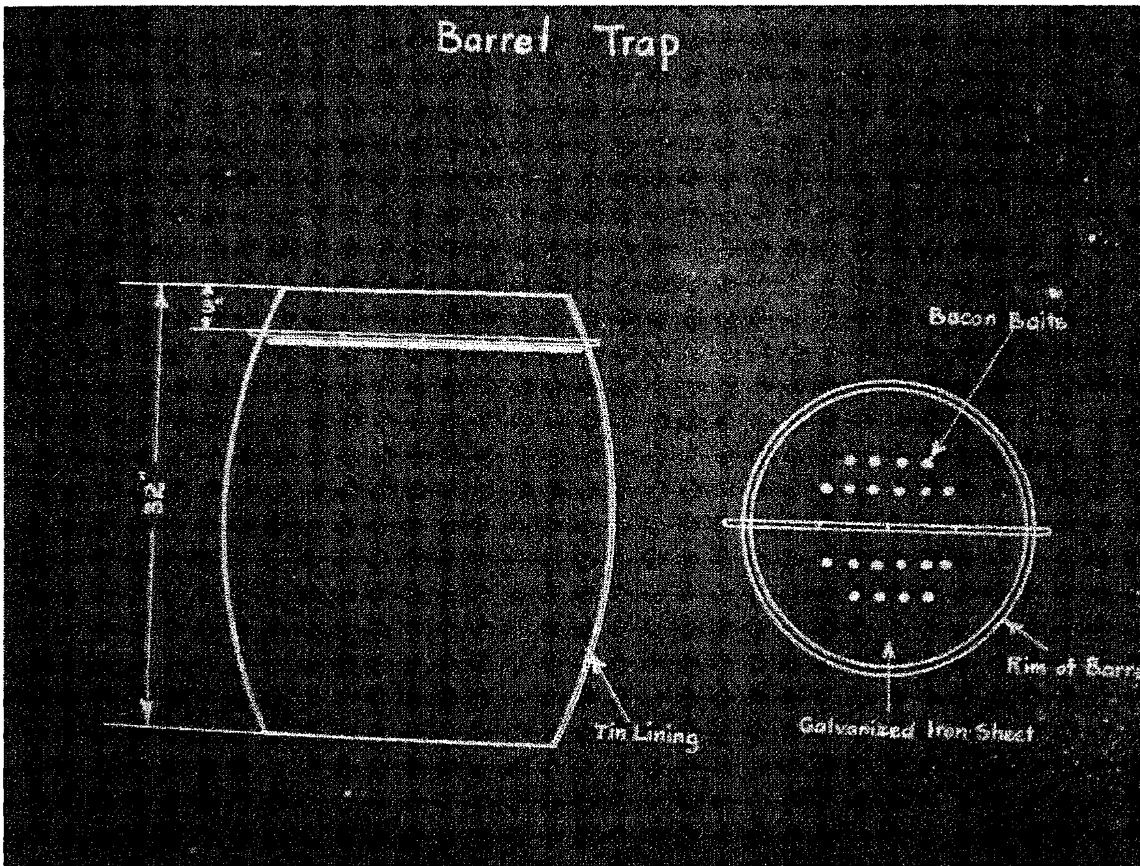
[illegible], HAWAII

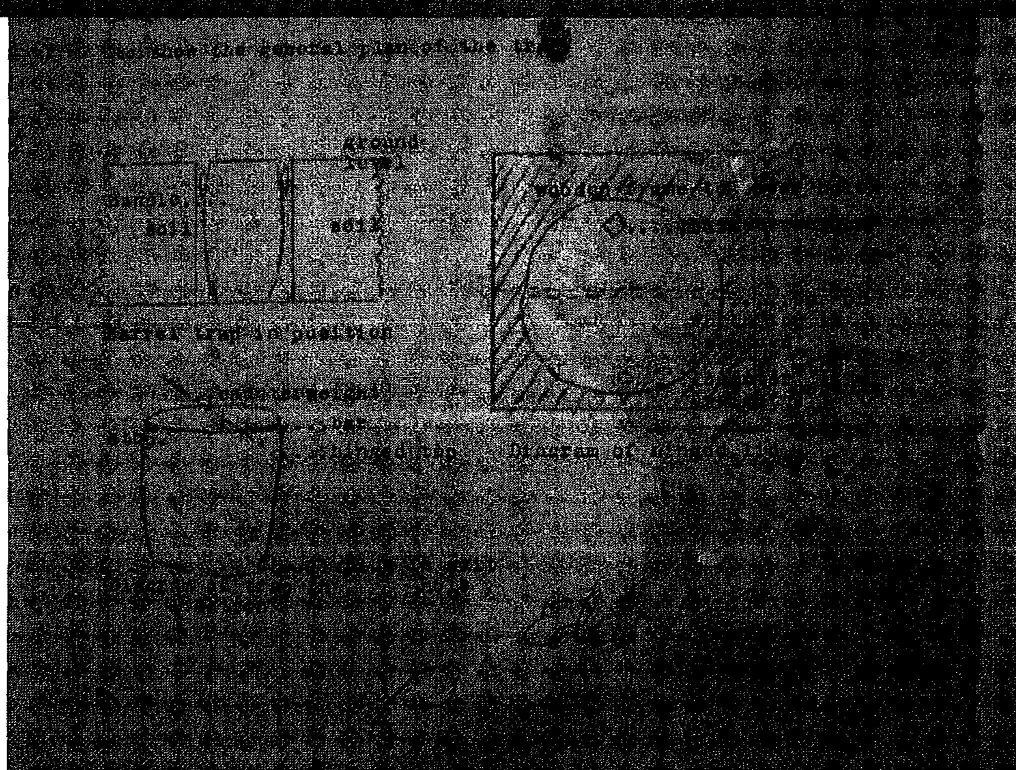
Fiscal Year Ended June 30, 19[illegible]

Plague Infected Rats	[illegible]
Total Rats Trapped	[illegible]
Total Mice Trapped	[illegible]
Trap Days	[illegible]
Rats/100 traps/day	[illegible]
Pieces of Phosphorus-Banana Bait Placed	240,[illegible]
Total Rats Found Dead	[illegible]
Total Mice Found Dead	[illegible]
Total Burrows Treated	[illegible]
Total Rats Killed	[illegible]
Total Mice Killed	[illegible]


L E G E N D
Recent Plague
Plantation Boundary

Appendix C: Barrel Traps





Appendix D: Doty's Prebaiting

Fig. 1. Materials for twenty feeding stations ready for distribution in the field. Twenty covers carried under the arm (weight twenty-six pounds); twenty pans carried in the other hand or in the bag (weight six pounds); and five pounds of grain carried in the bag.

Fig. 2. Same materials as shown in Fig. 1 showing covers placed on the shoulder as an alternate carrying position.

Fig. 3. Filling the pan with rolled oats. One cupfull (one-quarter pound) is a convenient amount of unpoisoned grain.

Fig. 3. Filling the pan with rolled oats. One cupfull (one-quarter pound) is a convenient amount of unpoisoned grain.

Appendix E: Warfarin

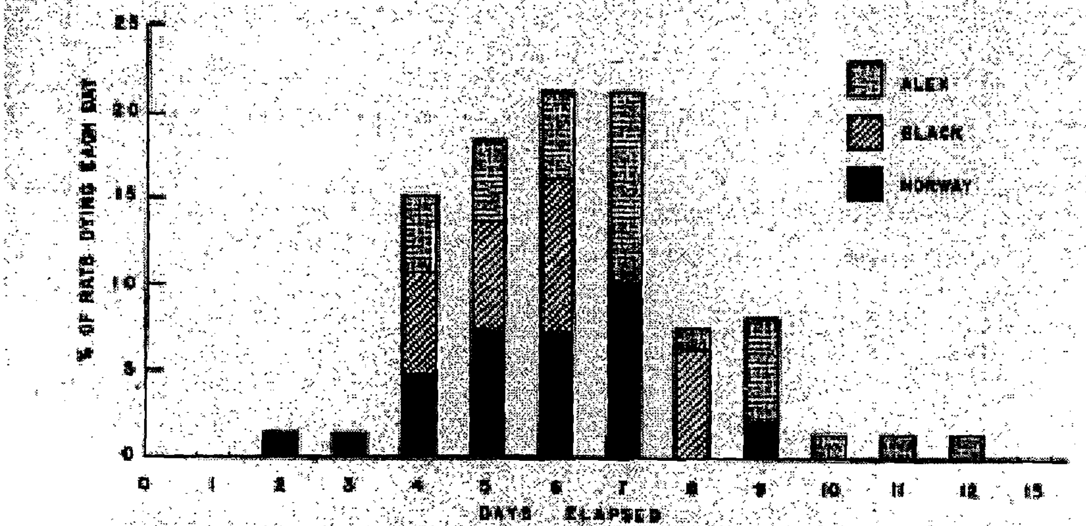


Figure 4. Percentage of rats dying each successive day following their first meal of warfarin-treated rolled oats. Record from 66 rats of three species. [From Table 2.]

Source: Doty 1951

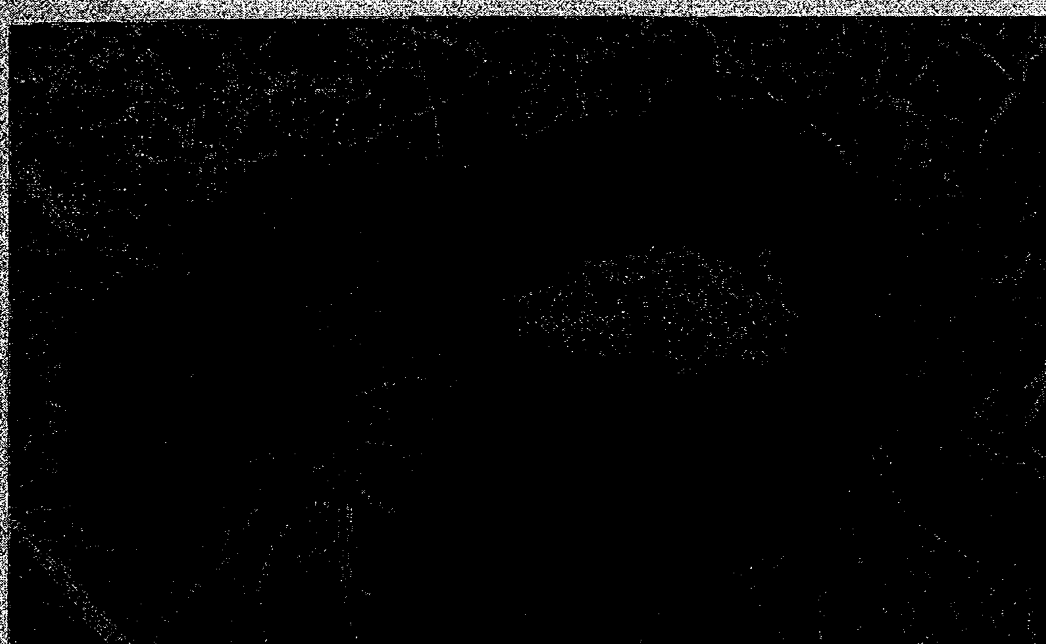
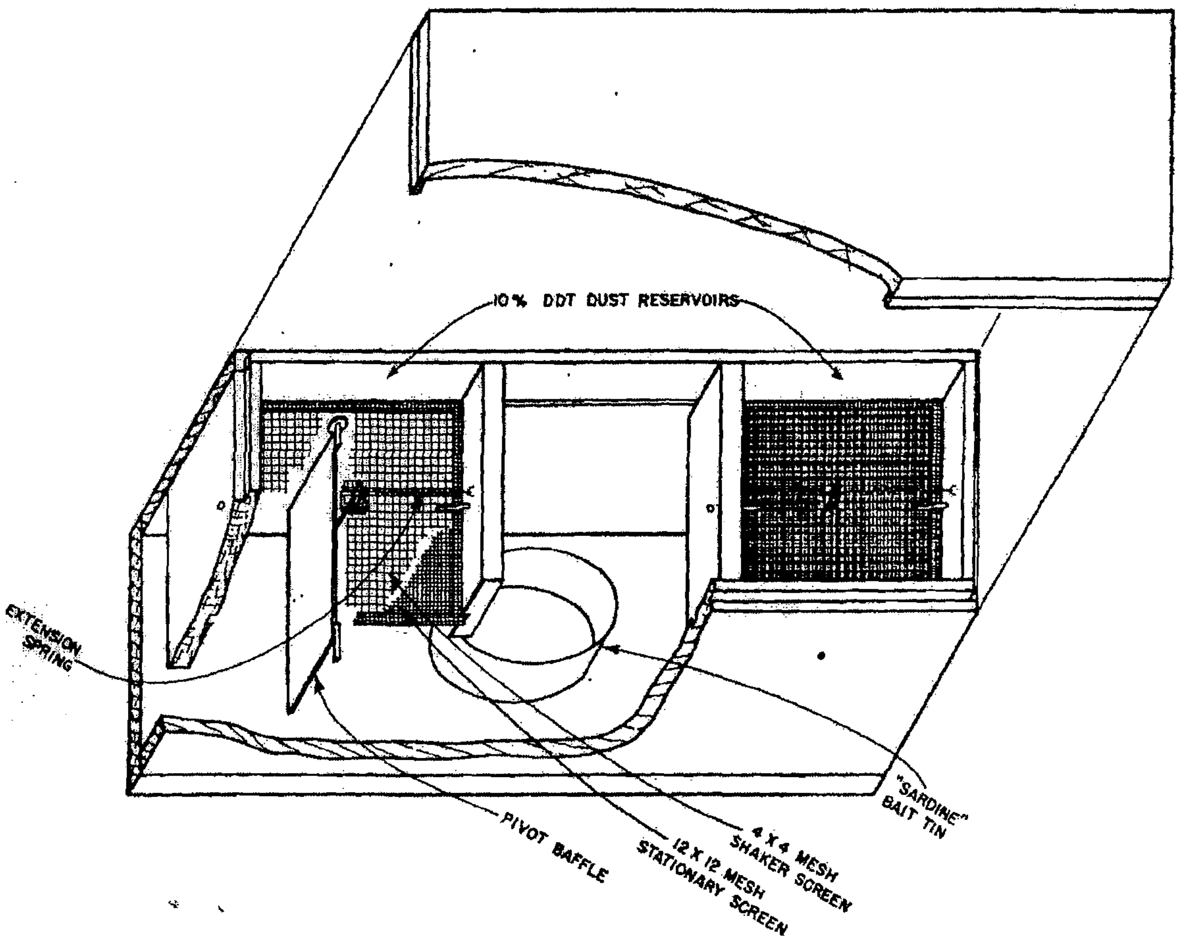


Figure 5. Wild Black rat dying after being fed warfarin treated oats. Note the blood spot on the rolled oats in the bait can. Blood stains on the bait are quite common in field feeding stations.

Source: Doty 1951

Appendix F: DDT Bait Boxes

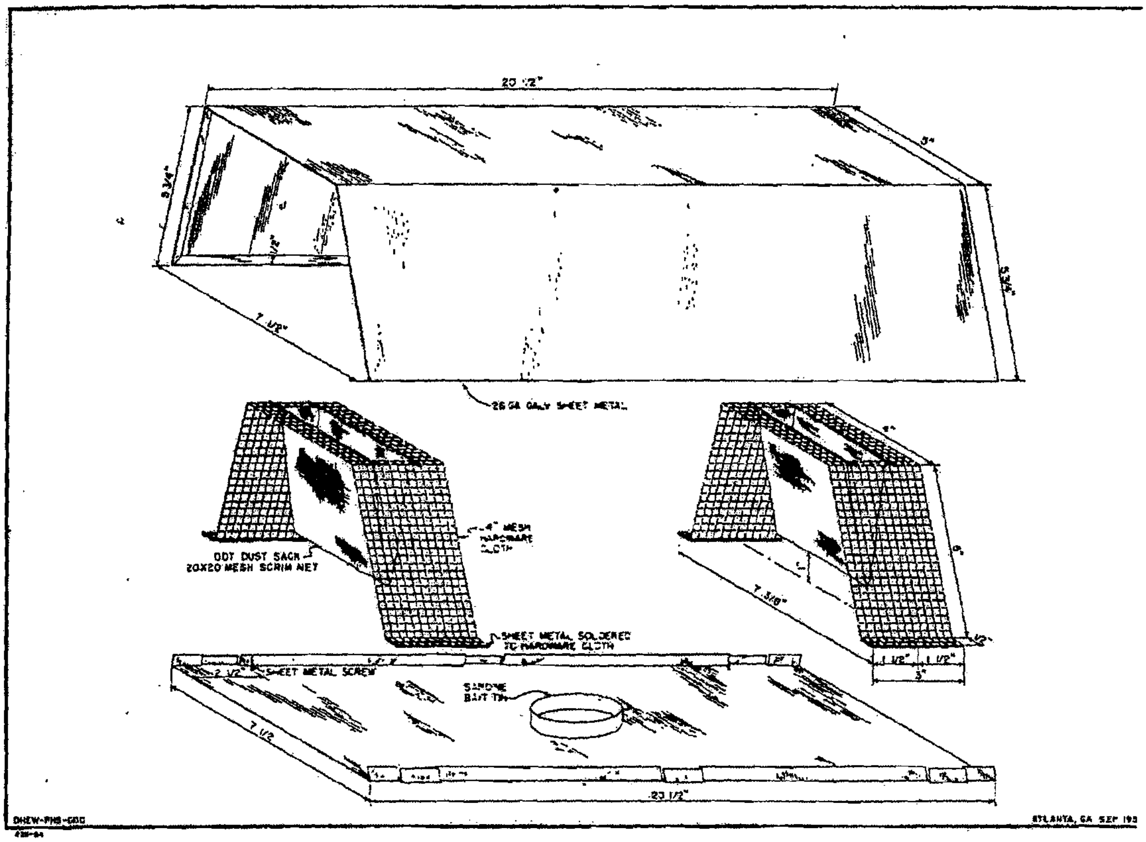
FIG. 1 DIAGRAM OF WOODEN DDT BAIT-BOX



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.

Source: Kartman 1955

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 pi inserted in holes bored in the sides of the hood ; the sacks are then filled through a (corked) hole bored through the to of the hood.

Source: Kartman 1955

Source: Gross 1951

Table 3. *Plague incidence, Hamakua, Hawaii, calendar years 1910–1949*

Year	Human cases	Rodent infections [1]	Year	Human cases	Rodent infections [1]
1910	3	8	1931	0	3
1911	5	3	1932	2	11
1912	7	86	1933	2	17
1913	4	15	1934	2	8
1914	4	3	1935	1	19
1915	4	12	1936	0	71
1916	0	[2] 6	1937	0	93
1917	5	22	1938	0	130
1918	0	2	1939	1	54
1919	7	19	1940	0	56
1920	4	[3] 7	1941	0	79
1921	4	3	1942	0	125
1922	12	14	1943	7	76
1923	1	16	1944	5	63
1924	2	17	1945	1	20
1925	1	7	1946	0	8
1926	7	4	1947	0	9
1927	7	10	1948	0	2
1928	8	11	1949	1	19
1929	5	13			
1930	0	4	Total	112	1,145

[1] Includes infections determined by tissue and flea pools.
[2] Includes one infection detected in vicinity of Ookala.
[3] Includes three infections detected in vicinity of Ookala. Politically this area is located in the North Hilo District but at present is included as part of the over-all region which is under surveillance by the Hamakua program.

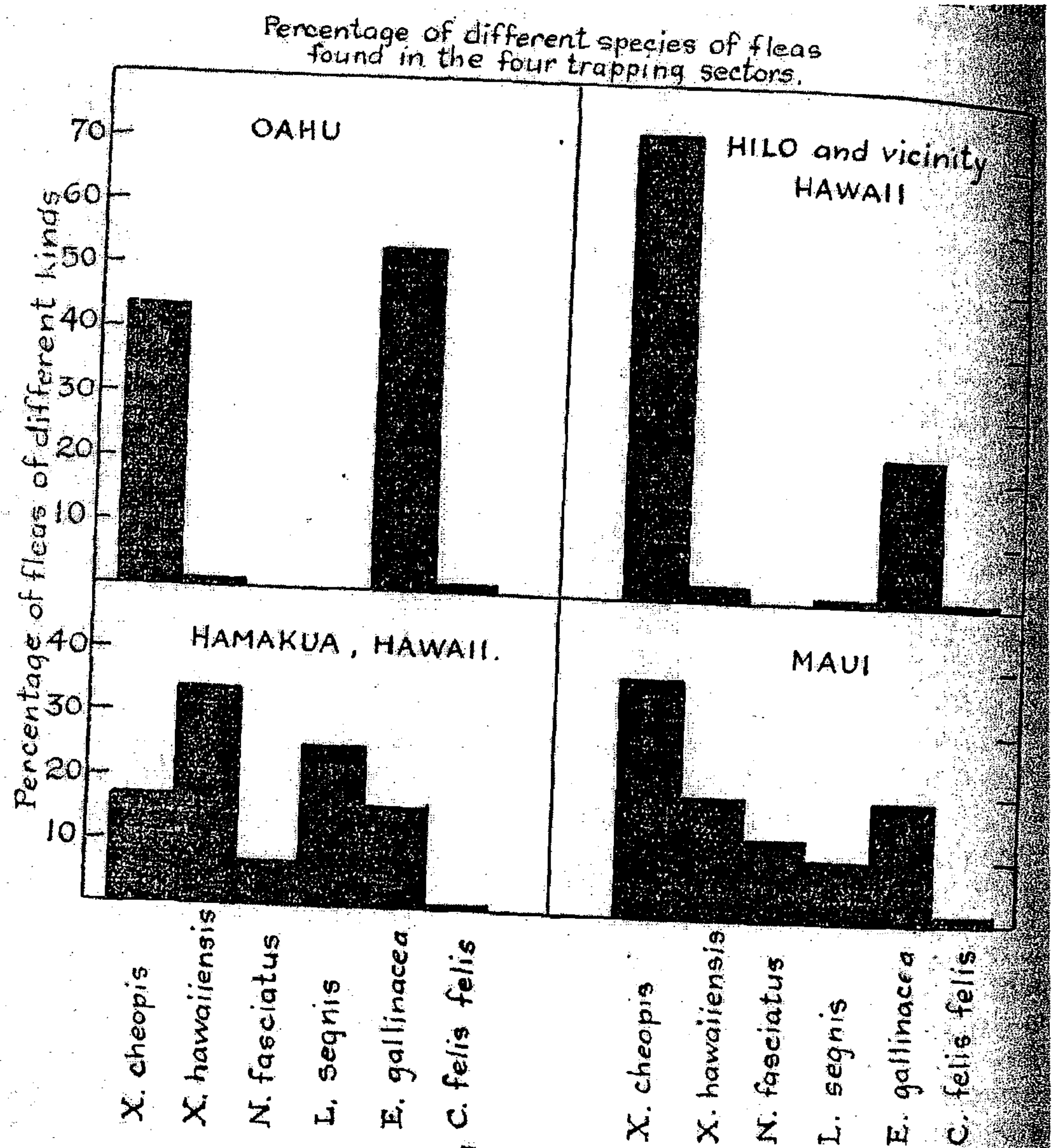


FIGURE 3.

Source: Eskey

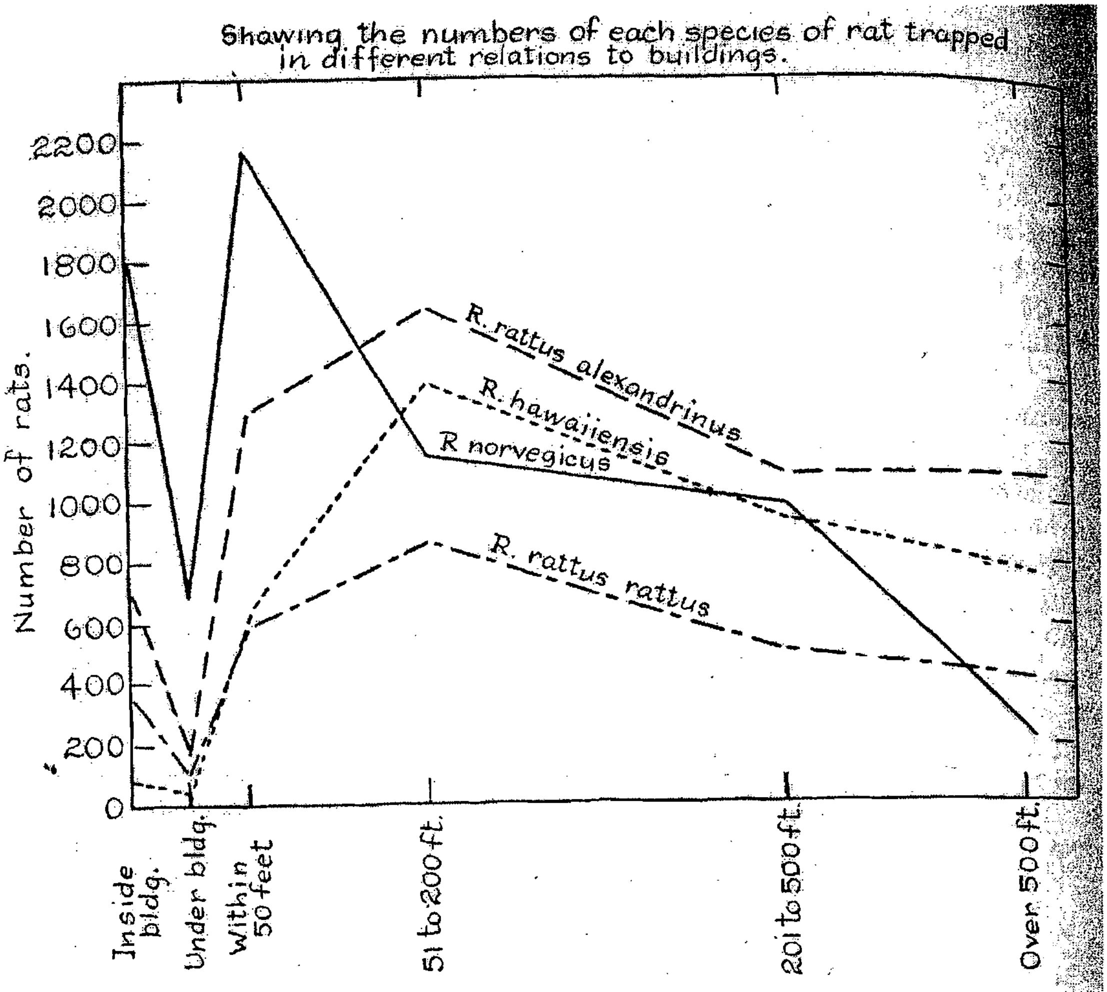


FIGURE 6.

Source: Eskey

Locality	*Period*	*Cases*
Oahu Island :		
Honolulu	**1899-1910**	**187**
Other places	**1902-7**	**41**
Kauai	**1901-6**	**15**
Maui	**1900**	**9**
	1930-2	**6**
	1938	**1**
Hawaii Island :		
Hilo sector	**1900-12**	**43**
North Hilo	**1918**	**2**
Hamakua district	**1910-45**	**111**
	1949	**1**

Total cases 1899-1949 = 416

Source: Pollitzer

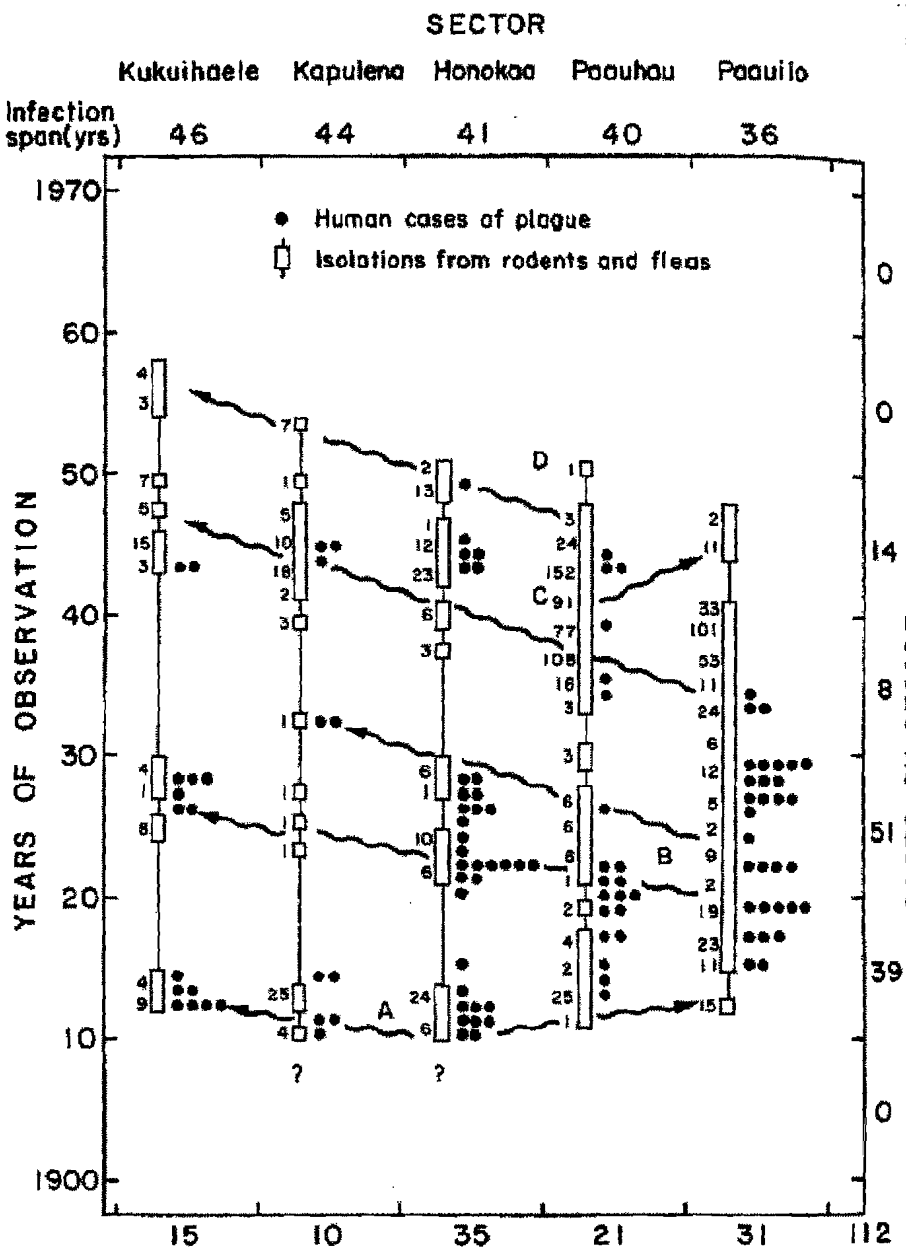


FIGURE 5. Plague in Hamakua District, island of Hawaii, 1900–1970. Infection span is the period of years for each of the five sectors from first to last detection of plague. Human cases are tallied by sector and by decade. Numerals represent numbers of rodent cases (isolations). Directional lines indicate trends in imputed temporal migration of infection between sectors via rodent and flea populations: A, from originally known 1910 sources in the Kapulena-Honokaa sectors; B, a first and second wave of reinfection from a then-established residual focus in Paauhau-Paauilo sectors; C, a third wave of reinfection perpetuated in part from a shifted focus in the Paauhau sector; D, a final wave from a dying focus in the Paauhau sector. (Territorial and State Health Department records and reports; compiled by Joseph S. Caceres and others.) Question mark indicates unknown, but possible, plague infection prior to 1910.

Source Tomich

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