# Occurrence and Distribution of Fleas (Siphonaptera: Pulicidae) of Public Health Importance on the Island of Oahu

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**Abstract.** The Vector Control Branch of the Hawaii State Department of Health has accumulated a large volume of written inspection data on pests of public health for the island of Oahu. Flea related complaints provided the third greatest amount of arthropod pest information available, following mosquitoes and other fly complaints. The objectives of this study were to conduct a survey of the occurrence of flea complaints on Oahu over a 10-year period, determine their distribution over time, graphically compare flea occurrence within and between district/areas, and correlate flea occurrence and distribution with season. Flea data were drawn from inspection reports from 1990 to 1999, population information was obtained from Hawaii Census and State of Hawaii Data Books, 125 district/area geographic locations were defined, and flea occurrence and distribution were adjusted for population and mapped using ArcView GIS 3.2. Most flea activity was reported within the central, south, east and west urban districts. The drier, low lying and leeward areas of the island had the highest number of complaints. The levels of flea activity were highest during the spring, summer and fall. The primary flea species recorded was *Ctenocephalides felis felis* (Bouche), the cat flea. The main sources of flea infestations were improperly cared for pet cats and dogs, feral cats and dogs, and pets dying or being removed from premises. Flea populations are being maintained in urban and agricultural districts by human activities. As a result, disease transmission is possible, especially in the lower elevation, leeward areas of Oahu. These results indicate that educational programs should be carried out in late winter, and that residential flea surveys may be concentrated in a limited number of district/areas.

**Key words:** Fleas, *Ctenocephalides felis*, *Ctenocephalides canis*, *Xenopsylla cheopis*, public health, vector control, Oahu, GIS

## Introduction

The Vector Control Branch (VCB) of the Hawaii State Department of Health was created in 1970 with the merging of Rodent Control and Mosquito Control programs. The VCB is a statewide inspection, education, regulatory, prevention and control program primarily concerned with the vector-borne diseases of dengue fever, murine typhus, leptospirosis and West Nile virus. Vector Control Inspectors deal with other arthropods of public health importance in addition to insect disease vectors and vertebrate pests. As a result, the VCB has accumulated a large volume of mainly hand-written inspection data on pests of public health importance for the island of Oahu. The objectives of this study were to conduct a survey of the occurrence of public health arthropod pest problems on Oahu over a 10-year period (1990–1999), obtain a general list of arthropod related problems and determine their

distribution over time, graphically compare pest occurrence within and between district/areas, correlate pest occurrence and distribution with season, and identify target areas for more efficient application of prevention, control and education programs. We report here the results obtained for fleas.

**Fleas of Hawaii.** The flea was a well known insect pest in native huts, in caves and on inter-island schooners in nineteenth century Hawaii (Haas et al. 1971). Reported problems with domestic fleas indicated they were introduced by European or American ships prior to 1809 during a period of increased voyages to the islands. Although no known specimens were collected and preserved from this time, it has been concluded from available evidence that the most common species present was *Ctenocephalides felis felis* (Bouche), the cat flea. Flea activity also occurred at high elevations and could have included *Pulex irritans* Linnaeus, the human flea; *P. simulans* Baker, the false human flea; and *C. canis* (Curtis), the dog flea. In addition, *Xenopsylla vexabilis* Jordan, the Hawaiian rat flea or Oriental-Pacific rat flea, was probably the earliest flea introduction as a parasite on *Rattus exulans*, the Polynesian rat; while *X. cheopis* (Rothschild), the Oriental rat flea, arrived much later on *R. norvegicus*, the Norway rat, and *R. rattus*, the roof rat, that escaped from ships in the latter part of the 1800s and the early 1900s (Haas et al. 1972, Tenorio and Goff 1980, Kitaguchi 1982). *Ctenocephalides felis* and *X. cheopis* were both first reported by McCoy and Bowman in 1914 from specimens collected off of rodents on the island of Hawaii. The earliest confirmed collections of *P. irritans* and *P. simulans* were made by C. E. Pemberton in 1922 on Hawaii Island, and there is confusion regarding the introduction of *C. canis* because it was misidentified as *C. felis* in the first half of the 20th century. There are 11 flea species occurring in Hawaii today with one being native (Tenorio and Nishida 1995) and by far the most common on Oahu is *C. felis*.

In addition to the possibility of developing a severe allergic reaction to its bites, *C. felis* serves as the intermediate host for the dog tapeworm (*Dipylidium caninum*) and the rodent tapeworm (*Hymenolepis diminuta*) (Kitaguchi 1982, Tenorio and Nishida 1995). Its irritating bites are also known to lead to secondary infections such as impetigo (*Staphylococcus aureus* and *Streptococcus pyogenes*) and scarring. *Xenopsylla cheopis* is second in importance due to the fact that it is the principal vector for plague (*Yersinia pestis*) and murine typhus (*Rickettsia typhi* = *R. mooseri*) (Kitaguchi 1982, Tenorio and Nishida 1995, Chin 2000). The remaining flea species are rarely encountered and are not a major health concern.

This is one of a series of six related papers submitted for publication in the *Proceedings of the Hawaiian Entomological Society.*

## Materials and Methods

**Study area.** Oahu is the third largest and most populous of the Hawaiian Islands. It is home to ~900,000 people, has a highly urbanized southern coast, and extensive growth has recently occurred in the central and Ewa Plains areas of the island. Oahu's climate is characterized by a two-season year, mild and fairly uniform temperature conditions, striking marked geographic differences in rainfall, and a general dominance of trade-wind flow. For a more detailed description of the area of study, see Leong and Grace (2009) or Leong (2008).

**Study methods.** A comprehensive arthropod pest data set was extracted from Hawaii State Department of Health Vector Control Branch inspection reports from 1990 to 1999. Population data were obtained from Hawaii Census 1990 and 2000 and The State of Hawaii Data Books from 1990 to 2004. The Vector Control inspection reports were reviewed and compiled into general pest categories using the reported problem on the original complaint. All together, a total of 8,936 individual pest problems were found from which 27 pest

categories plus a miscellaneous category were obtained. One-hundred twenty-five district/area geographic locations with varying populations were established using community structure, geographic features and inspection report designations, and the raw pest occurrence data for each district/area were standardized by dividing by the estimated population and multiplying the decimal number generated by 10,000. District/areas with populations of less than 500 were excluded from occurrence analysis. The resulting transformed pest occurrence data were mapped on a traditional four-season basis using ArcView GIS 3.2 to create 40 maps for each of 10 major pest categories along with four additional maps each showing cumulative seasonal activity. Pest occurrence was graphically compared within and between district/areas, and pest occurrence and distribution were correlated with season. Finally, pest occurrence and distribution were evaluated using inspection data, including species identifications. See Leong and Grace (2009) or Leong (2008) for a more complete description of methods.

## Results

Flea activity during the winter of 1990 was mostly very light (1–3 complaints) with light peaks (4–8 complaints) occurring in the south district/area of Kalihi Kai and in Kahaluu-Waihee Valley in the east. Complaints were mainly found along south Oahu and there were noticeably fewer problems across the east, central and west areas. In winter 1991, very light flea activity was scattered along south, east and west Oahu with light activity occurring in Kahuku on the east side and moderate activity (9–15 complaints) being found in the south district/area of Kakaako. Overall flea activity was nearly half as compared to the preceding fall. Flea activity in winter 1992 was very light around south and lower east Oahu with a moderate peak occurring in Lanikai on the east coast. Overall activity was about half that in the fall of 1991. Winter 1993 flea activity was reduced from that in fall 1992, and sparse and mainly very light from the north shore through central, south and lower east Oahu. There was a light peak in activity in Halawa Valley in central Oahu. Flea activity in the winter of 1994 was fairly spread out across the island and, again, reduced from that in the fall. Very light activity was found in the south, east, central and west district/areas of Oahu with light peaks occurring in Niu Valley on the south shore and in Waianae on the west coast. Moderate flea activity was found in Mokuleia on the north shore. The winter of 1995 saw an increase in flea activity over the previous fall. There was very light activity from the north shore through central, south and lower east Oahu. Flea activity peaked lightly in Halawa Valley, in Lanikai and Kaaawa on the east coast, and in Nanakuli on the west shore. Flea activity in winter 1996 decreased or did not occur over much of the island. Only leeward Oahu showed activity and there was clustering between Kalihi Kai and Makiki-Punahou in the south with a light peak in Kalihi Kai. Overall flea activity in winter 1997 was comparable to fall 1996 activity, but the mainly very light activity shifted more to the western half of the island. A single light peak occurred in Kahuku on the east coast of Oahu. The flea activity in winter 1998 peaked on the opposite side of the island from in the fall, but remained similar overall. Activity spiked moderately in Kahuku and six out of seven district/areas with very light flea activity occurred on the leeward side of the island. Finally, flea activity increased in intensity as well as in the number of district/areas in the winter of 1999 with activity mainly occurring around leeward Oahu. There was light activity in the central district/area of Halawa and a moderate peak in Kalihi Kai on the south shore.

Spring 1990 flea activity was found mostly along the central, south and lower east district/areas of Oahu, and was about two times as that in the winter. There was a concentration in flea activity on the south shore from Kalihi Kai to Kahala with light peaks occurring

in Kalihi Kai, Iwilei and Kaimuki-Waialae. Flea activity was noticeably reduced in spring 1991 with mainly very light activity occurring in south Oahu from Kalihi to Kalani Valley, including a moderate peak in Kalani Valley. In spring 1992, flea activity increased, and light peaks were found in Niu Valley on the south shore and Lanikai on the east side. Flea activity more than doubled in spring 1993 from that in the winter with the activity being found fairly well distributed across the island. Light activity was found in Yacht Club Knolls-Terrace in east Oahu and there was a moderate peak in Mokuleia on the north shore. Spring 1994 flea activity decreased in intensity, but had several more affected district/areas overall than the winter activity. Light peaks occurred in Olomana-Pohakupu on the east side and in Makaha Valley in the west. Flea activity in spring 1995 was comparable to the winter activity and a clustering of complaints was revealed from Downtown to Palolo-Palolo Valley. Activity peaked lightly in Kakaako in the south and Maili Kai in the west. Spring 1996 flea activity increased slightly from that in winter 1996. Activity peaked lightly in Maili in west Oahu and the majority of the activity occurred on the leeward side of the island. There was an increase in flea activity in south Oahu in spring 1997. Light peaks in flea activity occurred in Iwilei in south Oahu and Pupukea on the north shore. Flea activity in spring 1998 increased and was better distributed across the island over that of the winter. Light flea activity was found in Iwilei in the south and Kahuku along east Oahu, and there was a moderate peak in the west district/ area of Kahe Point-Honokai Hale. Lastly, spring 1999 showed decreased flea activity overall with activity occurring in central and leeward Oahu. Light activity occurred in Iwilei and in Maili Kai along west Oahu.

The number of district/areas reporting flea activity in summer 1990 was similar to that in the spring with activity mainly occurring in central and south Oahu. Light peaks were found in Aiea Heights in central Oahu, Portlock in the south and Waialua on the north shore. The level of flea activity in summer 1991 about doubled the activity in the spring and occurred mainly along leeward Oahu. There was a light peak in Kakaako on the south shore, and activity was found in lower central, south, lower east and west district/areas. Flea activity also doubled in the summer of 1992 and increased noticeably between Kalihi and Hawaii Kai in south Oahu. Light and heavy (16–24 complaints) peaks in flea activity occurred along the south shore in Portlock and Hawaiiloa Ridge respectively, and a moderate spike was found in Mokuleia on the north shore. Summer 1993 flea activity increased overall and became more concentrated in the lower central, south and lower east district/areas than that of spring. Light activity occurred in Kamehameha-Alewa Heights in south Oahu. As in 1993, summer 1994 showed increased flea activity overall that became more concentrated in the south and lower east Oahu district/areas. There was a moderate peak in activity in Kakaako on the south coastSummer 1995 flea activity showed an increase within central and east district/areas, and was more distributed over the island. Flea activity peaked lightly in Kakaako in the south, Waimanalo and Lanikai on the east side, and Waipio Acres in central Oahu. A moderate spike in flea activity occurred in Punaluu on the east coast. Overall flea activity in summer 1996 increased from that in the spring and was found on the windward side of the island. Flea activity peaked lightly in Pupukea on the north shore and half of the affected district/areas were located from Kalihi Valley to Kapahulu-Diamond Head in the south. Flea activity in summer 1997 was comparable to the spring activity. A light peak occurred in Niu Valley along the south coast. The flea activity in the summer of 1998 increased from that in the spring and was mainly found on the leeward side of the island. Light peaks in activity occurred in Saint Louis Heights and Niu Valley in south Oahu, and there were moderate spikes in Mokuleia on the north shore and Makaha Valley on the west side. Flea activity declined on the leeward side of the island as well as in the central district/areas of Oahu in summer 1999. Very light flea activity occurred from central Oahu, along the south shore to the east side of the island.

In the fall of 1990, flea activity remained the same overall from that in the summer and was fairly spread out over the island. There was a small cluster from Kalihi to Punchbowl-Pauoa in south Oahu, including a light peak in Iwilei, and light activity also occurred in Olomana-Pohakupu and Kahuku on the east side. During the fall of 1991, the flea activity decreased slightly, was very light and remained mostly in south Oahu. There was a decrease in flea activity in fall 1992 to less than half that of in the summer. A light peak occurred in Kakaako on the south shore. Fall 1993 saw a decrease in the number of district/areas reporting flea activity, especially those in south Oahu. There was a light peak in Lanikai on the east coast and most of the activity was on the leeward side of the island. There was a noticeable decrease in flea activity in the fall of 1994 with most of the affected district/areas occurring on the leeward side of the island. Light peaks in flea activity were found in Lanikai in east Oahu and Makaha Valley on the west coast. There was decreased flea activity in fall 1995. A moderate peak in activity was found in Maili Kai in west Oahu. In fall 1996, flea activity decreased by nearly half that of in the summer. Light peaks in activity were found in Kahuku in east Oahu and in Mikilua-Lualualei on the west coast of the island. An overall decrease in flea activity occurred in the fall of 1997. Light flea activity was found in Fort Shafter on the south coast and in Maili Kai along west Oahu. In fall 1998, flea activity again decreased from that of in the summer and all activity was very light. There was an increase in overall flea activity in fall 1999 with, as in previous years, activity mainly occurring in leeward district/areas. Light peaks in flea activity were found in Red Hill and Iwilei in south Oahu.

Most flea activity was reported within the central, south, east and west urban districts (Figure 1A–D). The drier, low lying and leeward areas of the island had the highest number of complaints. The levels of flea activity were highest during the spring, summer and fall with the summer showing the most flea complaints as well as having more activity in the higher central district/areas of the island. There were a very light number of flea problems around the ports of entry. However, the major ports of entry, Honolulu International Airport, Sand Island and Campbell Industrial Park, could not be evaluated by adjusting for population due to their low residential population.

## Discussion

The primary flea species recorded was *Ctenocephalides felis felis* (~99.3%; n = 274), the cat flea, and isolated *Xenopsylla cheopis* (~0.4%), Oriental rat flea, cases were also recorded (Table 1). The main sources of *C. felis* infestations were improperly cared for pet cats and dogs, feral cats and dogs, and pets dying or being removed from premises. *Xenopsylla cheopis* activity was usually associated with a heavy rat or mouse infestation. *Ctenocephalides canis* (~0.4%), the dog flea, was also recorded, but this occurrence was in Halawa Heights and the flea species identification was most likely in error since *C. canis* is rarely collected and naturally occurs only at elevations near 2,000 m or more (Haas et al. 1972, Tenorio and Goff 1980).

*Ctenocephalides felis* became notorious for its outbreaks in Honolulu as reported by C. E. Pemberton in 1934 and was probably the species that commonly attacked man, "… especially in low lying areas along the shore" (Haas et al. 1972). This was also found to be true in this survey with the drier, low lying and leeward areas of Oahu showing the highest number of complaints. In the Hamakua District of the Big Island of Hawaii, Haas (1966) found seasonal occurrence of *C. felis* on *Herpestes auropunctatus*, the mongoose, to be fairly stable on female mongooses while flea activity on male mongooses was observed to be higher during mongoose breeding season, December-July, than during non-breeding season, August–November. Pemberton (1934) had documented flea epidemics that occurred

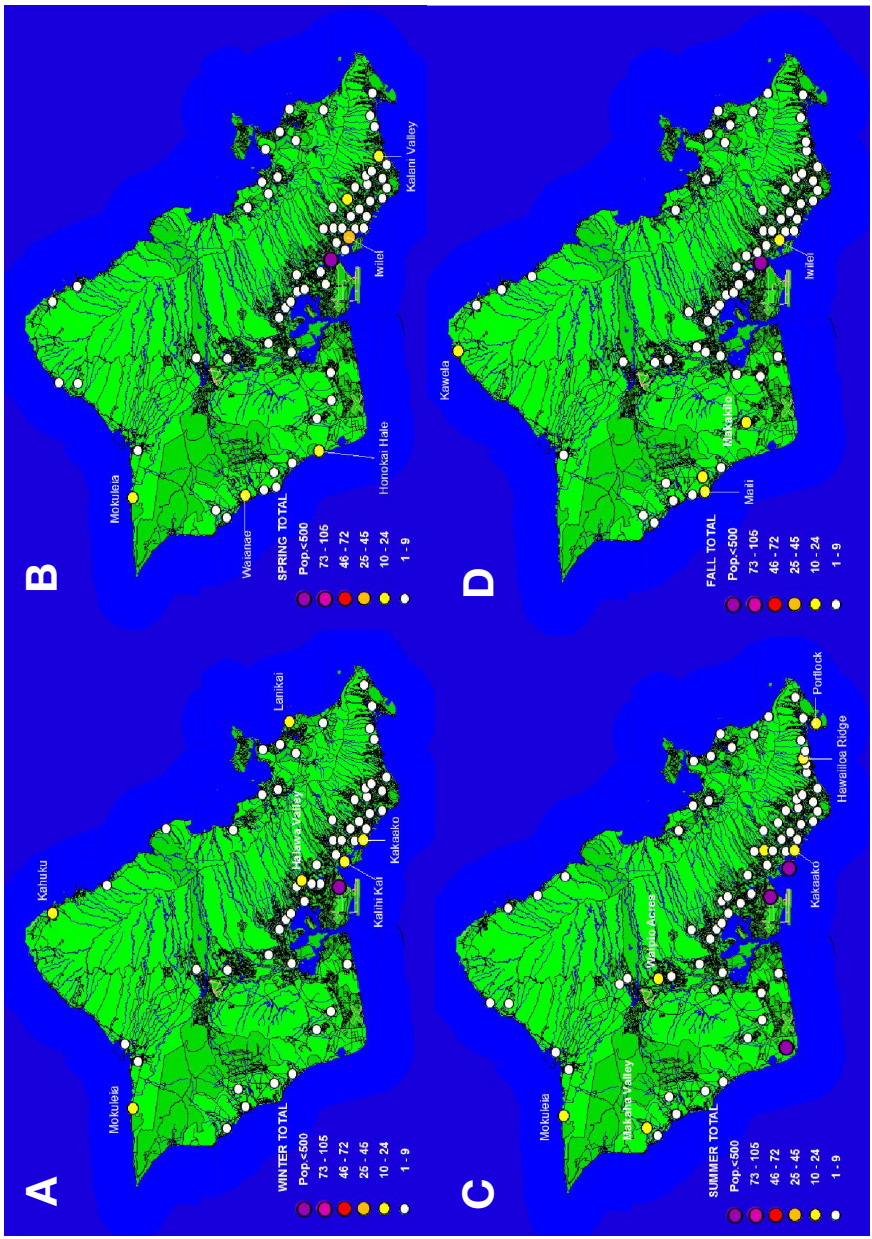


**Figure 1.** Fleas, seasonal totals (1990–1999) for winter (A), spring (B), summer (C) and fall (D).

in Honolulu in May and June of 1933. Although geographic analysis of inspection reports from 1990 to 1999 did reveal winter flea activity near that of spring and fall, both spring and fall flea activity were higher and summer flea activity clearly peaked above the rest of the seasons. Since the main sources of *C. felis* infestations on Oahu were cats and dogs

**Table 1. Flea species occurrence as determined by a sampling of 718 flea-related inspection reports.**

| Species | % | Mean | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Ctenocephalides canis* | 0.4 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | **1** |
| *C. felis felis* | 99.3 | 27.2 | 84 | 39 | 28 | 19 | 21 | 29 | 9 | 11 | 18 | 14 | **272** |
| *Xenopsylla cheopis* | 0.4 | 0.1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | **1** |
| **Total** | **100.0** | **27.4** | **84** | **39** | **28** | **20** | **21** | **29** | **9** | **11** | **19** | **14** | **274** |

rather than mongooses, it was not unexpected to find the occurrence of 1933 Honolulu flea epidemics to better match the survey results.

The island of Maui had a murine typhus outbreak in 2002 (CDC 2003) due to a mouse population explosion, and suspected or confirmed typhus cases resulting from rat infestations occurred on the leeward side of Oahu on an annual basis, often on animal farms. *Xenopsylla cheopis* was the vector involved in the transmission of the disease in these cases. Mice index trapping was already being conducted on a monthly basis on the neighbor islands in the 1990s to monitor mouse populations, collect fleas, test for murine typhus and carry out rodent control as needed. Oahu, on the other hand, was relying on mouse complaints from the public to indicate when to conduct index trapping to confirm a significant rise in mouse activity and, therefore, the need for rodent control. All islands also responded to reports of suspected or confirmed murine typhus cases from the state Epidemiology Branch (now the Disease Outbreak Control Division) in which flea control was automatically carried out in addition to the testing and eradication of rodents. In either case, mapping rodent complaints or problems, especially on the leeward side of Oahu, would enhance the prevention or control of murine typhus on the island.

Although plague was detected in Hawaii first on Oahu in December 1899 and rodents are routinely tested for plague today, no human or rodent cases have been detected since 1949 and 1957, respectively, on the island of Hawaii (Kitaguchi 1982). As a result, emphasis has been on preventing the reestablishment of plague in the islands through cordon sanitation. Prevention and control work primarily consists of continuous placement of rodenticide in insecticide treated bait stations located along all ports of entry, airports and seaports. Intermittent trapping with rat snap traps to assess the rat population and monitor for baiting effectiveness is also carried out. Rat complaints from along shoreline areas as well as the ports of entry help to reinforce the cordon sanitation by identifying and ensuring the treatment of isolated problem sites before the rodent activity increases to a level that leads to *X. cheopis* infestations. As with murine typhus, mapping rodent complaints or problems would enhance the prevention of the reintroduction of plague onto the island.

In addition to the occurrence of fleas on rodents and mongooses in wild and peri-domestic areas, flea populations are being maintained in urban and agricultural districts by human activities. As a result, disease transmission is possible, especially in the drier, lower elevation, leeward areas of Oahu. The results indicate that community or island-wide educational programs should be carried out in late winter

to remind the public that flea season is approaching, and that residential flea surveys may be concentrated in a limited number of district/areas according to flea complaints received. Educational activities are normally conducted only on a limited basis during inspections. Large scale mice index trapping is routinely carried out when mouse complaints increase to monitor for and respond to mice population blooms to prevent murine typhus outbreaks, while inspections conducted in response to complaints have confirmed the practicality of using small-target area surveys. In addition, limited monthly mice index trapping was initiated in Nanakuli in November 2006 to improve prevention activities.

Geographic analysis can help to target areas and times of the year for more efficient application of flea prevention, control and education programs by continuously tracking flea activity using Vector Control inspection reports. Improvements in methodology include using the actual number of complaints within a district/area and the severity of the flea infestation found together with data adjusted for population to more accurately determine the need for targeted survey, abatement and education efforts. For example, geographic analysis of transformed flea occurrence may flag a potential problem district/area for increased scrutiny, but additional action would be taken only if at least three complaints were received, the level of infestation was heavy and/or the flea problem was found to occur over an extensive area. The same deciding factors may be applied directly for the excluded district/areas with resident populations of less than 500.

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