OCCURRENCE AND DISTRIBUTION OF PESTS OF PUBLIC HEALTH IMPORTANCE ON THE ISLAND OF OAHU

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ABSTRACT

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 largely hand-written inspection data on pests of public health 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, 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. Pest occurrence and distribution were analyzed using a geographic information system, ArcView GIS 3.2.

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. A comprehensive arthropod pest data set was extracted from Hawaii State Department of Health Vector Control Branch inspection reports from 1990-1999. 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, geographical 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 specific species identifications.

Most of the mosquito activity was found within the central, south and east urban districts. Drier areas from Kalihi Kai to Portlock had the highest number of complaints, and the levels of mosquito activity were highest during the winter, spring and summer. The primary mosquito species recorded was *Aedes albopictus* (Skuse), the Asian tiger mosquito, and the main breeding sources were various containers, plus bromeliad plants. Gardening activities, irrigation, poor drainage, toys holding water, and man-made ponds and pools all contributed to mosquito breeding. *Aedes albopictus* populations are being maintained in urban districts by human activities. As a result, dengue transmission is possible in the drier, urban areas of Oahu. These results indicate that educational programs should be carried out in late fall and early spring, and that residential mosquito surveys may be concentrated in a limited number of district/areas.

Overall, reported fly activity was found to occur fairly evenly across the island's districts. Lower elevation areas around the perimeter of Oahu had the greatest number of complaints and the levels of fly activity were highest during the winter and summer. There were a light number of fly problems around the ports of entry with none being recorded in the fall months. The primary fly species recorded were *Phaencia cuprina* (Wiedemann), the bronze bottle fly; *Musca sorbens* Wiedemann, the dog dung fly; *Chrysomya megacephala* (Fabricius), the Oriental blow fly; and *M. domestica* Linneaus, the house fly. The main breeding sources were food garbage and slop, pet and farm animal dung, dead animals, and rotten fruits. Fly populations are being maintained in urban and agricultural districts by human activities. As a result, disease transmission is possible, especially in the lower elevation, urban and agricultural areas of Oahu. These results indicate that educational programs should be carried out in late fall and late spring, and that residential fly surveys may be concentrated in a limited number of district/areas.

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. There were a very light number of flea problems around the ports of entry. 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.

Reported bee activity was found mostly within the central, south and east urban districts. The eastern half of south Oahu and the southern half of the east districts showed the highest number of complaints. The levels of bee activity were highest during the spring, summer and fall, and there were bee problems around the airport throughout the year. The primary bee species recorded was *Apis mellifera* Linnaeus, the honey bee.

The main sources of bee problems were *A. mellifera* swarms, and bee hives established in urban areas from wild or domestic hives. Bee activity regularly occurs in urban areas as a result of past and present human activities. As a result, injury from bee stings is possible, especially in the eastern half of south Oahu and the southern half of the east districts from spring through fall when swarming activity is highest. The results indicate that educational programs should be carried out in late winter, and that residential bee surveys may be concentrated in a limited number of district/areas.

Most mite activity was reported within the central, south and east urban districts. The south urban districts of the island showed the highest number of complaints, and the levels of mite activity were highest during the spring, summer and fall. There were a very small number of mite problems around the ports of entry, mainly the airport. The primary mite species recorded were *Dermatophagoides pteronyssinus* (Trouessart), the European house dust mite; *Ornithonyssus bursa* (Berlese), the tropical fowl mite; *Glycyphagus domesticus* (De Geer), the grocer's itch mite; *Pyemotes boylei* Krczal, the straw itch mite; and *D. farinae* Hughes, the American house dust mite. The main sources of mite infestations were house dust, birds, stored food products, fiber-type furniture, dried plant materials and bean pods. Tick activity was mostly reported within the leeward urban districts. South and west urban districts showed the highest number of complaints, and the levels of tick activity were highest during the winter, summer and fall. There were very few tick problems around the ports of entry. The primary tick species identified was *Rhipicephalus sanguineus* Latrielle, the brown dog tick. No other established tick species were found to be a public health concern. The main sources of tick infestations were dogs that were taken into a tick infested location or poorly cared for, especially if the dog was relocated on premises, removed from the premises or died. Mite and tick activity regularly occurs in urban areas as a result of human activities. As a result, dermatitis from mite infestations is possible as well as disease transmission between dogs by ticks, especially along leeward Oahu. The results indicate that educational programs should be carried out in late winter for mites and late spring for ticks, and that residential mite and tick surveys may be concentrated in a limited number of district/areas.

Ant activity was mostly reported within the central, south and east urban districts. South urban districts from Kakaako to Kalani Valley showed some of the highest numbers of complaints. The levels of ant activity were highest during the summer and fall. There were very few ant problems around the ports of entry. The primary ant species recorded were *Monomorium pharaonis* (Linnaeus), the pharaoh ant; *Camponotus variegatus* (F. Smith), the Hawaiian carpenter ant; *Ochetellus glaber* (Mayr), the glaber ant; *Paratrechina longicornis* Latreille, the crazy ant; *Solenopsis geminata* (Fabricius), the tropical fire ant; *Tapinoma melanocephalum* (Fabricius), the tiny yellow house ant; *Anoplolepis longipes* Jerdon, the long-legged ant; *Pheidole megacephala* (Fabricius), the big-headed ant; and *Technomyrmex albipes* (F. Smith), the white-footed ant. The main causes of ant infestations were access to a food source, poor sanitation, openings allowing ants into a structure, and objects providing a bridge onto a structure. Ant populations are being maintained in urban areas as a result of human activities as well as naturally occurring conditions. As a result, injury from bites or stings is possible, especially in the south urban districts from Kakaako to Kalani Valley. The results indicate that educational programs should be carried out in late spring, and that residential ant surveys may be concentrated in a limited number of district/areas.

Reported cockroach activity was mainly found within the central, south and east urban districts. The central and south urban districts of the island showed the highest number of complaints. The levels of cockroach activity were highest during the spring and summer. There were a very small number of cockroach problems around the ports of entry, only in the airport area. The primary cockroach species recorded were *Periplaneta americana* (Linnaeus), the American cockroach; *Blattella germanica* (Linnaeus), the German cockroach; and *Diploptera punctata* (Eschscholtz), the Pacific beetle cockroach. The main causes of cockroach infestations were poor sanitation, garbage accumulation, access to a food source, openings allowing cockroaches into a structure, underground structures high in moisture, leaking plumbing, leaf litter accumulation and potted plants. Cockroach populations are being maintained in urban districts by human activities. As a result, disease transmission is possible, especially in the central and south urban districts of Oahu. The results indicate that educational programs should be carried out in late winter, and that residential cockroach surveys may be concentrated in a limited number of district/areas.

Most centipede activity was reported within the leeward urban districts. South urban districts from Hawaiiloa Ridge to Kalama Valley showed the highest number of complaints. The levels of centipede activity were highest during the winter, summer and fall. There were no centipede problems around the ports of entry. The primary centipede species recorded was *Scolopendra subspinipes* Leach, the large centipede. The main sources of centipede infestations were various ground covers such as wedelia, leaf litter accumulation, red wood chips, gravel, rock piles and wood piles. Undeveloped neighboring properties were also a source of centipede activity. Centipede activity is being maintained in urban areas by human activities as well as naturally occurring conditions. As a result, injury from centipede "bites" is possible, especially from Hawaiiloa Ridge to Kalama Valley. The results indicate that educational programs should be carried out in late spring, and that residential wasp surveys may be concentrated in a limited number of district/areas.

Wasp activity was fairly well distributed across the island. South, east and central urban districts showed the highest number of complaints, and the levels of wasp activity were highest during the fall. There were few wasp problems around the ports of entry. The primary wasp species recorded was *Polistes* sp., the paper wasp. Paper wasp infestations usually involved several to a dozen or more small to moderate size nests hanging beneath eaves and on walls, and problem sites bordered undeveloped lands or overgrown residential premises on which adult wasps may forage. Wasp activity regularly occurs in urban areas as a result of human activities. As a result, injury from wasp stings is possible, especially along south, east and central Oahu. The results indicate that educational programs should be carried out in late summer, and that residential wasp surveys may be concentrated in a limited number of district/areas.

Geographic analysis will help to target areas and times of the year for more efficient application of public health pest prevention, control and education programs by continuously tracking pest 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 pest 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 pest 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 pest 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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CHAPTER 1

Introduction and a Brief History of Vector Control on the Island of Oahu

Abstract

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 largely 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, 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. Pest occurrence and distribution were analyzed using a geographic information system, ArcView GIS 3.2.

Introduction

Rodent Control and Mosquito Control programs were established in the Territory of Hawaii in the early 1900s. The primary vector-borne diseases at that time were bubonic plague, dengue fever and yellow fever. Shortly before Hawaii became a state, Hayes (1958) reported that vector-borne diseases of humans were well under control. Murine typhus remained a significant problem, but plague had been eradicated from Oahu and restricted to limited enzootic foci on two major islands (Maui and the Big Island of Hawaii). The Vector Control Branch (VCB) of the Hawaii State Department of Health (HDOH) was created in 1970 with the merging of the Rodent Control and Mosquito Control programs. The VCB is a statewide inspection, education, regulatory, prevention and control program. It, along with other HDOH agencies, routinely monitors for plague, dengue fever, murine typhus, leptospirosis and West Nile virus (WNV). The primary vector-borne disease concerns today are dengue fever, murine typhus, leptospirosis and WNV. As part of their regular duties, Vector Control Inspectors deal with other arthropods of public health importance in addition to insect disease vectors and vertebrate pests. As a result, a large volume of largely hand-written inspection data on pests of public health importance has been accumulated for the island of Oahu.

I had four main goals in carrying out my thesis research: (1) to make practical use of a large portion of the Vector Control inspection data base; (2) to use the data to determine the occurrence, distribution and movement of public health pest problems over time; (3) to use this temporal analysis to reveal pest problem hotspots, and possible routes for pest introduction and spread; and (4) to correlate pest occurrence and distribution with demographic and meteorological data. Several early considerations, however, led to some modification and clarification of my initial objectives. These considerations included the fact that an average of 1,770 complaints per year were received by the VCB on the island of Oahu, over 50% of the inspection reports were non-arthropod specific problems, the study would involve well over a dozen different pest groups and a large number of district/area geographic locations would need to be documented.

I felt that a 10 year period was necessary to obtain sufficient data to draw reasonable conclusions. However, in order to effectively manage such a large volume of information, I decided that only arthropod specific pest problems would be included at this time. Thus, my final thesis objectives, in addition to my original goals, were to conduct a survey of the occurrence of public health arthropod pest and nuisance problems on Oahu over a 10 year period, 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 pests and regions for more efficient application of prevention, control and education programs.

At the core of my thesis project are reviewing written inspection reports and extracting appropriate information, and carrying out geographic analyses of derived data sets using ESRI© ArcView GIS 3.2. Some special problems with using written reports as a source of data are: How do you accommodate diverse writing styles and levels of expertise? How do you fill in data gaps where identifications or conclusions were not completed? And, how do you account for the subjective nature of a large portion of the data? These problems and other concerns regarding extracting appropriate data are addressed in Chapter 2: Study Area and Methods.

There are many examples of research employing GIS analysis, from simple population studies to infectious disease surveillance to complicated risk analysis modeling. Bunnell et al. (2003) carried out a spatial analysis of the Lyme disease vector *Ixodes scapularis*, the black-legged tick, across five states in the Middle Atlantic region. Tick abundance was found to be clustered, highest along the coastal plain of Chesapeake Bay, and significantly associated with land cover, distance to water, distance to forest edge, elevation and soil type. Roper et al. (2000) analyzed the spatial patterns in the distribution of malaria cases in Padre Cocha, Peru in a study on malaria transmission. Mapping of household malaria incidence data and limited adult female *Anopheles* *darlingi* collection data revealed that the outer areas of the village had consistently high malaria infection densities, a central area had low malaria incidence and mosquito abundance showed the closest correlation with disease incidence. Finally, Elnaiem et al. (2003) developed a model for mapping the distribution and incidence of visceral leishmaniasis, a vector-borne disease highly influenced by environmental factors, in relation to eight different factors, including rainfall, vegetation status, soil type and altitude. The use of disease incidence calculated from hospital records along with logistic and linear multivariate regression analyses led these authors to the finding that average rainfall and altitude were the best predictors of visceral leishmaniasis incidence.

CHAPTER 2

Study Area and Methods

Abstract

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. A comprehensive arthropod pest data set was extracted from Hawaii State Department of Health Vector Control Branch inspection reports from 1990-1999. 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 specific species identifications.

Area of Study

Oahu (Figure 2.1) is the third largest of the Hawaiian Islands and the most populous island in the State of Hawaii (Macdonald et al., 1983). It is 71 km (44 mi) long and 48 km (30 mi) wide with a total land area of 1,600 km^2 (608 $mile^2$), and there are 366 km (227 mi) of shoreline with many bathing beaches. The island was created by two separate shield volcanoes that resulted in two parallel mountain ranges, Waianae to the south and Koolau to the north, with a broad, rolling central Oahu Plain between them. The highest point on Oahu is Mt. Kaala in the Waianae Range which rises to 1,225 m (4019 ft) above sea level. The island has no active volcanoes, but there are many extinct craters, including Diamond Head, Koko Head and Punchbowl. In addition, Pearl Harbor's well sheltered lochs indent Oahu's southern coast.

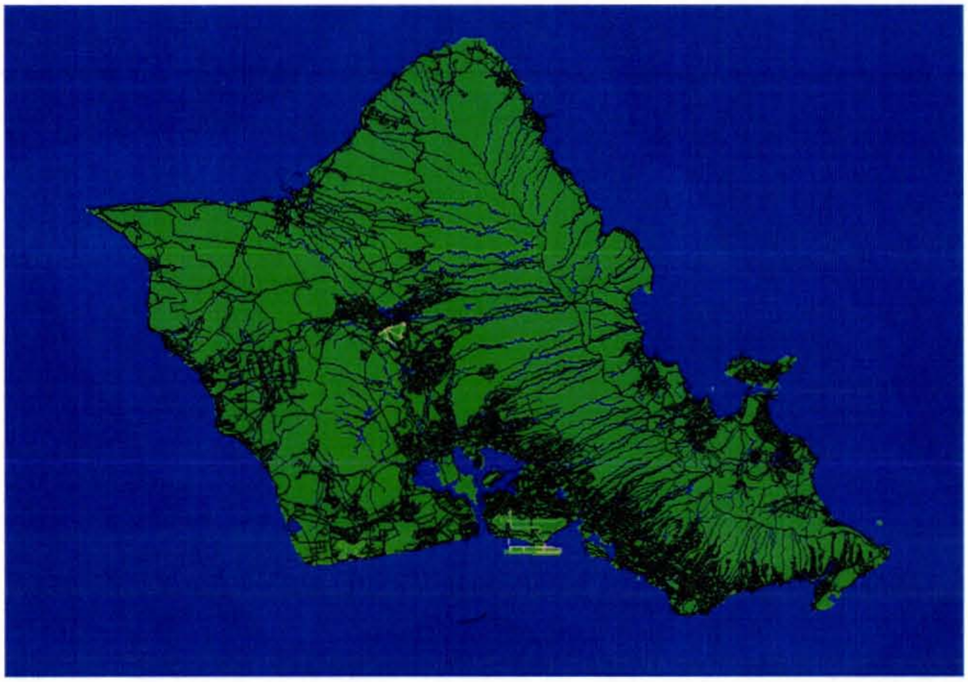

Figure 2.1. An ArcView GIS 3.2 generated map of the island of Oahu.

Oahu is home to ~900,000 people (approximately 75% of the resident population of the state). Honolulu, the state capital and the economic center of Hawaii, is on the island's highly urbanized southern coast. Development has expanded into the rural country side, and extensive growth has recently occurred in the central and Ewa Plains areas of the island. Large pineapple and sugarcane plantations that once covered the rural areas of Oahu are giving or have given way to residential development or diversified agriculture. Dairy, pig and chicken farming located primarily along the dry leeward coast has been declining over the past decade due to residential encroachment and socioeconomic pressures. Pearl Harbor continues to accommodate military and a large volume of commercial shipping, and the Honolulu International Airport is a busy commercial hub for the Asia-Pacific region. Although tourism remains the principal economic mainstay of Oahu and the rest of the state, agricultural exports are a very important part of the economy along with a growing high tech industry (Shore, 2000; Shore, 2001; Mark and Chrisafulli, 2001).

As with Hawaii in general, 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 (National Climatic Data Center, 2006). The cooler, winter season runs from October through April when widespread rainstorms are common, and the warmer, summer season runs from May through September during a period when there is an overwhelming dominance of trade winds. Windward lowlands on the north to northeast sides of the island are moderately rainy with frequent trade wind showers. The days are commonly partly cloudy, and temperatures are more uniform and mild. Leeward lowlands have slightly higher daytime temperatures and slightly lower nighttime temperatures than in windward locations. The weather is mainly dry except for occasional light trade showers and periods of major storms, and afternoon sea breezes are common in some areas. Interior lowlands in the northeast experience conditions like the windward lowlands and those in the southwest are like the leeward lowlands. The central areas are intermediate in character and sometimes experience intense local afternoon showers. Lower leeward mountain slopes have greater rainfall than on the adjacent lowlands, but less than at the same level on the windward side. Temperature extremes are greater than on the windward side and cloudiness is nearly the same. The rainy mountain slopes on the leeward side have very high cloudiness and rainfall in both winter and summer, temperatures are uniform, and humidity is higher than in any other region.

Materials and Methods

A comprehensive arthropod pest data set was extracted from Hawaii State Department of Health Vector Control Branch inspection reports from 1990-1999, with supporting data being drawn from Vector Control logbooks for the inspection reports. Population data were obtained from Hawaii Census 1990 and 2000 and The State of Hawaii Data Books for 1990 through 2004.

I reviewed the Vector Control inspection reports from 1990-1999 and compiled them into general pest categories using the reported problem on the original complaint that stimulated the inspection. This approach avoids the problem of introducing increasing complexity through the use of specific findings from multiple inspectors and the fact that a negative finding by an inspector doesn't necessarily mean the reported pest wasn't present prior to an inspection. It also preserves an aspect of the data that can be useful in an educational program, i.e., the public perception that a particular pest is a problem. Since inspections have been known to be ongoing or otherwise kept open for a year or more, using an earlier rather than a more recent time period for the study insures that the data set is as complete and accurate as possible. Out of a total of 17,695

Table 2.1. Pest categories by reported problem on the original complaint. The top 10 categories have been highlighted.

PEST CATEGORY	PEST COMPLAINTS %	No.
Ants	**6.4**	**572**
Aphids	0.0	1
Bedbugs	0.5	47
Bees	**8.3**	**740**
Beetles	0.2	21
Centipedes	**3.0**	**268**
Cockroaches	**6.1**	**546**
Crickets	0.0	1
Earwigs	0.0	2
Fleas	**9.2**	**820**
Flies	**15.0**	**1338**
Gnats	0.7	61
Lice	0.8	69
Mealybugs	0.0	1
Midges	0.1	6
Millipedes	0.2	19
Mites	**6.8**	**607**
Mosquitoes	**30.4**	**2718**
Moths	0.1	9
Psyllids	0.0	2
Scorpions	0.5	45
Silverfish	0.1	6
Spiders	0.9	84
Termites	0.4	33
Ticks	**2.1**	**186**
Wasps	**1.2**	**106**
Whiteflies	0.1	8
Miscellaneous - Insects, Bugs, Something Biting, worms	6.9	620
Total	**100.0**	**8936**

inspection reports over the 10 year study period, there were 8,154 (46.1%) arthropod related inspections. Twenty-four inspections were eliminated due to discrepancies in their site addresses leaving 8,130 inspections. All together, a total of 8,936 individual pest problems were found from which I obtained 27 pest categories, plus a miscellaneous category for very minor or anomalous reports (Table 2.1).

I established district/area geographic locations using community structure, geographic features and inspection report designations. Distinctions among communities were based upon subdivision outlines and major streets, types of land use, bodies of water such as large streams and lakes, mountains and valleys, and city and community boundaries. The total area of the established geographic locations did not cover the entire island as there are large tracts of vacant land, and individual district/areas vary in physical and population size. As a result, the data needed to be standardized for population differences. Population data drawn from Hawaii Census 1990 and 2000 and State of Hawaii Data Books were often grouped differently with respect to Honolulu county subdivisions and designated places, so census tracts and tract blocks were used in their entirety when appropriate, or subdivided along the same divisions I created between established communities as necessary. Since census data and state population estimates were available only for 1990, 1995 and 2000, I estimated the population for the intervening years using a straight-line curve. One-hundred twenty-five district/area geographic locations were defined (Table 2.2).

I standardized the raw pest occurrence data for each district/area by dividing by the estimated population and multiplying the decimal number generated by 10,000 ($n \div p \times 10{,}000$). The results were rounded up to the nearest whole number. Industrial parks,

Table 2.2. Examples of district/area geographic locations established for the island of Oahu together with their community populations. See Appendix B for a complete list of district/areas as well as the census tract:block divisions.

DISTRICT/AREA	CENSUS 1990	EST. POP 1991	EST. POP 1992	EST. POP 1993	EST. POP 1994	CENSUS 1995	EST. POP 1996	EST. POP 1997	EST. POP 1998	EST. POP 1999	CENSUS 2000
Airport	22	23	23	23	23	23	23	23	24	24	24
Kalihi Kai	2253	2153	2053	1953	1854	1754	1665	1576	1487	1398	1309
Sand Island	408	385	361	338	315	291	270	248	227	205	184
Downtown	8301	8474	8646	8818	8991	9163	9384	9605	9826	10047	10269
Nuuanu/Dowsett Highlands	10693	10650	10607	10564	10521	10478	10494	10510	10526	10542	10558
Kakaako	1147	1443	1739	2034	2330	2626	2932	3239	3545	3852	4159
Punchbowl/Pauoa/Pacific Hts.	19007	18989	18970	18952	18933	18915	19002	19089	19176	19263	19350
Ala Moana	10986	11127	11268	11409	11550	11691	11895	12099	12303	12507	12711
Makiki/Punahou	21112	21016	20921	20825	20730	20634	20655	20675	20695	20716	20736
Makiki Hts./Tantalus/Round Top	4487	4415	4343	4271	4199	4127	4079	4031	3982	3934	3886
Waikiki/Kapiolani Park	20190	20122	20053	19984	19916	19847	19890	19933	19975	20018	20061
McCully/Moiliili	28551	28263	27976	27688	27400	27112	26979	26845	26712	26578	26445
Kapahulu/Diamond Head	13370	13226	13082	12938	12795	12651	12579	12507	12436	12364	12293
Manoa/Woodlawn	18500	18489	18478	18468	18457	18446	18538	18630	18722	18814	18906
Saint Louis Heights	5431	5344	5257	5169	5082	4995	4937	4878	4820	4762	4704
Kaimuki/Waialae	14093	13976	13859	13742	13625	13508	13468	13428	13387	13347	13307
Palolo/Palolo Valley	12838	12814	12790	12767	12743	12719	12766	12814	12861	12908	12955
Wilhelmina Rise/Maunalani Hts.	6468	6472	6476	6480	6484	6488	6529	6569	6609	6649	6689
Kahala	7742	7705	7667	7630	7592	7555	7560	7565	7571	7576	7581
Waialae Nui	1645	1635	1625	1615	1605	1595	1595	1594	1593	1592	1591
Kalani Valley	781	775	770	764	758	753	751	750	749	747	746
Waialae Iki	3169	3205	3241	3277	3313	3349	3403	3457	3511	3565	3619
Wailupe	604	602	600	598	596	593	595	596	597	599	600
Aina Haina	4071	4092	4113	4134	4155	4176	4220	4264	4308	4352	4396
Hawaiiloa Ridge	850	868	885	903	920	937	960	982	1005	1027	1050
Niu Valley	2413	2410	2407	2405	2402	2399	2410	2421	2432	2442	2453

heavy commercial areas and very small communities produced standardized pest occurrence well into the 100's and 1000's, and required that district/areas with populations of less than 500 be excluded from occurrence analysis. I then mapped the resulting transformed pest occurrence data on a traditional four-season basis (winter, January to February plus December; spring, March to May; summer, June to August; and fall, September to November) rather than with two-seasons so that a better picture of activity during the year could be obtained. ArcView GIS 3.2 was used to create 40 maps for each of 10 major pest categories (Figure 2.2) along with four additional maps each showing cumulative seasonal activity. Three of the major pest categories did not contain enough data to make annual, seasonal mapping very useful. The maps of the seasonal

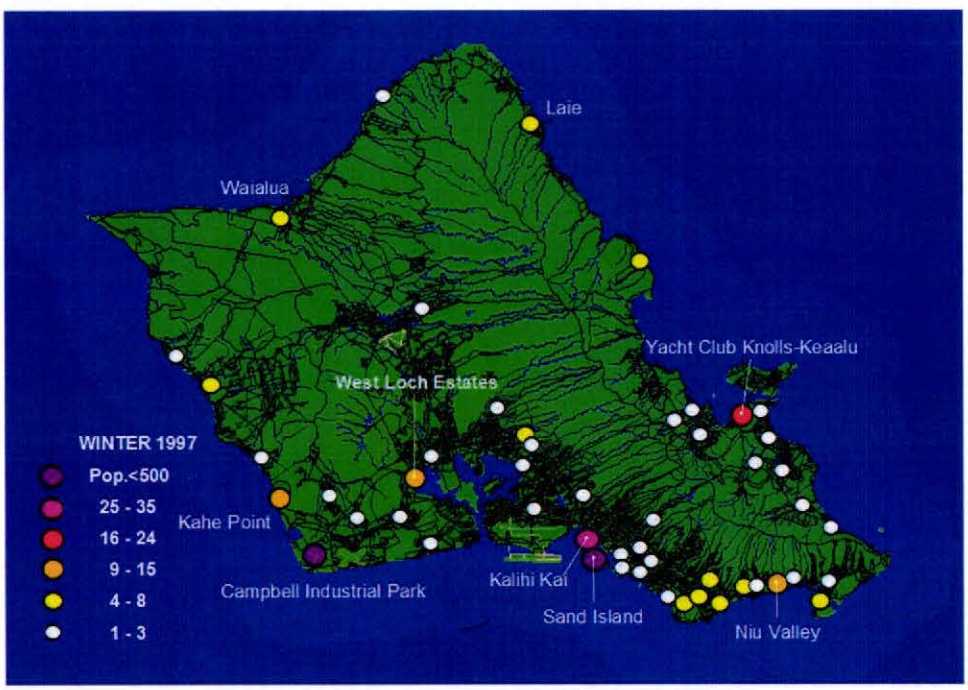

Figure 2.2. Example of a map including all levels of pest activity.

totals are included in each of six major pest chapters while the annual, seasonal maps may be viewed from off of an enclosed CD.

The occurrence data are presented in six mapped groups or levels of activity, 1-3 (very light; white), 4-8 (light; yellow), 9-15 (moderate; orange), 16-24 (heavy; red), 25-35 (very heavy; pink) and Pop.<500 (excluded; violet) (Figure 2.2). I graphically compared pest occurrence within and between district/areas, and correlated pest occurrence and distribution with season. Finally, I evaluated pest occurrence and distribution using inspection data, including specific species identifications. The results and discussions for six of the most common pest complaints are presented in detail in Chapters 3 through 7, four major pest category results are discussed more broadly in Chapter 8, and the remaining 18 pest groups are listed in Appendix A.

CHAPTER 3

Mosquitoes

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. By far, the greatest amount of arthropod pest information available is on mosquitoes. The objectives of this study were to conduct a survey of the occurrence of mosquito complaints on Oahu over a 10 year period, determine the distribution of complaints over time, graphically compare mosquito occurrence within and between district/areas, and correlate mosquito occurrence and distribution with season. Mosquito data were drawn from inspection reports from 1990-1999, population information was obtained from Hawaii Census and State of Hawaii Data Books, 125 district/area geographic locations were defined, and mosquito occurrence and distribution were adjusted for population and mapped using ArcView GIS 3.2. Most of the mosquito activity was found within the central, south and east urban districts. Drier areas from Kalihi Kai to Portlock had the highest number of complaints, and the levels of mosquito activity were highest during the winter, spring and summer. The primary mosquito species recorded was *Aedes albopictus* (Skuse), the Asian tiger mosquito, and the main

breeding sources were various containers, plus bromeliad plants. Gardening activities, irrigation, poor drainage, toys holding water, and man-made ponds and pools all contributed to mosquito breeding. *Aedes albopictus* populations are being maintained in urban districts by human activities. As a result, dengue transmission is possible in the drier, urban areas of Oahu. These results indicate that educational programs should be carried out in late fall and early spring, and that residential mosquito surveys may be concentrated in a limited number of district/areas.

Introduction

There are six biting species of mosquitoes in the State of Hawaii, all of which are non-native and were introduced accidentally through human activities. These include two night-biting species, *Culex quinquefasciatus* Say, the southern house mosquito, and *Aedes vexans nocturnus* (Theobald), the floodwater mosquito; and four day-biting species, *Ae. aegypti* (Linnaeus), the yellow fever mosquito, *Ae. albopictus* (Skuse), the dengue or Asian tiger mosquito, *Wyeomyia mitchellii* (Theobald), the bromeliad mosquito, and a new introduction, *Ae. (Finlaya) japonicus japonicus* (Theobald). *Culex quinquefasciatus* was introduced to Hawaii in 1826 from Mexico in water barrels aboard the ship Wellington when it landed at the port of Lahaina, Maui (Van Dine, 1904; Usinger, 1944; Hess, 1957; Hardy, 1960; Ikeda, 1982a), and *Ae. vexans nocturnus* was discovered on the island of Oahu in 1962 by Joyce and Nakagawa (1963) (Ikeda, 1982a). *Aedes aegypti* was widespread in Hawaii when Perkins (1913) started his collection for

Fauna Hawaiiensis in 1892 (Usinger, 1944; Hess, 1957; Hardy, 1960; Ikeda, 1982a), and *Ae. albopictus* arrived shortly thereafter, probably around 1895, since it was very abundant by 1902. *Wyeomyia mitchellii* was recovered by D. Shroyer in July 1981 while collecting in the Tantalus-Makiki area of Oahu (Shroyer, 1981; Ikeda, 1982a), and *Ae. (Finlaya) japonicus japonicus* was collected from a mosquito light trap in Laupahoehoe on the island of Hawaii by Linda Burnham Larish in November 2003 (Larish and Savage, 2005). Four of these six mosquito species, *C. quinquefasciatus*, *Ae. vexans nocturnus*, *Ae. albopictus* and *W. mitchellii*, occur on the island of Oahu today.

Culex quinquefasciatus is a known vector of human and canine filariasis (Hardy, 1960; Goff, 1980; Ikeda, 1982a; Chin, 2000), has transmitted avian malaria (*Plasmodium relictum*) between introduced and native bird populations (van Riper III et al., 1986), and research confirms that it will be the primary vector for West Nile virus (WNV) if the disease should be introduced into Hawaii (Sardelis et al., 2001; Goddard et al., 2002). Human filariasis (*Wuchereria bancrofti*) has not been a problem in Hawaii, but canine filariasis or the dog heartworm (*Dirofilaria immitis*) is transmitted primarily by *C. quinquefasciatus* and is of major veterinary importance (Hardy, 1960; Gubler, 1966). *Aedes vexans nocturnus* is a vector for dog heartworm (Joyce and Nakagawa, 1963; Goff, 1980), and may be a competent, though low risk vector for WNV like its sibling species *Ae. vexans* (Meigen) (Goddard et al., 2002; Kilpatrick et al., 2002). *Aedes albopictus* is an important vector of dengue fever and has been implicated in a recent dengue outbreak on Maui that peaked in September 2001 (Effler et al., 2005). It is also a vector for dog heartworm (Hardy, 1960; Goff, 1980; Ikeda, 1982a), is listed by Boyd (1949) as a minor vector of avian malaria (Goff, 1980), and is a very competent and important bridge vector for WNV (Sardelis et al., 2002). Despite being a painful biter, *W. mitchellii* is not known to vector any human diseases (Frank, 1990) and was not found to be carrying any arboviruses by Nayar et al. (2001).

As a reminder of the increased frequency of pest introductions into Hawaii, I recovered an *Anopheles sp.*, subsequently identified as *An. punctipennis* (Say) (Furumizo et al., 2005; Larish and Savage, 2005), from a Sand Island mosquito light trap in December 2003. Fortunately, extensive surveillance indicated this human malaria and WNV vector was not established on Oahu.

Results

Mosquito activity during the winter of 1990 was mainly very light (1-3 complaints) to light (4-8 complaints), and was scattered along the north shore and south, lower east, central and west Oahu. There were noticeable concentrations of activity in the central area of Halawa Valley and from Kapahulu to Aina Haina along the south coast. A total of 27 district/areas had reported mosquito activity in the winter of 1990. In winter 1991, light to heavy (16-24 complaints) mosquito activity was concentrated in lower central, south and lower east Oahu from Halawa, around Makapuu to Mahinui-Kokokahi. There were seven moderate peaks (9-15 complaints) from Halawa Valley to

Portlock, including Kalihi Kai, Kakaako, Makiki Heights-Round Top, Kahala and Aina Haina; and heavy spikes in mosquito activity occurred in Waialae Iki and Hawaiiloa Ridge. Overall mosquito activity doubled as compared to the preceding fall with a total of 52 district/areas reporting problems with mosquitoes in winter 1991. Mosquito activity in winter 1992 was mainly very light to light through central, south and east Oahu. Light activity was concentrated in the south between Saint Louis Heights and Kuliouou with a moderate peak occurring in Kalani Valley. A total of 41 district/areas reported mosquito activity in winter 1992. Winter 1993 mosquito activity was much reduced from that in 1992, very light to light and well scattered across the island. There was light activity in south Oahu between Kalihi Kai and Portlock, and along the east coast from Lanikai to Kaaawa. One moderate peak occurred in Hawaiiloa Ridge. A total of 29 district/areas reported mosquito activity in winter 1993. A sharp drop in mosquito activity occurred in the winter of 1994. Mostly very light activity was found along the central, south and east areas of Oahu from Waipahu to Kaaawa with light peaks occurring in Aina Haina and Kaaawa. A total of 18 district/areas reported mosquito activity in the winter of 1994. There were no west Oahu district/areas reporting any activity. The winter of 1995 saw mostly very light mosquito activity with several light peaks occurring around south, east and north Oahu in Aina Haina, Niu Valley, Mahinui/Kokokahi and Waialee-Waimea. There was one moderate peak in Mokuleia and a very heavy spike (25-35 complaints) in mosquito activity in Wailupe. A total of 30 district/areas reported mosquito activity in the winter of 1995. Mosquito activity in winter 1996 was mainly very light to light, and concentrated in south and east Oahu. There was a moderate peak in activity in Punaluu and a heavy spike in Portlock. A total of 46 district/areas reported mosquito activity in winter 1996. No north shore district/areas had reported any activity. The mosquito activity in winter 1997 was fairly spread out over the island with a concentration of light activity occurring in five district/areas along the south coast from Kapahulu to Waialae Iki, activity peaking moderately in Niu Valley and mosquito activity spiking very heavily in Kalihi Kai. Moderate peaks in activity also occurred in West Loch Estates in central Oahu and in the vicinity of Kahe Point in the west, and there was a heavy spike in mosquito activity in Yacht Club Knolls on the east side of the island. A total of 51 district/areas reported mosquito activity in winter 1997. Nearly all of the mosquito activity in winter 1998 was in south, east and central Oahu. Except for a heavy spike in activity on Mariners Ridge in south Oahu, mosquito activity was very light to light across the island. A total of 22 district/areas reported mosquito activity in winter 1998. No west Oahu district/areas reported any mosquito activity. Finally, mosquito activity increased sharply in the winter of 1999 with activity mainly occurring in the south, east and central district/areas. The activity was most intense along east Oahu where moderate peaks were found in Yacht Club Knolls, Waiahole-Waikane and Kaaawa. In addition, an area of unusual inactivity between Kahala and Hawaii Kai in south Oahu was noted. A total of 41 district/areas reported mosquito activity in the winter of 1999.

Spring 1990 mosquito activity remained scattered in general like that in the winter, but there was increased activity along the south districts from Kalihi Kai to

Hawaii Kai. Moderate peaks were found in Kalihi Kai and Aina Haina, and a heavy spike occurred in Kakaako. A total of 40 district/areas reported mosquito activity in spring 1990. Mosquito activity was reduced in spring 1991 with mainly light activity occurring in south Oahu from Kalihi Kai to Niu Valley. There were moderate peaks in Yacht Club Knolls-Keaalu on the east shore and Pupukea in the north, and a very heavy spike in mosquito activity in Kalani Valley on the south coast. A total of 38 district/areas reported mosquito activity in spring 1991. In spring 1992, mosquito activity increased across north, south, west and lower east Oahu. Activity was again concentrated in the south between Kapahulu-Diamond Head and Niu Valley with a moderate peak occurring in Kalani Valley and a very heavy spike showing up in Wailupe. A total of 51 district/areas reported mosquito activity in spring 1992. Mosquito activity decreased in spring 1993 with very light to light activity being concentrated in south Oahu between Kalihi Kai and Aina Haina. The areas of light activity were grouped fairly close to each other and included Kalihi Kai, Iwilei and Kakaako. A total of 21 district/areas reported mosquito activity in spring 1993. Overall spring 1994 mosquito activity was three times that of in the winter with new and increased activity occurring mainly in the west, central and south Oahu district/areas. In the south, there were moderate peaks in Kalihi Kai, Kakaako and Aina Haina together with a heavy spike in activity in Portlock. A total of 54 district/areas reported mosquito activity in spring 1994. Mosquito activity also increased in spring 1995, especially in south and east Oahu. Activity peaked moderately in Kahala and Hawaiiloa Ridge in the south and Waiahole-Waikane in the east, and spiked heavily in Wailupe. A total of 48 district/areas reported mosquito activity in spring 1995. Spring 1996 mosquito activity was comparable overall to that in winter 1996 with occurrence decreasing in east Oahu, and increasing in central and west Oahu. Activity peaked moderately in Fort Shafter and spiked heavily in Wailupe in the south, and moderate peaks in mosquito activity occurred in Waianae Valley and the Kahe Point area in the west. A total of 44 district/areas reported mosquito activity in spring 1996. There was an increase in mosquito activity in south and west Oahu in spring 1997, and a decrease in activity on the east coast. Most of the activity occurred in the south, east and central district/areas with activity peaking moderately in Kahala and Portlock on the south shore. A total of 58 district/areas reported mosquito activity in spring 1997. Mosquito activity in spring 1998 was much reduced and was at only a very light level across south, lower east and central Oahu. A total of 15 district/areas reported mosquito activity in spring 1998. No north shore or west Oahu district/ areas reported problems with mosquitoes. Lastly, spring 1999 showed decreased mosquito activity in east and central Oahu, and an increase in intensity on the north shore with the occurrence of a moderate peak in Waialee-Waimea and a heavy spike in Kawela. The activity was mostly in the south and central district/areas. A total of 32 district/areas reported mosquito activity in spring 1999.

There was a slight decrease in overall mosquito activity in summer 1990 from that in the spring with mild increases in north and lower east Oahu. Moderate peaks occurred on the south coast in Kakaako and Kahala, and Portlock had a heavy spike in activity. A total of 31 district/areas reported mosquito activity in summer 1990. There was a mild increase in the number of district/areas affected in summer 1991, but this was accompanied by a reduction in the level of individual site activity. Mosquito activity peaked moderately in Kakaako and Portlock as well as in Mokuleia on the north shore. A heavy spike occurred in Wailupe in south Oahu. A total of 40 district/areas reported mosquito activity in summer 1991. The number of district/areas reporting mosquito activity decreased in the summer of 1992 from in the spring. South and lower east Oahu were most affected, yet three south shore areas peaked moderately, Kahala, Kalani Valley and Hawaiiloa Ridge, and a very heavy spike occurred in Wailupe. A total of 43 district/areas reported mosquito activity in the summer of 1992. Summer 1993 mosquito activity increased to above that of spring and winter with the affected district/areas being fairly well scattered island wide. Activity peaked moderately in east Oahu in Yacht Club Knolls-Keaalu and Waiahole-Waikane, and on the north shore in Mokuleia. A total of 35 district/areas reported mosquito activity in summer 1993. Summer 1994 showed reduced mosquito activity in the south, east, central and west Oahu district/areas and a mild increase on the north shore. There was a moderate peak in Mokuleia and very light to light activity throughout south Oahu. A total of 35 district/areas reported mosquito activity in summer 1994. Summer 1995 mosquito activity showed a decrease in south and east Oahu by close to half from that in the spring. Activity peaked moderately in Mokuleia and a heavy spike in mosquito activity occurred in Portlock on the south shore. A total of 29 district/areas reported mosquito activity in summer 1995. Overall mosquito activity in summer 1996 was unchanged with occurrence decreasing in south Oahu, and increasing in north and central Oahu. Except for the upper east district/areas, a more widely distributed pattern of activity was apparent. Mosquito activity peaked heavily in Wailupe in the south and a very heavy spike occurred in Mokuleia in the north. A total of 44 district/areas reported mosquito activity in summer 1996. A large decrease in mosquito activity occurred in summer 1997 in the north, south and west district/areas. The remaining activity was mainly in south, lower east and central Oahu. There was a moderate peak in the south in Portlock along with heavy spikes in mosquito activity in Hawaiiloa Ridge and Niu Valley, and heavy activity was also found in the east in Yacht Club Knolls-Keaalu. A total of 35 district/areas reported mosquito activity in summer 1997. No west Oahu district/areas reported any mosquito activity. Except for a decrease in activity in central Oahu, the summer of 1998 saw a general increase in mosquito activity from that in the spring to up to a light level across the island. The main areas of activity were Downtown to Portlock in the south and Kailua to Ahuimanu in the east. A total of 26 district/areas reported mosquito activity in the summer of 1998. Mosquito activity declined on the north shore as well as in the east and central district/areas of Oahu in summer 1999. There was a small rise in activity on the west coast, and overall activity was concentrated in south Oahu from Kalihi Valley to Niu Valley. A total of 29 district/areas reported mosquito activity in summer 1999. No north shore areas reported any mosquito problems.

In the fall of 1990, mosquito activity further decreased from that in the summer with a moderate peak in activity occurring only in Kapolei. A total of 26 district/areas reported mosquito activity in the fall of 1990. The activity was mainly in the south Oahu district/areas and no west Oahu areas reported any mosquito activity. During the fall of 1991, the number of district/areas affected remained about the same as in the summer while the level of individual site mosquito activity decreased. Mostly light activity was found in south Oahu from Foster Village to Niu Valley with a moderate peak occurring in Kakaako. A total of 41 district/areas reported mosquito activity in the fall of 1991. There was a light increase in mosquito activity in fall 1992 with reported activity moving up into central Oahu and central east Oahu. Activity peaked moderately in West Loch Fairways, Kahala, Waialae Nui and Waiahole-Waikane, and spiked very heavily in Kalani Valley. In addition, a heavy spike occurred in Mokuleia. A total of 49 district/areas reported mosquito activity in fall 1992. Only one of which was from a west Oahu district/area, Makaha. Fall 1993 saw an increase in the number of district/areas reporting mosquito activity, but no more than a light level of activity occurred anywhere on the island. Over half of the activity in the east Oahu district/areas were light while those in north, south, central and west Oahu district/areas were predominantly very light. A total of 41 district/areas reported mosquito activity in fall 1993. There was an overall decrease in mosquito activity in the fall of 1994 across the island. However, a clear increase in activity occurred on the north shore with light activity in Haleiwa and heavy spikes in Kawela and Mokuleia. A light increase in mosquito activity also occurred in Lanikai and Olomana-Pohakupu in lower east Oahu. A total of 24 district/areas reported mosquito activity in the fall of 1994. There was increased mosquito activity in fall 1995 with much of the increase occurring in south Oahu, especially from Kahala to Queen's Gate-Kalama Valley. Moderate peaks in activity were found in Kahala, Mariners Ridge, Portlock and Punaluu, and a heavy spike occurred in Wailupe. A total of 40 district/areas reported mosquito activity in fall 1995. In fall 1996, mosquito activity increased in south, east and west Oahu while it decreased in north and central Oahu. Moderate peaks in activity occurred in Mokuleia in the north and Kahe Point in the west, and mosquito activity spiked heavily in Wailupe in the south. A total of 48 district/areas reported mosquito activity in fall 1996. A further decrease in mosquito activity from in the summer occurred in the fall of 1997 in the south, east and central district/areas. Very light and light activity were found largely around south and east Oahu. A total of 25 district/areas reported mosquito activity in the fall of 1997. In fall 1998, there was a decrease in mosquito activity in the south and east district/areas that resulted in an overall level of occurrence about half that of in the summer. The problem sites were scattered and mostly lightly active with a moderate peak appearing in Kakaako in south Oahu. A total of 13 district/areas reported mosquito activity in fall 1998. There was a mild decrease in overall mosquito activity in fall 1999 and occurrence was more distributed over the island. Activity was mainly very light, and mostly in the south and central district/areas. A total of 27 district/areas reported mosquito activity in fall 1999.

Most of the mosquito activity was found within the central, south and east urban districts of the island of Oahu (Figures 3.1-3.4, seasonal totals). Drier areas from Kalihi Kai to Portlock showed the highest number of complaints, and the levels of mosquito activity were highest during the winter, spring and summer. There were a relatively low number of mosquito problems around the ports of entry. However, the major ports of

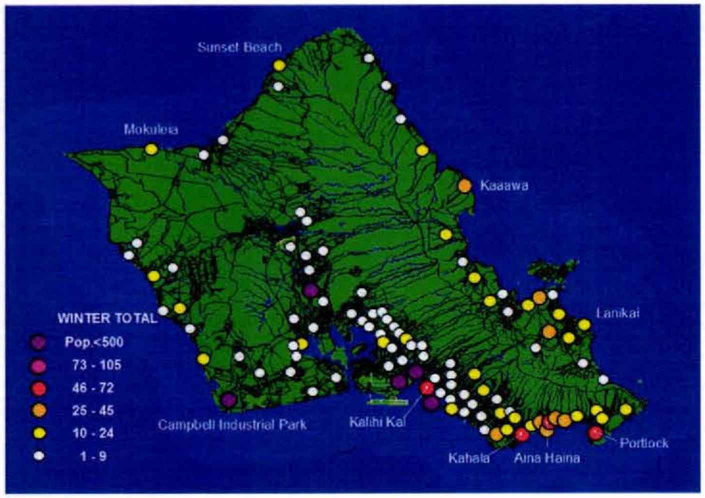

Figure 3.1. Mosquitoes, winter total (1990-1999).

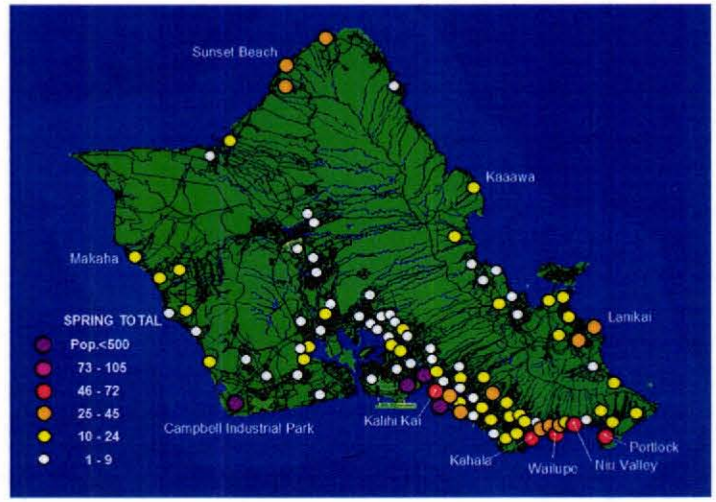

Figure 3.2. Mosquitoes, spring total (1990-1999).

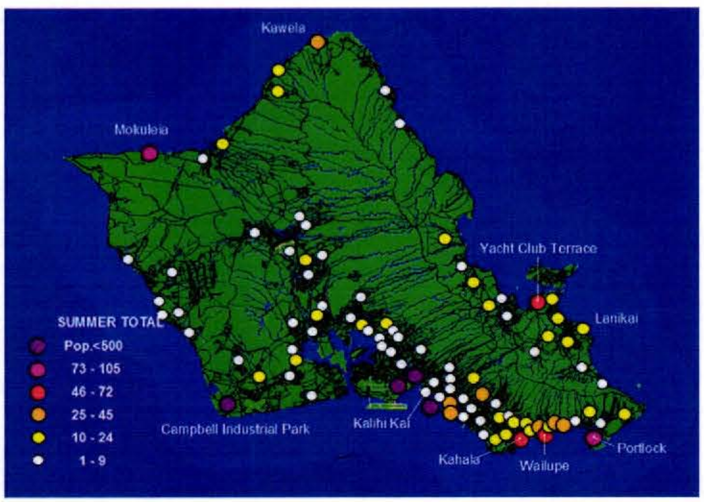

Figure 3.3. Mosquitoes, summer total (1990-1999).

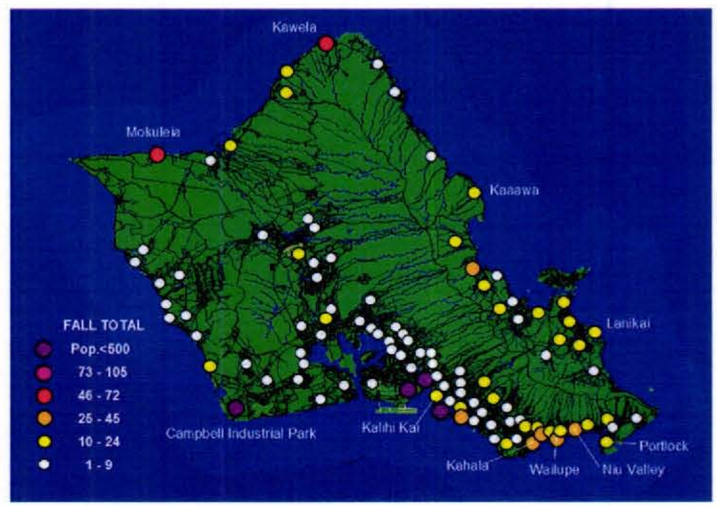

Figure 3.4. Mosquitoes, fall total (1990-1999).

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 mosquito species recorded was *Aedes albopictus* (~81.3%; n = 2,163), the Asian tiger mosquito (Table 3.1). Isolated *Wyeomyia mitchellii* (~7.1%), bromeliad mosquito, and few *Culex quinquefasciatus* (~11.6%), southern house mosquito, cases were recorded. Species occurrence increased slightly to ~89.5%, ~7.8% and ~12.8% respectively when the number of sites (n = 1,965) was taken into consideration since multiple species have been found together on the same site. The main breeding sources found were various containers (~41.2%; n = 631) such as plant pots, buckets and tires plus bromeliad plants (Bromeliaceae; ~34.4%) (Table 3.2). Gardening activities, irrigation, poor drainage, toys holding water, and man-made ponds and pools all contributed to mosquito breeding. Although it may appear there was a significant socioeconomic component to the high occurrence of mosquito activity from Kahala to Portlock, the cases actually involved residents with a broad range of ethnic and social backgrounds. Economic status was a more important consideration since it allowed for extensive landscaping and gardening which often included the planting of bromeliads and regular watering, and the presence of swimming pools and man-made ponds. Although the major ports of entry and other industrial district/areas had a relatively low number of mosquito complaints, infestations were generally heavy when

Table 3.1. Mosquito species occurrence as determined by a sampling of 2,536 mosquito-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Aedes albopictus	81.3	175.8	204	193	228	108	120	194	225	246	88	152	**1758**
Culex quinquefasciatus	11.6	25.1	20	28	34	19	24	28	45	16	12	25	**251**
Wyeomyia mitchellii	7.1	15.4	7	8	9	3	6	12	38	42	10	19	**154**
Total	**100.0**	**216.3**	**231**	**229**	**271**	**130**	**150**	**234**	**308**	**304**	**110**	**196**	**2163**

Table 3.2. Mosquito breeding sources as determined by a sampling of 1,459 mosquito-related inspection reports.

BREEDING SOURCES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Ape/Spider Lilies	2.1	2.2	N/A*	N/A	N/A	N/A	4	2	1	3	3	0	**13**
Bromeliads	34.4	36.2	N/A	N/A	N/A	N/A	26	44	52	51	13	31	**217**
Containers/Tires	41.2	43.3	N/A	N/A	N/A	N/A	6	29	15	66	46	98	**260**
Ground Pools/Ditches	4.8	5.0	N/A	N/A	N/A	N/A	4	1	3	5	7	10	**30**
Pools/Ponds/Sumps	17.6	18.5	N/A	N/A	N/A	N/A	4	16	9	25	24	33	**111**
Total	**100.0**	**105.2**	**N/A**	**N/A**	**N/A**	**N/A**	**44**	**92**	**80**	**150**	**93**	**172**	**631**

*Data not available.

they occurred. The main breeding sources in these areas were car and truck tires, buckets and various other storage containers, and construction materials such as large sections of plumbing.

It was previously thought that there would be a higher occurrence of mosquito activity around the east, north and west areas of Oahu due to known *C. quinquefasciatus* breeding sites and within district/areas bordering forested lands due to standing populations of *Ae. albopictus*, also known as the forest-day mosquito. However, instead, this survey has determined that *Ae. albopictus* populations were being maintained in urban districts by human activities. As a result, dengue transmission is possible in the drier, urban areas of Oahu. This is especially significant since dengue cases in the past (Usinger, 1944) had occurred in nearly inverse proportion to the incidence of mosquito breeding and could be correlated with the density of the human population rather than with mosquito density (note: a 1948 mosquito survey finding reported by Bonnet (1949) that *Ae. aegypti*, an excellent dengue vector, was found strictly on the seaward side of a line drawn along Beretania Street may be a contributing factor for this observation). There was limited information for assessing the occurrence and distribution of night biting mosquitoes across the island. Inspection reports, therefore, need to be supplemented with mosquito light trap data to better determine *C. quinquefasciatus* and *Ae. vexans nocturnus* activity.

As in this study, Usinger (1944) also indicated that mosquito activity was usually low during the fall months since they form the ending of the dry season and anticipated an increase in mosquito breeding with the coming of winter rains. The results indicate that community or island-wide educational programs should be carried out in late fall and early spring to prepare the public for and reinforce awareness during Hawaii's mosquito season, and that residential mosquito surveys may be concentrated in a limited number of district/areas according to mosquito complaints received. Educational activities are currently conducted in response to dengue cases identified locally and West Nile virus (WNV) threats from the continental U.S.A., or on a limited basis during inspections. A WNV prevention and mosquito control effort carried out in September 2004, WNV Mosquito Survey and Larviciding for Ports of Entry on Oahu, confirmed the practicality of using small-target area surveys. In a survey that encompassed all areas within 2 miles of Honolulu Harbor and Kalaeloa Barbers Point Harbor, only 17 of 1051 (1.6%) of the sites inspected contained mosquito activity and much of the major breeding areas were already known. As pointed out earlier, relatively few mosquito complaints were received for industrial parks and heavy commercial areas overall, but particular mosquito problems were often found to be severe. Taking the workforce, visitor and transient resident populations into consideration, this is a very important implication for the spread of a vector-borne disease or introduction of a new mosquito vector, especially in the industrial parks and harbor areas.

Geographic analysis can help to target areas and times of the year for more efficient application of mosquito prevention, control and education programs by continuously tracking mosquito activity using Vector Control inspection reports. Improvements in methodology include incorporating mosquito gravid trap (currently employed only in the ports of entry) and light trap data to achieve a better picture of night-biting mosquito activity, and using the actual number of complaints within a district/area and the severity of the mosquito 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 mosquito 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 mosquito 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.

CHAPTER 4

Flies

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. Fly related problems, excluding both mosquitoes and odor complaints that often lead to fly breeding violations, provided the second greatest amount of arthropod pest information available, after mosquitoes. The objectives of this study were to conduct a survey on the occurrence of fly complaints on Oahu over a 10 year period, determine their distribution over time, graphically compare fly occurrence within and between district/areas, and correlate fly occurrence and distribution with season. Fly data were drawn from inspection reports from 1990-1999, population information was obtained from Hawaii Census and State of Hawaii Data Books, 125 district/area geographic locations were defined, and fly occurrence and distribution were adjusted for population and mapped using ArcView GIS 3.2. Overall, reported fly activity was found to occur fairly evenly across the island's districts. Lower elevation areas around the perimeter of Oahu had the greatest number of complaints and the levels of fly activity were highest during the winter and summer. There were a light number of fly problems

around the ports of entry with none being recorded in the fall months. The primary fly species recorded were *Phaencia cuprina* (Wiedemann), the bronze bottle fly; *Musca sorbens* Wiedemann, the dog dung fly; *Chrysomya megacephala* (Fabricius), the Oriental blow fly; and *M. domestica* Linneaus, the house fly. The main breeding sources were food garbage and slop, pet and farm animal dung, dead animals, and rotten fruits. Fly populations are being maintained in urban and agricultural districts by human activities. As a result, disease transmission is possible, especially in the lower elevation, urban and agricultural areas of Oahu. These results indicate that educational programs should be carried out in late fall and late spring, and that residential fly surveys may be concentrated in a limited number of district/areas.

Introduction

Of 360 non-native fly species, excluding mosquitoes, present in Hawaii (Tenorio and Nishida, 1995), only four have been major domestic pests on Oahu. These are *Musca domestica* Linneaus, the house fly; *M. sorbens* Wiedemann, the dog dung fly; *Phaenicia cuprina* (Wiedemann), the bronze bottle fly; and *Chrysomya megacephala* (Fabricius), the Oriental blow fly. *Musca domestica* was first recorded in Hawaii by Thompson in 1868 in the Diptera of the "Eugenies Resa" (Grimshaw, 1901; Hardy, 1981; DuPonte and Larish, 2003a), and apparently arrived in the islands along with the Polynesians because it was here before contact with Westerners (Illingworth, 1923; Hardy, 1960; Tenorio and Nishida, 1995). Joyce (1950) found *M. sorbens* in Hawaii in 1949 (Wilton, 1963; Legner et al., 1974; Hardy, 1981; Tenorio and Nishida, 1995; DuPonte and Larish, 2003b) and, although it was already well established, *P. cuprina* was not reported in Hawaii until 1947 (James, 1947; Joyce, 1954; Hardy, 1981; DuPonte and Larish, 2003c). Hardy (1981) reviewed insect collections for *P. cuprina* and found the oldest record to be from Oahu in January 1914. *Chrysomya megacephala* was first collected in Kona, Hawaii in July 1892 by Grimshaw (1901) (Hardy, 1981; DuPonte and Larish, 2003d). In addition, minor pest problems have been caused by isolated, short-lived and/or seasonal infestations of fly species in the families Chironomidae (midges), Drosophilidae (vinegar flies), Phoridae (hump-backed flies), Psychodidae (moth flies), Sarcophagidae (flesh and small dung flies) and Sciaridae (dark-winged fungus gnats). A few of the minor fly pests, midges and gnats, were also recorded separately and are listed in Appendix A.

In general, disease transmission by flies is primarily through the mechanical transfer of pathogens from a fly's body, regurgitated saliva and stomach contents, and excrement (Ebeling, 1975; Toyama, 1982b). Flies are known vectors of bacillary dysentery (*Shigella dysenteriae*), shigellosis (*Shigella*), conjunctivitis (*Haemophilus* and *Streptococcus*), trachoma (*Chlamydia trachomatis*) and *Campylobacter* enteritis (*Campylobacter jejuni*); and are suspected of transmitting amoebic dysentery (*Entamoeba histolyica*), typhoid fever (*Salmonella enterica* Typhi), salmonellosis (*Salmonella*), tuberculosis (*Mycobacterium tuberculosis*), cholera (*Vibrio cholerae*), tularemia (*Francisella tularensis*), anthrax (*Bacillus anthracis*), leprosy (*Mycobacterium leprae*), yaws (*Treponema pallidum*), poliomyelitis (Poliovirus), infectious hepatitis

(Hepatitis A virus), and eggs of pinworms (*Enterobius vermicularis*), whipworms (*Trichuris trichiura*), hookworms (*Necator americanus* and *Ancylostoma*), roundworms (*Ascaris lumbricoides*) and tapeworms (*Echinococcus granulosus*) (Hayes, 1958; James and Harwood, 1971; Ebeling, 1975; Toyama, 1982b; Chin, 2000; Hald et al., 2004). Human myiasis, the entry of fly larvae into the human body via festering wounds, ingestion, eyes and other body openings, occasionally occurs in Hawaii. These cases are usually facultative or accidental in nature. *Musca domestica* is a vector of dysentery, *Campylobacter*, tuberculosis, fowl cholera, poultry tapeworm and Newcastle disease. *Musca sorbens* is a vector of trachoma and has been implicated in transmitting a variety of viruses, bacteria and parasites to animals and man. It is also a major source of annoyance in addition to being a health concern because it is very attracted to the human body, especially to open wounds. *Phaenicia cuprina* breeds heavily in garbage, has invaded homes, and has caused myiasis of wounds in humans and animals. *Chrysomya megacephala* vectors dysentery and typhoid fever, causes myiasis of diseased tissue, and breeds in large numbers in animal carcasses, food waste and garbage on farms.

Results

Fly activity during the winter of 1990 was very light (1-3 complaints) with a light peak (4-8 complaints) occurring in the south district/area of Portlock. Complaints were mainly found along south Oahu and there were noticeably fewer problems across the east, north shore and central areas. No west Oahu district/areas reported any activity. A total of 13 district/areas had reported fly activity in the winter of 1990. In winter 1991, very light fly activity was scattered over the island, and light activity occurred in Kakaako, Niu Valley and Portlock along south Oahu and Waimanalo and Kaaawa on the east side. The majority of the complaints were on the leeward side of the island and most of these were found in south Oahu. Overall fly activity at least doubled as compared to the preceding fall with a total of 23 district/areas reporting problems with flies in winter 1991. Fly activity in winter 1992 was very light to light through central, south, lower east and west Oahu. Activity was mainly in the south and lower east district/areas with light peaks occurring in Kahala, Lanikai and Maunawili. A total of 19 district/areas reported fly activity in winter 1992. Winter 1993 fly activity was mostly very light, reduced from that in 1992 and more spread out across the island. There was light activity in Niu Valley in south Oahu, Lanikai on the east coast, and Maili Kai and Maili on the west side. One heavy spike (16-24 complaints) occurred in Halawa Valley in central Oahu. A total of 13 district/areas reported fly activity in winter 1993. A sharp drop in fly activity occurred in the winter of 1994. Mostly very light activity was found along the south and west areas of Oahu from Kaimuki-Waialae to Makaha with a light peak occurring in West Loch Fairways. Moderate fly activity (9-15 complaints) was found in Waiahole-Waikane in east Oahu and there was no activity reported on the north shore. A total of 12 district/areas reported fly activity in the winter of 1994. The winter of 1995 saw an increase in fly activity over the previous fall with over twice as many district/areas on the leeward side of the island reporting problems than the windward side. There were light peaks in Aina Haina and Kalama Valley in south Oahu, Waimanalo

Beach on the east coast, and Sunset Beach on the north shore. Moderate fly activity occurred in Mokuleia on the north shore and in Mikilua in west Oahu, and a heavy spike was found in Wailupe on the south coast. A total of 29 district/areas reported fly activity in the winter of 1995. Fly activity in winter 1996 again increased over the previous fall with the majority of the activity occurring on the leeward side of the island. There was light activity in Foster Village in south Oahu, Waianae on the west coast, and Waimanalo Beach, Waimanalo and Kaaawa on the east side of the island. A moderate peak in activity occurred in the area of Honokai Hale on the west coast of Oahu. A total of 28 district/areas reported fly activity in winter 1996. No north shore district/areas had reported any activity. The fly activity in winter 1997 followed the same general pattern as in the previous two years. Light activity occurred in Niu Valley and Hahaione Valley in south Oahu, Heeia Kea on the east coast, and Waialua on the north shore. A total of 27 district/areas reported fly activity in winter 1997. The fly activity in winter 1998 slightly decreased and was better distributed over the island. Activity peaked lightly in Lanikai in east Oahu and Waialua on the north shore, and moderate spikes occurred in Waiahole-Waikane on the east side and Mokuleia on the north shore. A total of 19 district/areas reported fly activity in winter 1998. Finally, fly activity increased in the winter of 1999 with activity mainly occurring in the south and lower east district/areas. There was light activity in Kakaako and Hahaione Valley on the south shore, Lanikai on the east coast, Halawa Heights in central Oahu, and Waianae on the west coast. A moderate peak in fly activity occurred in the area of Yacht Club Knolls in east Oahu. A total of 28 district/areas reported fly activity in the winter of 1999.

Spring 1990 fly activity occurred mostly along the south and east coasts of Oahu and in about the same number of district/areas as in the winter, but there was a noticeable increase in the level of activity in a few south and central districts. Light fly activity was present in Lanikai on the east side, and moderate peaks were found in Kakaako, Iwilei and West Loch Estates along leeward Oahu. No north shore district/areas reported any activity. A total of 12 district/areas reported fly activity in spring 1990. Fly activity was reduced in spring 1991 with mainly very light activity occurring in south and central Oahu. There were light peaks in Pupukea on the north shore and Kakaako in the south. A total of 12 district/areas reported fly activity in spring 1991. In spring 1992, fly activity decreased, and occurred only in the eastern half of south Oahu and the lower east coast of the island. Light activity was found in Kakaako and Niu Valley on the south shore, and Waimanalo and Lanikai on the east side. A total of 13 district/areas reported fly activity in spring 1992. Fly activity increased in spring 1993 from that in the winter with the mostly very light activity occurring mainly in south and central Oahu. Light activity was found in Waialua in the north and Hahaione Valley in the south, and there was a heavy peak in Mokuleia on the north shore. A total of 20 district/areas reported fly activity in spring 1993. Spring 1994 fly activity increased and the very light to light activity was distributed across the island. Light peaks occurred in the Sunset Beach area on the north shore, Iwilei in the south, Kahuku along east Oahu and Waianae Valley in the west. A total of 20 district/areas reported fly activity in spring 1994. Fly activity also increased in spring 1995, especially in south Oahu, but the overall level of activity of individual sites decreased. Activity peaked lightly in Kakaako and Saint Louis Heights in the south, Waimanalo and Hauula in the east, and Halawa Heights in central Oahu. Fly activity spiked moderately in Kalama Valley in south Oahu. A total of 39 district/areas reported fly activity in spring 1995. Spring 1996 fly activity decreased overall from that in winter 1996. Activity peaked lightly in Pacific Palisades in central Oahu and the majority of the activity occurred on the leeward side of the island. A total of 20 district/areas reported fly activity in spring 1996. There was a decrease in fly activity in east and west Oahu in spring 1997, and a noticeable grouping of very light activity from Kamehameha Heights to Diamond Head in the south. A light peak in fly activity occurred in Iwilei in south Oahu. A total of 21 district/areas reported fly activity in spring 1997. Fly activity in spring 1998 was much reduced and was well spread out across the island. Light fly activity was found in Kahuku in east Oahu and there was no activity reported in west district/ areas. A total of nine district/areas reported fly activity in spring 1998. Lastly, spring 1999 showed decreased fly activity overall with increases on the north shore and in west Oahu, and decreases in south, east and central Oahu. Light activity occurred in Pupukea on the north shore and Kahala in the south, and there was a moderate peak in the Honokai Hale area along west Oahu. A total of 21 district/areas reported fly activity in spring 1999.

There was a slight increase in the number of district/areas reporting fly activity in summer 1990 from that in the spring. Light activity was found in Iwilei in the south and a moderate peak occurred in Halawa Valley in central Oahu. A total of 15 district/areas reported fly activity in summer 1990. There was a light increase in the level of fly activity in summer 1991 and the affected district/areas were well scattered across the island. Fly activity was light in Kakaako on the south shore, and peaked moderately in Mahinui-Kokokahi on the east side and Mokuleia on the north shore. A total of 12 district/areas reported fly activity in summer 1991. Fly activity also increased lightly in the summer of 1992 from in the spring. Several district/areas on the northern half of Oahu reported activity and, as in the spring, there were no fly complaints on the west side of the island. Light peaks in fly activity occurred on the north shore in Haleiwa, in Kalihi Kai on the south side, and in east Oahu in Lanikai and Maunawili. A total of 15 district/areas reported fly activity in the summer of 1992. Summer 1993 fly activity increased noticeably above that of spring and winter with most of the affected district/areas occurring on the leeward side of Oahu. Light activity occurred in Pupukea on the north shore, Kakaako and Portlock along south Oahu, and Lanikai and Kahuku on the east side of the island. Fly activity peaked moderately in south Oahu in Kalani Valley and Kuliouou. A total of 38 district/areas reported fly activity in summer 1993. Summer 1994 showed increased fly activity in the south Oahu district/areas. There were light peaks in activity in the Sunset Beach area of the north shore, West Loch Estates in central Oahu, Hahaione Valley on the south side, and in Lanikai and Kahuku along the east coast. A total of 27 district/areas reported fly activity in summer 1994. Summer 1995 fly activity showed a light decrease overall with much of the activity occurring in the south and central district/areas. Fly activity peaked lightly in Haleiwa in the north, Iwilei and Niu Valley in the south, and Halawa Valley in central Oahu. A heavy spike in fly activity occurred in Kawela on the north shore. A total of 36 district/areas reported fly activity in summer 1995. Overall fly activity in summer 1996 increased from that in the spring and was similar to the winter activity. Fly activity peaked lightly in West Loch Fairways, Iwilei and Portlock in the south, Waipio Acres in central Oahu, and Waianae Valley on the west side of the island. A moderate spike in fly activity occurred in the Honokai Hale area of west Oahu. No activity was reported on the north shore and the fly activity was clearly concentrated on the leeward side of the island. A total of 28 district/areas reported fly activity in summer 1996. A slight increase in fly activity occurred in summer 1997 with activity peaking lightly in Pupukea on the north shore and Waiau in central Oahu. A total of 23 district/areas reported fly activity in summer 1997. The fly activity in the summer of 1998 doubled from that in the spring. A light peak in activity occurred in Kahuku along east Oahu and there was a moderate spike in Mokuleia on the north shore. A total of 19 district/areas reported fly activity in the summer of 1998. Fly activity declined on the north shore as well as in the east and west district/areas of Oahu in summer 1999. There was no reported activity on the north shore, and very light fly activity occurred mainly from Mililani Town in central Oahu to Kahala on the south shore. A moderate peak in activity was found in Kunia in central Oahu. A total of 22 district/areas reported fly activity in summer 1999.

In the fall of 1990, fly activity decreased overall from that in the summer and was fairly spread out over the island. A light peak in activity occurred in Kahaluu-Waihee Valley in east Oahu. A total of 12 district/areas reported fly activity in the fall of 1990. During the fall of 1991, the number of district/areas affected and levels of site activity increased to nearly double the summer activity. Mostly very light activity was found in south, east and central Oahu with no activity being reported along the north shore and west district/areas. Light fly activity was found in Niu Valley and Portlock on the south coast, a moderate peak occurred in Waikele in central Oahu and a heavy spike was recorded for Kakaako on the south shore. A total of 21 district/areas reported fly activity in the fall of 1991. There was an increase in fly activity in fall 1992 with reported activity shifting from the northern areas of the island into central and west Oahu. As in the winter, spring and summer, the district/areas with consistent fly activity were in the eastern half of the south shore and the lower east coast. The highest activity occurred in south Oahu with light peaks being found in Kakaako, Kahala, Waialae Nui, Hahaione Valley and Portlock. A total of 23 district/areas reported fly activity in fall 1992. Fall 1993 saw a noticeable decrease in the number of district/areas reporting fly activity. There were light peaks in Haleiwa on the north shore, Kakaako and Niu Valley on the south coast, and Waimanalo Beach, Olomana-Pohakupu and Heeia in east Oahu. A total of 27 district/areas reported fly activity in fall 1993. There was an overall decrease in fly activity in the fall of 1994 with no activity being reported on the north shore and most of the affected district/areas occurring on the leeward side of the island. Light peaks in fly activity were found in Waikele in central Oahu and Maili on the west coast. A total of 21 district/areas reported fly activity in the fall of 1994. There was decreased fly activity in fall 1995 to less than half of that in the summer, and no activity was reported on the north shore or along east Oahu. Light peaks in activity were found in Kalihi Kai and Iwilei on the south coast, and in Maili Kai in west Oahu. A total of 17 district/areas reported fly activity in fall 1995. In fall 1996, fly activity also decreased by about half with no activity being reported on the north shore or along east Oahu. Light peaks in activity were found in Kalihi Kai, Waikiki-Kapiolani Park and Saint Louis Heights in south Oahu, and in Maili on the west coast of the island. A total of 14 district/areas reported fly activity in fall 1996. An overall increase in fly activity from in the summer occurred in the fall of 1997. Increases in the number of district/areas affected and level of site activity were found in the eastern half of south Oahu and along the lower east shore. Light fly activity was reported in Hahaione Valley on the south coast and in Lanikai along east Oahu, and moderate peaks in activity occurred in Iwilei and Kakaako on the south shore of the island. A total of 25 district/areas reported fly activity in the fall of 1997. In fall 1998, fly activity was comparable to that of in the summer. There was light activity in West Loch Fairways in south Oahu, Mahinui-Kokokahi on the east coast and in Makaha Valley on the west side of the island, and a moderate peak occurred in Kalani Valley on the south shore. A total of 20 district/areas reported fly activity in fall 1998. No activity was reported on the north shore. There was a slight increase in overall fly activity in fall 1999 with activity mainly occurring in leeward district/areas. Moderate peaks in fly activity were found in Kalani Valley in south Oahu and in the Honokai Hale area of the west side of the island. There were no reports of activity on the north shore. A total of 22 district/areas reported fly activity in fall 1999.

Although fly activity was often higher on the leeward side of Oahu and concentrated around the eastern half of the south shore to the lower east side of the

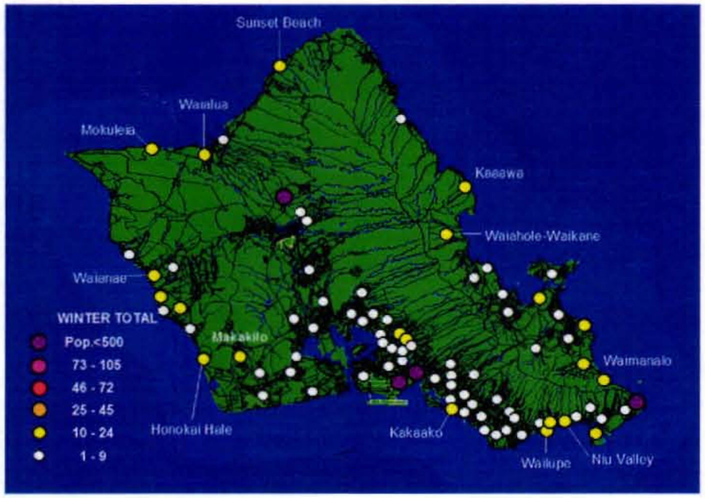

Figure 4.1. Flies, winter total (1990-1999).

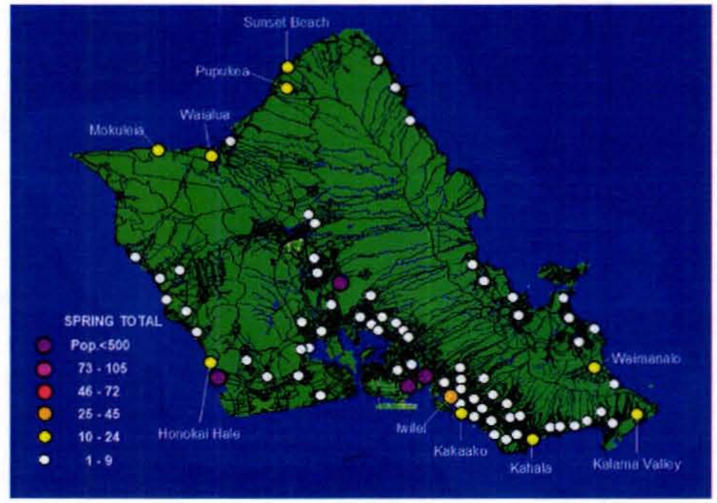

Figure 4.2. Flies, spring total (1990-1999).

Figure 4.3. Flies, summer total (1990-1999).

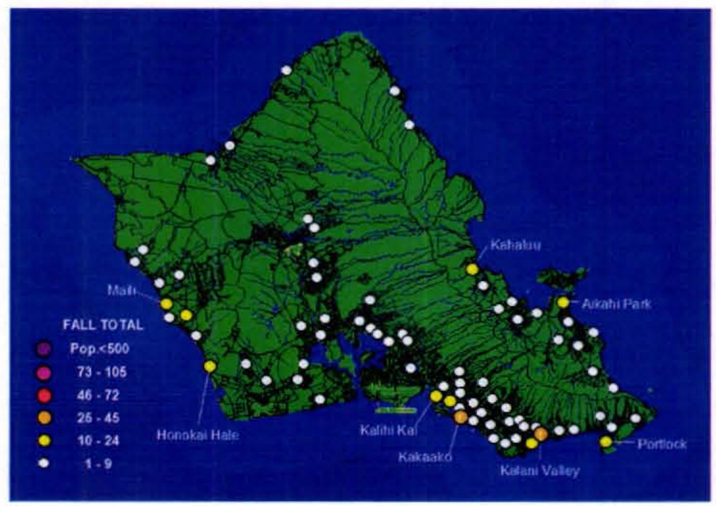

Figure 4.4. Flies, fall total (1990-1999).

island, reported activity was found to occur fairly evenly across the island's districts overall (Figures 4.1-4.4, seasonal totals). Lower elevation areas around the perimeter of Oahu had the greatest number of complaints and the levels of fly activity were highest during the winter and summer. There were a small number of fly problems around the ports of entry with none being recorded in the fall months. 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 fly species recorded were *Phaencia cuprina* (~39.2%; n = 689), the bronze bottle fly; *Musca sorbens* (~29.2%), the dog dung fly; *Chrysomya megacephala* (~10.0%), the Oriental blow fly; and *M. domestica* (~9.0%), the house fly (Table 4.1). *Chrysomya megacephala* occurrence often overlapped with *P. cuprina*, and smaller numbers of Sarcophagidae, flesh and small dung flies; Psychodidae, moth fly; Phoridae, hump-backed fly; and Drosophilidae, vinegar fly, cases were also recorded. The main breeding sources were food garbage and slop (~45.0%; n = 451), pet and farm animal dung (~47.0%), dead animals (~5.8%), and rotten fruits (~1.6%) (Table 4.2). The major sources of fly infestations in residential areas were improperly bagged and/or accumulated loose garbage, and dog and cat feces accumulation (~39.5%). Agricultural lands and residential properties bordering farm land mainly experienced fly problems due to the improper use of slop or other food garbage, and wet chicken manure after heavy

Table 4.1. Fly species occurrence as determined by a sampling of 1,073 fly-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Chironomidae	0.1	0.1	0	0	0	0	0	1	0	0	0	0	**1**
Chrysomya megacephala	10.0	6.9	19	4	5	0	1	9	6	15	5	5	**69**
C. rufifacies	0.1	0.1	0	0	0	0	0	0	0	1	0	0	**1**
Drosophila spp.	2.9	2.0	8	3	0	0	1	4	0	1	2	1	**20**
Hermetia illucens	0.1	0.1	0	0	0	0	1	0	0	0	0	0	**1**
Musca domestica	9.0	6.2	6	6	4	5	3	16	12	4	3	3	**62**
M. sorbens	29.2	20.1	17	21	24	14	4	46	24	16	14	21	**201**
Ophyra chalcogaster	0.6	0.4	0	2	1	0	0	0	0	1	0	0	**4**
Phaenicia cuprina	39.2	27.0	33	24	16	6	8	53	33	41	24	32	**270**
Phoridae	0.7	0.5	0	0	0	1	1	1	2	0	0	0	**5**
Placopsidella marquesana	0.1	0.1	0	0	0	0	0	1	0	0	0	0	**1**
Psychodidae	0.3	0.2	0	0	0	0	0	0	1	1	0	0	**2**
Sarcophagidae	5.1	3.5	2	2	8	1	1	6	6	3	3	3	**35**
Sciaridae	0.4	0.3	0	0	0	0	0	2	0	1	0	0	**3**
Tricharaea occidua	2.0	1.4	0	0	1	0	0	2	0	4	5	2	**14**
Total	**100.0**	**68.9**	**85**	**62**	**59**	**27**	**20**	**141**	**84**	**88**	**56**	**67**	**689**

Table 4.2. Fly breeding sources as determined by a sampling of 874 fly-related inspection reports.

BREEDING SOURCES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Dead Animals	5.8	3.7	N/A*	N/A	N/A	0	3	3	6	4	5	5	26
Fruits	1.6	1.0	N/A	N/A	N/A	1	0	1	0	1	1	3	7
Garbage/Refuse/Slop	45.0	29.0	N/A	N/A	N/A	4	13	32	36	54	31	33	203
Manure, Bird/Pigeon	0.7	0.4	N/A	N/A	N/A	1	0	0	0	1	1	0	3
Manure, Chicken	5.5	3.6	N/A	N/A	N/A	0	4	11	3	3	2	2	25
Manure, Dog/Cat	39.5	25.4	N/A	N/A	N/A	14	15	41	22	22	21	43	178
Manure, Pig/Horse/Cow/Goat	1.3	0.9	N/A	N/A	N/A	1	0	3	1	0	1	0	6
Stored Food	0.2	0.1	N/A	N/A	N/A	0	1	0	0	0	0	0	1
Wastewater	0.4	0.3	N/A	N/A	N/A	0	0	0	0	0	1	1	2
Total	**100.0**	**64.4**	**N/A**	**N/A**	**N/A**	**21**	**36**	**91**	**68**	**85**	**63**	**87**	**451**

*Data not available.

rains (~5.5%). Although the major ports of entry and other industrial district/areas had a relatively light number of fly complaints, occasional heavy infestations have occurred. Fly infestations in these district/areas were usually the result of improper handling of food waste or the presence of farm animal wastes.

As in the late 1950's and early 1960's, garbage containers remain an important source of fly production, especially in garbage cans and dumpsters of apartment buildings, food establishments and public parks where unprotected refuse is commonly found. In fact, the current practice of at least twice-a-week refuse pick-up is essential for the control of fly breeding and the prevention of heavy fly infestations since mature maggot activity has often been found to be already present prior to scheduled pick-ups. Fly surveys in Honolulu, Kailua and Lanikai on Oahu by Wilton (1961) showed that breeding in garbage cans was most frequently positive for *P. cuprina* (88.2%) followed by *M. domestica* (35.3%) and *C. megacephala* (20.6%), and there was considerably more garbage can fly production in areas containing apartment buildings. Today, *M. domestica* is mainly a problem related to chicken farming and wet manure while *P. cuprina* and *C. megacephala* continue to be important garbage breeding species. In addition, *M. sorbens* has also continued to be a major source of annoyance in residential and public park areas as a result of dog and/or cat feces accumulation. A study carried out from September 1961 to March 1962 (Wilton, 1963) found fly breeding in exposed, dry dog feces to be mainly *M. sorbens* (78.9%) and concluded that dog feces was a very significant factor in community fly problems. This 1990 to 1999 survey has determined that fly populations are being maintained in urban and agricultural districts by human activities. As a result, disease transmission is possible, especially in the lower elevation, urban and agricultural areas of Oahu where warmer temperatures encourage faster fly development and more prolific reproduction. No disease outbreaks were associated with any of the heavy fly infestations that occurred during the survey period, but the significant potential for disease transmission shows the importance of continued prevention activities. The results indicate that community or island-wide educational programs should be carried out in late fall and late spring to reinforce public awareness during the year, and that residential fly surveys may be concentrated in a limited number of district/areas according to fly complaints received. Educational activities are currently conducted only on a limited basis during inspections. Small area or neighborhood fly infestation surveys and area wide investigations encompassing Waianae through Nanakuli conducted in response to complaints have confirmed the practicality of using small-target area surveys. Once the species of fly causing the problem was identified, known breeding sites such as nearby garbage dumpsters or chicken farms located miles away could be targeted for inspections. As pointed out earlier, mainly light fly complaints were received for industrial parks and heavy commercial areas overall. Fortunately, the causes of these problems, even for the occasional heavy infestation, were easily identified and posed a limited public health concern.

Geographic analysis can help to target areas and times of the year for more efficient application of fly prevention, control and education programs by continuously tracking fly 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 fly 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 fly 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 fly 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.

CHAPTER 5

Fleas

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 1990-1999, 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. There were a very light number of flea problems around the ports of entry. 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.

Introduction

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 1800's and the early 1900's (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.

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. No north shore district/areas reported any activity. A total of 10 district/areas had reported flea activity during the winter of 1990. 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. No flea activity was reported on the north shore or in central district/areas. Overall flea activity was nearly half as compared to the preceding fall with a total of 11 district/areas reporting problems with fleas in winter 1991. 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. No flea activity was reported in north shore, central and west district/areas, and overall activity was about half that in the fall of 1991. A total of six district/areas reported flea activity in winter 1992. 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. A total of seven district/areas reported flea activity in winter 1993. 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. A total of nine district/areas reported flea activity in the winter of 1994. 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. A total of 15 district/areas reported flea activity in the winter of 1995. Flea activity in winter 1996 decreased or did not occur over much of the island. No flea activity was reported on the north shore, in central Oahu or along the east coast. 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. A total of nine district/areas reported flea activity in winter 1996. 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. A total of eight district/areas reported flea activity in winter 1997. 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. A total of eight district/areas reported flea activity in winter 1998. 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. A total of 14 district/areas reported flea activity in the winter of 1999.

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. A total of 21 district/areas reported flea activity in spring 1990. 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. No flea activity was reported in the north shore, central or east district/areas of the island. A total of eight district/areas reported flea activity in spring 1991. In spring 1992, flea activity increased, and light peaks were found in Niu Valley on the south shore and Lanikai on the east side. A total of 11 district/areas reported flea activity in spring 1992. 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. A total of 14 district/areas reported flea activity in spring 1993. 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. A total of 12 district/areas reported flea activity in spring 1994. 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. A total of 16 district/areas reported flea activity in spring 1995. 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 were no reports of flea activity on the north shore or along the east side of the island. A total of 12 district/areas reported fly activity in spring 1996. 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. A total of 11 district/areas reported flea activity in spring 1997. 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. A total of 12 district/areas reported flea activity in spring 1998. Lastly, spring 1999 showed decreased flea activity overall with activity occurring in central and leeward Oahu, and no reports of flea activity on the north shore or east side of the island. Light activity occurred in Iwilei and in Maili Kai along west Oahu. A total of 12 district/areas reported flea activity in spring 1999.

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. A total of 20 district/areas reported flea activity in summer 1990. 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, no flea problems were reported on the north shore, and activity was found in lower central, south, lower east and west district/areas. A total of 17 district/areas reported flea activity in summer 1991. 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. A total of 22 district/areas reported fly activity in the summer of 1992. 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, and no flea activity was reported on the north shore or in west district/areas. A total of 21 district/areas reported flea activity in summer 1993. 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 coast, and no flea activity was reported on the north shore or in west district/areas. A total of 20 district/areas reported flea activity in summer 1994. Summer 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. A total of 16 district/areas reported flea activity in summer 1995. 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. No activity was reported along west Oahu. A total of 16 district/areas reported flea activity in summer 1996. Flea activity in summer 1997 was comparable to the spring activity. A light peak occurred in Niu Valley along the south coast and no activity was reported on the north shore. A total of 13 district/areas reported flea activity in summer 1997. 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. A total of 15 district/areas reported flea activity in the summer of 1998. Flea activity declined on the leeward side of the island as well as in the central district/areas of Oahu in summer 1999. There was no reported activity on the north shore, and very light flea activity occurred from central Oahu, along the south shore to the east side of the island. A total of nine district/areas reported flea activity in summer 1999.

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. A total of 19 district/areas reported flea activity in the fall of 1990. During the fall of 1991, the flea activity decreased slightly and remained mostly in south Oahu. The activity was very light, and none was reported on the north shore or along the west coast. A total of 16 district/areas reported flea activity during the fall of 1991. 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 and no activity was reported in west Oahu. A total of 10 district/areas reported flea activity in fall 1992. 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. A total of 15 district/areas reported flea activity in fall 1993. There was a noticeable decrease in flea activity in the fall of 1994 with no activity being reported on the north shore and 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. A total of 11 district/areas reported flea activity in the fall of 1994. There was decreased flea activity in fall 1995 and no activity was reported on the north shore. A moderate peak in activity was found in Maili Kai in west Oahu. A total of 16 district/areas reported flea activity in fall 1995. In fall 1996, flea activity decreased by nearly half that of in the summer and no activity was reported on the north shore. Light peaks in activity were found in Kahuku in east Oahu and in Mikilua-Lualualei on the west coast of the island. A total of eight district/areas reported flea activity in fall 1996. 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. No flea activity was reported on the north shore. A total of nine district/areas reported flea

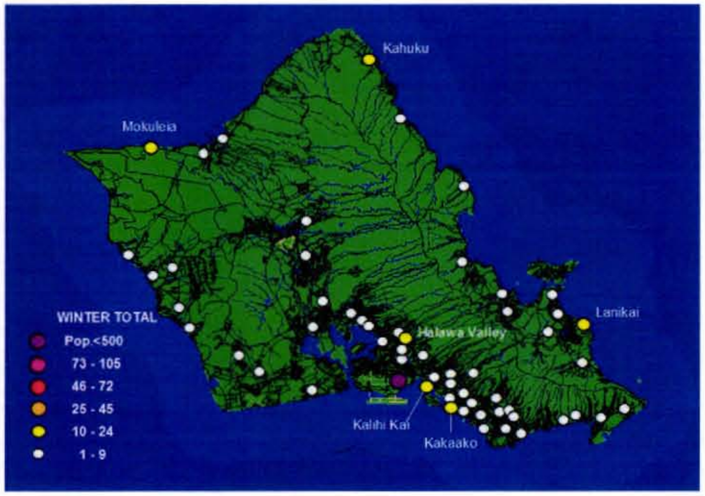

Figure 5.1. Fleas, winter total (1990-1999).

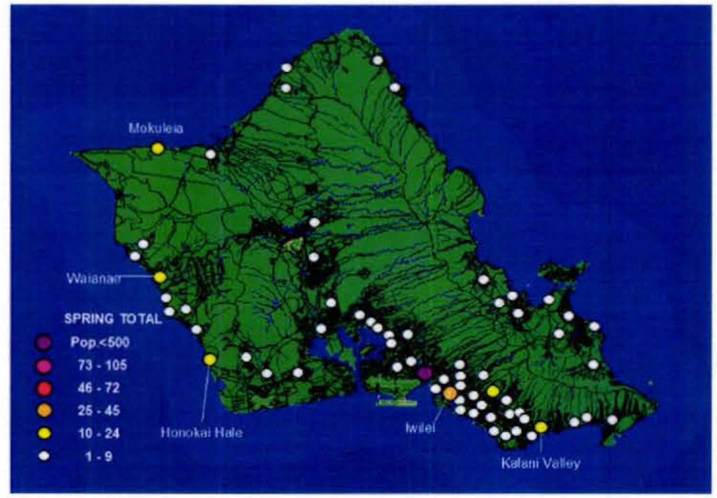

Figure 5.2. Fleas, spring total (1990-1999).

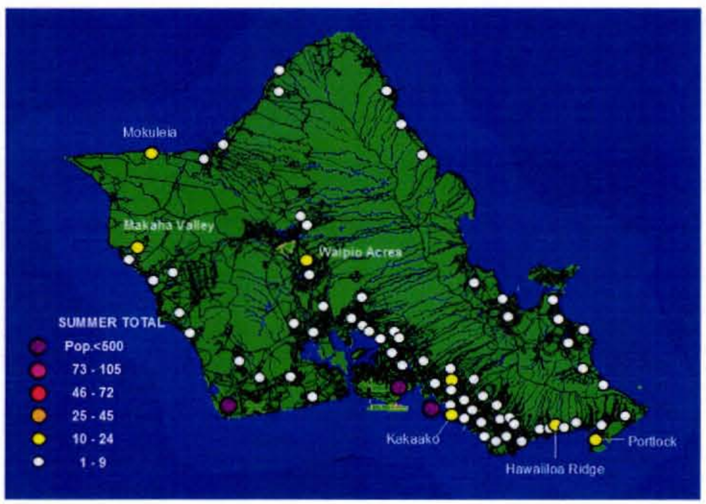

Figure 5.3. Fleas, summer total (1990-1999).

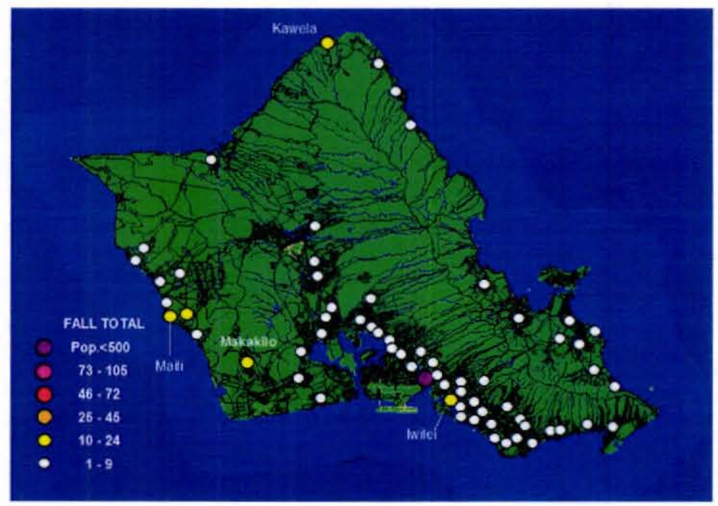

Figure 5.4. Fleas, fall total (1990-1999).

activity in the fall of 1997. In fall 1998, flea activity again decreased from that of in the summer. All activity was very light and no activity was reported on the north shore. A total of 12 district/areas reported flea activity in fall 1998. 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, and there were no reports of activity on the north shore. A total of 14 district/areas reported flea activity in fall 1999.

Most flea activity was reported within the central, south, east and west urban districts (Figures 5.1-5.4, seasonal totals). 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 5.1). The main sources of *C. felis* infestations were improperly

Table 5.1. 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**

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 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 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 1990's 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.

CHAPTER 6

Bees

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. Bee complaints provided the fourth greatest amount of arthropod pest information available, following mosquito, other fly and flea complaints. The objectives of this study were to conduct a survey of the occurrence of bee complaints on Oahu over a 10 year period, determine their distribution over time, graphically compare bee occurrence within and between district/areas, and correlate bee occurrence and distribution with season. Bee data were drawn from inspection reports from 1990-1999, population information was obtained from Hawaii Census and State of Hawaii Data Books, 125 district/area geographic locations were defined, and bee occurrence and distribution were adjusted for population and mapped using ArcView GIS 3.2. Reported bee activity was found mostly within the central, south and east urban districts. The eastern half of south Oahu and the southern half of the east districts showed the highest number of complaints. The levels of bee activity were highest during the spring, summer and fall, and there were bee problems around the airport throughout the year. The

primary bee species recorded was *Apis mellifera* Linnaeus, the honey bee. The main sources of bee problems were *A. mellifera* swarms, and bee hives established in urban areas from wild or domestic hives. Bee activity regularly occurs in urban areas as a result of past and present human activities. As a result, injury from bee stings is possible, especially in the eastern half of south Oahu and the southern half of the east districts from spring through fall when swarming activity is highest. The results indicate that educational programs should be carried out in late winter, and that residential bee surveys may be concentrated in a limited number of district/areas.

Introduction

There are three species of bees that are of medical importance in Hawaii, they are *Apis mellifera* Linnaeus, the honey bee; *Xylocopa sonorina* (Smith), the Sonoran carpenter bee; and *Halictus* sp., the sweat bee (Komatsu, 1982a). The bee species most often encountered on Oahu are *A. mellifera* and *X. sonorina*. The first introduction of *A. mellifera* into Hawaii arrived on Oahu in 1853 from Boston, Massachusetts in the form of two hives (Roddy and Arita-Tsutsumi, 1997). However, the colonies reached the islands in poor condition and survived for only a short time before dying out. Another attempt was made about four years later and three hives of the dark, German honey bee, *A. mellifera mellifera*, arrived in Honolulu in November 1857 from San Jose, California. This time, the hives survived the voyage in good condition, were placed in Nuuanu Valley and became successfully established. The Italian honey bee, *A. mellifera* *liguistica*, was subsequently shipped to the islands in 1880 from Los Angeles via San Francisco and became established as well. *Xylocopa sonorina* was abundant on the lowlands of Hawaii (Perkins and Forel, 1899) prior to 1899. It was unknown until long after the islands were settled by foreigners, but was introduced well before 1883 and probably was imported by man in lumber from the warmer parts of America (Perkins, 1913). Perkins noted, however, that *X. sonorina's* fondness for breeding in dead logs on the sea-beaches might have enabled it to reach the islands by natural immigration. Blackburn and Kirby (1880) noted *X. sonorina* as a common South American insect that was common near Honolulu and elsewhere. Hawaii has a total of 11 non-native bee species (Tenorio and Nishida, 1995).

The main concerns regarding bees in general, especially *A. mellifera*, are bee attacks and the possibility of a severe allergic reaction to bee stings or anaphylactic shock. The severity of reactions to bee stings varies widely among individuals from localized pain and swelling to the serious and sometimes fatal, systemic reaction (Komatsu, 1982a). *Xylocopa sonorina* is rarely a serious public health concern due to its relatively shy behavior despite its formidable appearance (Nishida and Tenorio, 1993). In addition, bee nesting in the structure of a home can increase stinging hazards as well as lead to damage to the home. *Apis mellifera* hives in wall voids can melt and leak wax and honey, and *X. sonorina* may bore into walls, eaves and structural beams.

Results

Bee activity during the winter of 1990 included only one district/area with very light problems (1-3 complaints) each in the south and lower east areas of the island, and one light peak (4-8 complaints) occurring in Maunawili in east Oahu. No north shore, central or west district/areas reported any activity. A total of three district/areas had reported bee activity during the winter of 1990. In winter 1991, very light bee activity was present in south and lower east Oahu with light activity occurring in Olomana-Pohakupu on the east side. No bee activity was reported on the north shore, in central or west district/areas. Overall bee activity was nearly half as compared to the preceding fall with a total of five district/areas reporting problems with bees in winter 1991. Bee activity in winter 1992 was very light in south and lower east Oahu with a light peak occurring in Mahinui-Kokokahi on the east coast. No bee activity was reported in north shore, central and west district/areas, and overall activity was a sixth of that in the fall of 1991. A total of three district/areas reported bee activity in winter 1992. Winter 1993 bee activity was much reduced at less than one-sixth of that in fall 1992. Light activity was found only in Kaaawa on the east coast, and no north shore, central or west Oahu district/areas reported bee activity. A total of four district/areas reported bee activity in winter 1993. Bee activity in the winter of 1994 only occurred in south Oahu with a light peak in Kakaako and was, again, reduced from that in the fall. Activity decreased by well over 50% and a total of three district/areas reported bee activity in the winter of 1994. The winter of 1995 saw a reduction in bee activity to less than one-eighth of the previous fall. Activity was very light and only occurred in south Oahu. A total of two district/areas reported bee activity in the winter of 1995. No bee activity was reported in the winter of 1996. Overall bee activity in winter 1997 was nearly one-fourth of fall 1996 activity, and only occurred in south and east Oahu district/areas. Light peaks were found in Kalihi Kai in the south and Olomana-Pohakupu on the east coast. A total of six district/areas reported bee activity in winter 1997. Bee activity in winter 1998 was very light with only a single district/area, Waialua on the north shore, being affected. Finally, as in the previous year, bee activity in the winter of 1999 was very light with only a single district/area being affected. Kailua on the east coast of Oahu reported the bee activity.

Spring 1990 bee activity was found mostly along the central, south and lower east district/areas of Oahu, and was about four times as that in the winter. Light peaks in activity occurred in Olomana-Pohakupu and Yacht Club Knolls-Terrace on the east side. No bee activity was reported on the north shore. A total of 15 district/areas reported activity in spring 1990. Bee activity had a noticeably lower increase in spring 1991 with activity mainly occurring in south and lower east Oahu. A light peak occurred in Lanikai on the east coast and no bee activity was reported in the west district/areas of the island. A total of nine district/areas reported bee activity in spring 1991. In spring 1992, bee activity about doubled from in the winter, but remained very light and occurred only in south and lower east district/areas. No north shore, central or west Oahu district/areas reported activity. A total of nine district/areas reported bee activity in spring 1992. Bee activity increased lightly in spring 1993 with the activity being found only in south, lower east and central Oahu. A moderate peak (9-15 complaints) was found in Makiki Heights-Tantalus. A total of five district/areas reported bee activity in spring 1993. Overall spring 1994 bee activity was comparable to that in the previous winter. Very light activity was found only in south and lower east district/areas of the island. A total of four district/areas reported bee activity in spring 1994. Bee activity in spring 1995 substantially increased in occurrence and intensity over the winter activity. Activity peaked lightly in Oneawa Hills-Aikahi Park on the east coast and in Whitmore Village in central Oahu, and a moderate spike was found in the east district/area of Maunawili. No west Oahu district/areas reported any activity. A total of 14 district/areas reported bee activity in spring 1995. Spring 1996 bee activity was fairly well distributed across central, south and lower east Oahu. Activity peaked lightly in Waimanalo on the east side of the island, and there were no reports of bee activity on the north shore or in west district/areas. A total of 17 district/areas reported bee activity in spring 1996. The bee activity in spring 1997 was about twice that in the winter. Moderate peaks in bee activity occurred in Kalani Valley in south Oahu and Kahe Point-Honokai Hale on the west shore. No reports of bee activity on the north shore were received. A total of 12 district/areas reported bee activity in spring 1997. Bee activity in spring 1998 was well over 10 times that of in the winter. Light bee activity was found in Kahuku along the east coast and in Wahiawa in central Oahu. A total of 13 district/areas reported bee activity in spring 1998. Lastly, spring 1999 bee activity was found mainly in south Oahu from Pearl Harbor-Hickam Air Force Base to Kakaako with a light peak occurring in Kakaako.

There were no reports of bee activity in north shore, central or west district/areas. A total of six district/areas reported bee activity in spring 1999.

The number of district/areas reporting bee activity in summer 1990 was nearly half that in the spring with activity mainly occurring in south and lower east Oahu. A light peak was found in the east district/area of Olomana-Pohakupu, and no activity was reported on the north shore or along the west side of the island. A total of eight district/areas reported bee activity in summer 1990. The level of bee activity in summer 1991 increased in intensity from in the spring and occurred mainly in south and east Oahu. There were light peaks in Kakaako on the south shore, and in Waimanalo and Kaaawa on the east side of the island. A moderate spike occurred in the east district/area of Heeia Kea. There was no activity reported on the north shore or along the west side of the island. A total of nine district/areas reported bee activity in summer 1991. Bee activity in the summer of 1992 increased noticeably in occurrence and intensity in east Oahu. Light activity was found in Waimanalo, Olomana-Pohakupu and Hauula on the east side along with a moderate peak in Maunawili and a heavy spike (16-24 complaints) in Heeia Kea. No activity was reported on the north shore or along west Oahu. A total of 16 district/areas reported bee activity in the summer of 1992. Summer 1993 bee activity increased slightly over that of in the spring, and occurred in the south and lower east district/areas. Light activity was found in Waialae Nui in south Oahu, and in Olomana-Pohakupu and Heeia Kea on the east side of the island. There were no reports of bee activity in north shore, central or west district/areas. A total of six district/areas reported bee activity in summer 1993. Summer 1994 showed increased bee activity by almost three times that in the spring. There was a light peak in activity in Royal Summit in central Oahu, activity mainly occurred in south and lower east district/areas, and no bee activity was reported on the north shore. A total of 10 district/areas reported bee activity in summer 1994. Summer 1995 bee activity showed an increase overall. Activity peaked lightly in Downtown in the south and Waimanalo on the east side. Moderate spikes occurred in Olomana-Pohakupu and Waiahole-Waikane in east Oahu, and in Mokuleia on the north shore. There were no reports of activity on the west side of the island. A total of 19 district/areas reported bee activity in summer 1995. As in the spring, bee activity in summer 1996 was found in central, south and lower east district/areas. Activity decreased in central and south Oahu, and increased on the east side of the island. Bee activity peaked lightly in Moanalua Valley in the south and Maunawili in east Oahu, and a moderate spike occurred in Olomana-Pohakupu. A total of 18 district/areas reported bee activity in summer 1996. Summer 1997 bee activity also decreased in central and south Oahu, and increased on the east side of the island. Light peaks in activity occurred in Moanalua Valley and Portlock in the south, and in Olomana-Pohakupu, Mahinui-Kokokahi, Heeia Kea and Kahuku along the east side of the island. A total of 15 district/areas reported bee activity in summer 1997. The bee activity in the summer of 1998 increased from that in the spring and was mainly found in the central, south and lower east district/areas of the island. Light peaks in activity occurred in Halawa Valley in central Oahu, Mariners Ridge in the south, and Olomana-Pohakupu on the east side of Oahu. No bee activity was reported along the west coast of the island. A total of 22 district/areas reported bee activity in the summer of 1998. Bee activity declined in summer 1999 leaving, except for a cluster of three very light sites from Downtown to Nuuanu-Dowsett Highlands in the south, a few widely spaced district/areas that reported activity. A light peak occurred in Kahuku on the east coast, and there was no reported bee activity on the north shore or along the west side of Oahu. A total of five district/areas reported bee activity in summer 1999.

In the fall of 1990, bee activity remained similar overall to that in the summer with most of the activity being found in the south and lower east district/areas of the island. There was a moderate peak in Kakaako, but no reports of activity were received for the north shore, central Oahu or the west coast. A total of eight district/areas reported bee activity in the fall of 1990. During the fall of 1991, the bee activity increased noticeably with activity concentrated from Kakaako to Wilhelmina Rise-Maunalani Heights in south Oahu and Lanikai to Kahaluu-Waihee Valley on the lower east side of the island. Light peaks were found in the central district/area of Royal Summit, in Kakaako, and in Lanikai, Olomana-Pohakupu, Maunawili and Heeia Kea in east Oahu. No activity was reported on the north shore or along the west coast. A total of 18 district/areas reported bee activity during the fall of 1991. The bee activity in fall 1992 was comparable in occurrence and distribution to that of in the summer. There was a cluster of activity from Kakaako to Nuuanu-Dowsett Highlands in south Oahu and a concentration in activity from Lanikai to Kahaluu-Waihee Valley on the east side. Light peaks were found in Portlock on the south shore, and in Lanikai, Olomana-Pohakupu, Oneawa-Aikahi Park, Yacht Club Knolls and Terrace, and Ahuimanu on the lower east side of the island. Moderate spikes in bee activity were present in Kakaako and in Punaluu on the east coast. No activity was reported on the north shore or in west Oahu district/areas. A total of 20 district/areas reported bee activity in fall 1992. Fall 1993 saw a slight overall increase in bee activity and distribution. There was a light peak in Yacht Club Knolls and Terrace. Activity was not reported in north shore or west district/areas. A total of 10 district/areas reported bee activity in fall 1993. Overall bee activity about doubled in the fall of 1994 with concentrations in activity appearing from Downtown to Saint Louis Heights in south Oahu and Lanikai to Oneawa-Aikahi Park on the east side. Light peaks in bee activity were found in Lanikai and Olomana-Pohakupu in east Oahu and a very heavy spike (25-35 complaints) was recorded in the central district/area of Kunia. A total of 16 district/areas reported bee activity in the fall of 1994. There was an overall increase in bee activity in fall 1995 with activity decreasing on the north shore and increasing in south Oahu. Light peaks in activity were found in the area of Sunset Beach on the north shore; Moanalua Valley, Downtown and Manoa-Woodlawn in south Oahu; Olomana-Pohakupu, Maunawili and Kahuku on the east side of the island; and the central district/area of West Loch Estates. There was a moderate spike in Makiki Heights-Tantalus, and bee activity was highest from Moanalua Valley to Manoa-Woodlawn in the south and in lower east Oahu. No activity was reported along the west coast. A total of 26 district/areas reported bee activity in fall 1995. In fall 1996, bee activity increased in south and east Oahu as well as on the north shore. Activity on the windward side of the island was mainly in the lower east district/areas. Light peaks were found in the Sunset Beach area and Waialua on the north shore; in Red Hill in south Oahu; and in Olomana-Pohakupu, Mahinui-Kokokahi, Heeia Kea and Kahuku on the east side of the island. A single moderate spike occurred in the south district/area of Halawa Valley. A total of 25 district/areas reported bee activity in fall 1996. An overall increase in bee activity occurred in the fall of 1997. Activity was mainly found from Kalihi Valley to Waialae Iki in south Oahu and from Olomana-Pohakupu to Heeia Kea on the lower east side of the island. Light peaks occurred in the south district/area of Nuuanu-Dowsett Highlands, and in Olomana-Pohakupu, Maunawili, Yacht Club Knolls and Terrace, and Heeia Kea in east Oahu. No bee activity was reported on the west coast. A total of 21 district/areas reported bee activity in the fall of 1997. In fall 1998, bee activity decreased from that of in the summer, and remained mostly in south and lower east district/areas. Light peaks occurred in Foster Village and Moanalua Valley in south Oahu, and in Maunawili on the east side of the island. No activity was reported on the north shore or along the west coast. A total of 12 district/areas reported bee activity in fall 1998. Bee activity in fall 1999 decreased by well over 50% from that in the summer. Very light activity was found only in McCully-Moiliili in south Oahu and in Heeia on the lower east coast, and there were no reports of activity in north shore, central or west district/areas. A total of two district/areas reported bee activity in fall 1999.

Reported bee activity was found mostly within the central, south and east urban districts (Figures 6.1-6.4, seasonal totals). The eastern half of south Oahu and the southern half of the east districts showed the highest number of complaints. The levels of

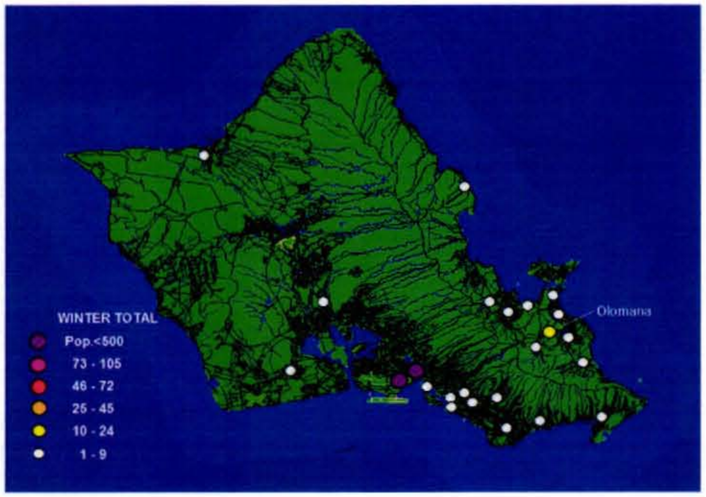

Figure 6.1. Bees, winter total (1990-1999).

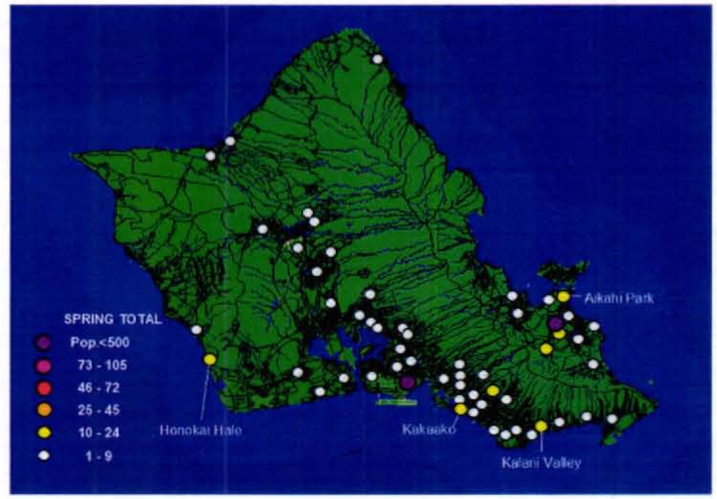

Figure 6.2. Bees, spring total (1990-1999).

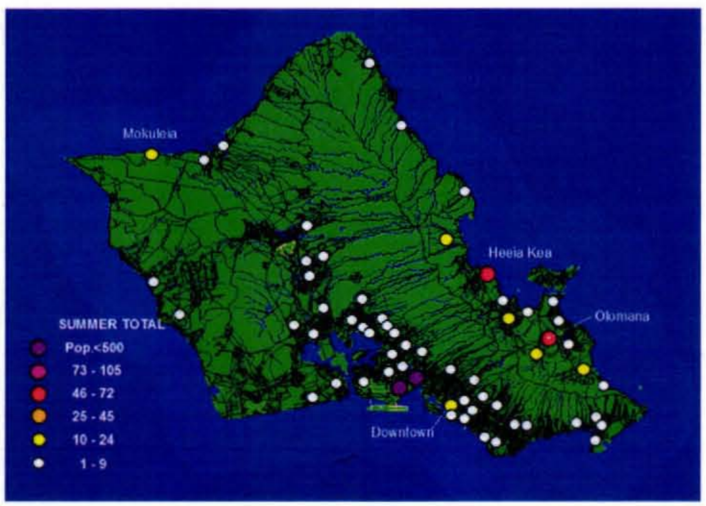

Figure 6.3. Bees, summer total (1990-1999).

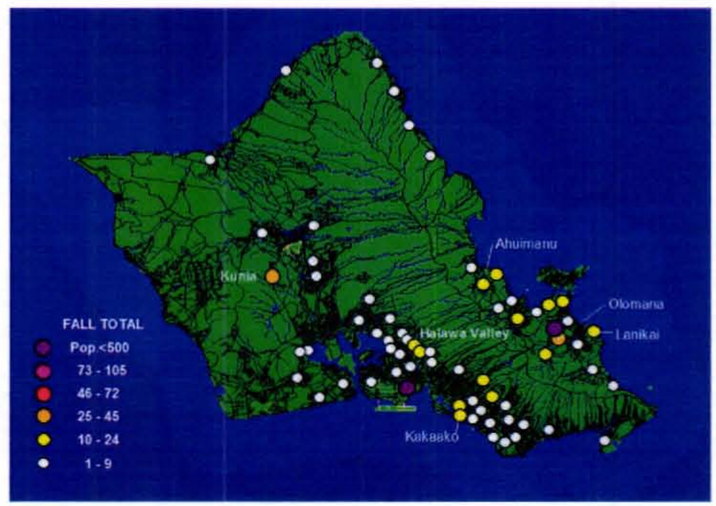

Figure 6.4. Bees, fall total (1990-1999).

bee activity were highest during the spring, summer and fall, and there were bee problems around the airport throughout the year. 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 bee species recorded was *Apis mellifera* (~96.8%; n = 666), the honey bee (Table 6.1). A few *Xylocopa sonorina* (~3.2%), Sonoran carpenter bee, cases were also recorded. The main sources of bee problems were *A. mellifera* swarms, and bee hives established in urban areas from wild or domestic hives, and, in the case of carpenter bees, bees burrowing into the eaves of homes or in dead wood on the premises.

Hawaii has more than 160 beekeepers, including 15 commercial operations (Dicus, 2007a). On Oahu, managed hives were present in Manoa, Makiki Heights, Round Top, Tantalus, Whitmore Village, Nanakuli, Waimanalo, and Punaluu and near Kahuku (Dicus, 2007b; Dicus, 2007c; Dicus, 2007d). Among many other locations, a colony was also present in Diamond Head crater. The concentration in *A. mellifera* activity in the eastern half of south Oahu and the southern half of the east districts was probably partly due to the presence of these hives, but was mainly due to the fact that the colonies that were originally placed in Nuuanu Valley in 1857 eventually hived off and established feral colonies in the surrounding forests (Roddy and Arita-Tsutsumi, 1997).

Table 6.1. Bee species occurrence as determined by a sampling of 716 bee-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Apis mellifera	96.8	64.5	45	51	82	43	42	115	102	77	65	23	**645**
Xylocopa sonorina	3.2	2.1	8	2	1	0	1	4	2	1	1	1	**21**
Total	**100.0**	**66.6**	**53**	**53**	**83**	**43**	**43**	**119**	**104**	**78**	**66**	**24**	**666**

Subsequent *A. mellifera* introductions hived off as well such that feral colonies of both the German and Italian honey bee strains are common in the wild, and swarms from these hives as well as domestic hives regularly find their way into urban areas. Perkins (1913) reported *X. sonorina* to be an injurious species "since it does considerable damage by riddling fence-posts, telephone poles and other wood with its borings." It also burrows in the dead or nearly dead parts of living trees. This is still true today with damage mainly occurring in fences, walls, eaves and structural beams built with soft woods.

This survey has determined that bee activity regularly occurs in urban areas as a result of past and present human activities. As a result, injury from bee stings is possible, especially in the eastern half of south Oahu and the southern half of the east districts during the spring, summer and fall months when swarming activity is highest. The results indicate that community or island-wide educational programs should be carried out in late winter to remind the public that bee season is approaching, and that residential bee surveys may be concentrated in a limited number of district/areas according to bee complaints received. Educational activities are currently conducted only on a limited basis during inspections, and direct intervention in the form of treatment and removal of an *A. mellifera* swarm or hive may be carried out if a public health threat is present. Small area or neighborhood bee surveys have confirmed the practicality of using small-target area surveys since a single *A. mellifera* swarm or hive is normally found in any given area, and *X. sonorina* nests are usually restricted to the problem site reported. As pointed out earlier, there are bee problems around the airport throughout the year. The bees involved were *A. mellifera*. Fortunately, abatement response for these problems was immediate so that they posed a limited public health concern. However, considering the visitor, workforce and heavy machinery activity, the potential for a serious bee problem will always be present.

Geographic analysis can help to target areas and times of the year for more efficient application of bee prevention, control and education programs by continuously tracking bee 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 bee 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 bee 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 bee 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.

CHAPTER 7

Mites and Ticks

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. Mite complaints provided the fifth greatest amount of arthropod pest information available, following mosquito, other fly, flea and bee complaints; and tick complaints provided the ninth greatest amount of arthropod pest information, following ants, cockroaches and centipedes. The objectives of this study were to conduct a survey of the occurrence of mite and tick complaints on Oahu over a 10 year period, determine their distribution over time, graphically compare mite and tick occurrence within and between district/areas, and correlate mite and tick occurrence and distribution with season. Mite and tick data were drawn from inspection reports from 1990-1999, population information was obtained from Hawaii Census and State of Hawaii Data Books, 125 district/area geographic locations were defined, and mite and tick occurrence and distribution were adjusted for population and mapped using ArcView GIS 3.2. Most mite activity was reported within the central, south and east urban districts. The south urban districts of the island showed the highest number of complaints, and the levels of

mite activity were highest during the spring, summer and fall. There were a very small number of mite problems around the ports of entry, mainly the airport. The primary mite species recorded were *Dermatophagoides pteronyssinus* (Trouessart), the European house dust mite; *Ornithonyssus bursa* (Berlese), the tropical fowl mite; *Glycyphagus domesticus* (De Geer), the grocer's itch mite; *Pyemotes boylei* Krczal, the straw itch mite; and *D. farinae* Hughes, the American house dust mite. The main sources of mite infestations were house dust, birds, stored food products, fiber-type furniture, dried plant materials and bean pods. Tick activity was mostly reported within the leeward urban districts. South and west urban districts showed the highest number of complaints, and the levels of tick activity were highest during the winter, summer and fall. There were very few tick problems around the ports of entry. The primary tick species identified was *Rhipicephalus sanguineus* Latrielle, the brown dog tick. No other established tick species were found to be a public health concern. The main sources of tick infestations were dogs that were taken into a tick infested location or poorly cared for, especially if the dog was relocated on premises, removed from the premises or died. Mite and tick activity is being maintained in urban areas by human activities. As a result, dermatitis from mite infestations is possible as well as disease transmission between dogs by ticks, especially along leeward Oahu. The results indicate that educational programs should be carried out in late winter for mites and late spring for ticks, and that residential mite and tick surveys may be concentrated in a limited number of district/areas.

Introduction

Of at least 521 species of mites in Hawaii (Tenorio and Nishida, 1995), about 32 species are considered to be of public health concern (Ikeda, 1982b). These important species fall into three general ecological groups: free-living predacious forms, free-living phytophagous forms and ectoparasitic forms. Five of these mite species have been commonly found on the island of Oahu. They are *Dermatophagoides pteronyssinus* (Trouessart), the European house dust mite; *D. farinae* Hughes, the American house dust mite; *Ornithonyssus bursa* (Berlese), the tropical fowl mite; *Glycyphagus domesticus* (De Geer), the grocer's itch mite; and *Pyemotes boylei* Krczal, the straw itch mite.

Dermatophagoides pteronyssinus was first recorded as *D. scheremetewskyi* Bogdanow collected from a rug on Oahu in 1959 by F. H. Haramoto (Haramoto, 1961; Garrett and Haramoto, 1967; Sharp and Haramoto, 1970; Goff, 1987), and *D. farinae* was found to be well established in house dust on the islands of Oahu, Maui, Kauai and Hawaii by 1968 (Sharp and Haramoto, 1970). *Ornithonyssus bursa* was reported to have "caused some trouble to human beings" in 1943 by Zimmerman (1944), and was found to be common in nests of English sparrows and mynah birds. It was likely already present by 1930 when Erhorn (1931) "related several instances of dwellings being infested by chicken mites" due to mynah bird nests. *Glycyphagus domesticus* was determined to be new to the Hawaiian fauna by E. W. Baker in 1945 from specimens collected on Oahu (Zimmerman, 1956). *Pyemotes boylei* was originally described in Honolulu by H. Krczal in 1959 from specimens collected from *Cryptotermes brevis* (Walker), the dry-wood termite, and *Araecerus levipennis* Jordan, the koa haole seed weevil, by W. W. Boyle, but it was likely present in Hawaii much earlier since it is morphologically very similar to and it was probably misidentified as *P. ventricosis* (Newport) (Vaivanijkul and Haramoto, 1969; Goff, 1987). All specimens available for examination from before 1959 were found by Goff (1987) to be *P. boylei* and it was probably in Hawaii as early as 1911, when E. M. Erhorn reported the discovery of *P. ventricosis* as the cause of "Kiawe itch" (Erhorn, 1913; Vaivanijkul and Haramoto, 1969). There are nine species of ticks in Hawaii (Tenorio and Nishida, 1995). Two of these species, *Rhipicephalus sanguineus* Latrielle, the brown dog tick, and *Otobius megnini* (Duges), the spinose ear tick of cattle and horses, are of public health importance (Ikeda, 1982b; Nishida and Tenorio, 1993). And, of these two species, only *R. sanguineus* has been encountered during inspections on Oahu. Although already very abundant, it was first formally recorded on Oahu in 1921 (Fullaway, 1922).

Dermatophagoides pteronyssinus and *D. farinae* and house dust mite allergy are most commonly associated with asthma, perennial rhinitis (post nasal drip), and childhood eczema or atopic dermatitis (Sharp and Haramoto, 1970; Ebeling, 1975; Ikeda, 1982b; Tenorio and Nishida, 1995). *Ornithonyssus bursa* is primarily a parasite of poultry, pigeons, sparrows, mynahs and other birds, but it also attacks man and causes itching by both its bite and crawling over the skin (Baker et al., 1956; Ikeda, 1982b). In some individuals, the irritating bite develops into prolonged, intense itching and painful dermatitis (Nishida and Tenorio, 1993; Denmark and Cromroy, 2003). Also known as the furniture mite, *G. domesticus* is often associated with fiber-type furniture and is mycetophagus (Ikeda, 1982b), but it has caused dermatitis in man from infested stored food products (Ebeling, 1975) as well as furniture. *Pyemotes boylei* causes a severe dermatitis known as "kiawe itch" or "straw itch" (Baker et al., 1956; Vaivanijkul and Haramoto, 1969; Ikeda, 1982b). A rosy red, pruritic skin lesion develops on each bite site that often presents a raised, whitish area with a small, central vesicle. Intense itching of the lesion leads to rubbing and scratching that usually break the central vesicle which allows the possibility of secondary infection. Fever, headache, backache and asthma can also accompany itching if a person is bitten extensively. *Rhipicephalus sanguineus* is principally parasitic on dogs and rarely attacks man (Ebeling, 1975; Ikeda, 1982b), and is not known to have been a vector of disease in man in Hawaii (McQuiston et al., 1999; Sasaki, 2000; Bratton and Corey, 2005). However, *R. sanguineus* is the vector for canine ehrlichiosis (*Ehrlichia canis*) (Chapman, 2000; Sasaki, 2000; Skotarczak, 2003), a potentially fatal disease in dogs. In other parts of the world, *R. sanguineus* is the primary vector for boutonneuse fever or tick-borne typhus (*Rickettsia conorii*) (Ikeda, 1982b) and canine babesiosis (*Babesia canis*), a sporozoan blood parasite (Ebeling, 1975; Homer et al., 2000).

Results

Mite activity during the winter of 1990 was mostly very light (1-3 complaints) with a light peak (4-8 complaints) occurring in the south district/area of Kalihi Kai. Complaints were mainly found in south Oahu and in the lower east side of the island. No north shore, central or west district/areas reported any activity. A total of eight district/areas had reported mite activity during the winter of 1990. In winter 1991, very light mite activity was scattered along south, lower east and lower central Oahu. No mite activity was reported on the north shore or in west district/areas. Mite activity slightly decreased as compared to the preceding fall with a total of nine district/areas reporting problems with mites in winter 1991. Mite activity in winter 1992 was very light around south and lower east Oahu with light peaks occurring in Lanikai and Olomana-Pohakupu on the east side of the island. No mite activity was reported in north shore, central and west district/areas, and overall activity was comparable to that in the fall of 1991. Activity had decreased in the south and increased in lower east Oahu, and a total of nine district/areas reported mite activity in winter 1992. Winter 1993 mite activity was reduced by about half from that in fall 1992, and spread across south, central and west Oahu. There was a light peak in activity in Waikele in central Oahu, and no mite activity was reported on the north shore or in east district/areas. A total of six district/areas reported mite activity in winter 1993. Mite activity in the winter of 1994 was slightly reduced from that in the fall, and was sparse and spread across south, central and west Oahu. A light peak occurred in the central district/area of Halawa Valley, and there were no mite complaints on the north shore or on the east side of the island. A total of five district/areas reported mite activity in the winter of 1994. The winter of 1995 saw a slight increase in mite activity over the previous fall. Activity was mainly in south Oahu where it peaked lightly in Kakaako. A light peak was also found in the area of Sunset Beach on the north shore. No reports of mite activity were received for any central district/areas. A total of 10 district/areas reported mite activity in the winter of 1995. Mite activity in winter 1996 decreased both in occurrence and in the areas of the island reporting problems. There was a concentration in activity from Kalihi Kai to Kaimuki-Waialae in south Oahu with a light peak in Kalihi Kai, and no mite activity was reported in north shore, central or east district/areas. A total of 10 district/areas reported mite activity in winter 1996. Reported mite activity in winter 1997 was nearly zero. No mite activity was reported in north shore, central, east or west district/areas. Only the excluded Airport district/area in south Oahu reported mite activity in winter 1997. The mite activity in winter 1998 was less than one-third that of the fall. Very light activity was found in Kahala in south Oahu and a light peak occurred in Lanikai on the east coast. A total of two district/areas reported mite activity in winter 1998. Finally, mite activity in the winter of 1999 was one-sixth the activity in the fall. A total of one district/area reported mite activity in the winter of 1999, with very light activity found in Hawaii Kai in south Oahu.

Spring 1990 mite activity was found across all areas of the island, and was about two times as that in the winter. A light peak was present in Kahaluu-Waihee Valley on the east coast and there was a concentration in mite activity in south Oahu from Kamehameha-Alewa Heights to Kapahulu-Diamond Head with a heavy (16-24 complaints) spike occurring in Kakaako. A total of 15 district/areas reported mite activity in spring 1990. Mite activity increased slightly in spring 1991 with very light activity occurring in south, east and west district/areas, and a moderate (9-15 complaints) peak was found in Punaluu on the east coast. No mite activity was reported on the north shore or in central Oahu. A total of nine district/areas reported flea activity in spring 1991. In the spring of 1992, overall mite activity was comparable to that in the winter, but was spread across south, east and central district/areas. A moderate peak was present in Hawaiiloa Ridge in south Oahu, and there were no reports of mite activity on the north shore or on the west side of the island. A total of nine district/areas reported mite activity in the spring of 1992. Mite activity in spring 1993 was similar overall to winter activity except for activity being reported on the east side of the island rather then in central Oahu and all activity being very light. A total of six district/areas reported mite activity in spring 1993. Spring 1994 mite activity increased by greater than two times the winter activity and most of the complaints occurred in south Oahu. A Light peak was found in Maunawili on the east side and there was a moderate spike in Mokuleia on the north shore. A total of 11 district/areas reported mite activity in spring 1994. Mite activity in the spring of 1995 increased noticeably and was spread out around the island. All activity was very light and it mostly occurred in south Oahu. A total of 19 district/areas reported mite activity in the spring of 1995. Spring 1996 mite activity increased from that in winter 1996 and was more spread out across the island. Activity peaked lightly in

Lanikai and Haiku Village and Plantations in east Oahu, and in Pupukea on the north shore. A total of 14 district/areas reported mite activity in spring 1996. There was an increase in mite activity in spring 1997. A light peak occurred in Pupukea on the north shore, and there was very light activity in several south and east district/areas. No mite activity was reported in central or west Oahu. A total of five district/areas reported mite activity in spring 1997. Mite activity during the spring of 1998 was very light and about three times that of in the winter. There was no reported activity on the north shore or in West Oahu. A total of nine district/areas reported mite activity during the spring of 1998. Lastly, spring 1999 showed increased mite activity by 10 times the winter activity, but it remained very light overall. Occurrence was fairly evenly spread out across the island, with the exception of no reports of mite activity on the north shore. A total of 10 district/areas reported mite activity in spring 1999.

The number of district/areas reporting mite activity in the summer of 1990 was similar to that in the spring, with activity mainly occurring in south and lower east Oahu. Light peaks were found in Downtown in south Oahu, and in Olomana-Pohakupu and Kahaluu-Waihee Valley in the lower east side of the island. A moderate spike occurred in Kakaako on the south coast. No mite activity was reported on the north shore. A total of 13 district/areas reported mite activity in the summer of 1990. The overall level of mite activity in summer 1991 was also similar to the activity in the spring. There were light peaks in Kakaako in south Oahu and in Lanikai on the east coast. There was a small cluster of very light activity on the east side of the island from Kaneohe to Haiku Village and Plantations, and no mite problems were reported on the north shore. A total of 10 district/areas reported mite activity in summer 1991. Mite activity increased in the summer of 1992 and was found in all major areas of the island. Light peaks in activity occurred in Hahaione Valley in south Oahu and in Pupukea on the north shore, and there was a moderate spike in Kalani Valley on the south side of the island. A total of 10 district/areas reported mite activity in the summer of 1992. Summer 1993 mite activity increased overall to about three times that in the spring. Most of the activity occurred in south Oahu including light peaks in Downtown and Portlock. Light activity also occurred in Yacht Club Knolls and Terrace on the east coast. No mite activity was reported on the north shore or in west district/areas. A total of 14 district/areas reported mite activity in summer 1993. As in 1993, summer 1994 showed increased mite activity overall. There were light peaks in Portlock, Heeia Kea on the east coast, and in the Sunset Beach area and Waialua on the north shore. Mite activity was not reported in central or west district/areas. A total of 13 district/areas reported mite activity in summer 1994. During the summer of 1995 mite activity was mostly on the leeward side of the island and was comparable overall to the spring activity. Mite activity peaked lightly in Waikiki-Kapiolani Park in south Oahu and in Waianae on the west coast. No mite activity was reported on the north shore. A total of 16 district/areas reported mite activity during the summer of 1995. Mite activity in summer 1996 decreased around the north, east and west sides of the island and increased in south Oahu. Mite activity peaked lightly in the central district/area of Halawa Valley and in Maunawili in the east. A moderate spike occurred in Kalihi Kai in south Oahu and mite activity was concentrated from Kalihi Kai to Kapahulu-Diamond Head. There were no reports of mite activity along the north shore and west coast. A total of 15 district/areas reported mite activity in summer 1996. Mite activity in summer 1997 was over double that in the spring. The activity was very light and was found mostly in south Oahu. A total of 16 district/areas reported mite activity in summer 1997. The mite activity in south Oahu in the summer of 1998 increased by about two times from that in the spring. A light peak in activity occurred in the south district/area of Niu Valley. No reports of mite activity were received for the north shore. A total of 12 district/areas reported mite activity in the summer of 1998. Mite activity increased in summer 1999, but was very light and was concentrated between Kalihi and Wilhelmina Rise-Maunalani Heights in south Oahu. There was no reported activity on the north shore. A total of 13 district/areas reported mite activity in summer 1999.

In the fall of 1990, there was a decrease in mite activity in south and east Oahu. A light peak occurred in Oneawa-Aikahi Park in east Oahu and no mite activity was reported on the north shore. A total of 10 district/areas reported mite activity in the fall of 1990. During the fall of 1991, overall mite activity was comparable to the summer activity and remained very light to light as well. However, complaints increased in south Oahu and decreased elsewhere around the island, and showed a concentration of reports from Punchbowl-Pacific Heights to Kahala. A light peak in activity occurred in Mariners Ridge, and no reports of mite activity were received for north shore, central or west district/areas. A total of 10 district/areas reported mite activity during the fall of 1991.

The mite activity in fall 1992 was, again, similar overall to that of in the summer. The activity was mainly in south and lower east district/areas, and there were no reports of mite activity in central or west Oahu. Light peaks occurred in Iwilei and Waialae Iki on the south shore, and in the east district/area of Lanikai. A total of 11 district/areas reported mite activity in fall 1992. Fall 1993 saw a decrease in the number of district/areas reporting mite activity to less than half the summer activity. Only very light activity was reported, activity occurred only in south and lower east Oahu, and a total of seven district/areas reported mite activity in fall 1993. There was a noticeable decrease in mite activity in the fall of 1994 with no activity being reported on the north shore or in central Oahu. Light peaks in mite activity were found in Fort Shafter and Iwilei along the south shore, and a total of nine district/areas reported mite activity in the fall of 1994. Fall 1995 mite activity showed a slight overall decrease and occurred mainly on the leeward side of the island. Light peaks were found in Moanalua Valley and Kakaako in south Oahu, and no activity was reported on the north shore. A total of 14 district/areas reported mite activity in the fall of 1995. In fall 1996, mite activity decreased in south and central Oahu, and increased on the north and west shores. There were light peaks in the Sunset Beach area along the north shore and in the south district/area of Kapolei, and a moderate spike in activity in Maili Kai on the west coast. There were no reports of activity in central district/areas and a total of 14 district/areas reported mite activity in fall 1996. An overall decrease in mite occurrence and distribution occurred in the fall of 1997. Light mite activity was found in Fort Shafter in south Oahu and a moderate spike was present in Punaluu along the east coast. No mite activity was reported on the north or west shores. A total of eight district/areas reported mite activity in the fall of 1997. In fall 1998, mite activity decreased by about half from that of in the summer. All activity was very light and no activity was reported on the north shore. A total of six district/areas reported mite activity in fall 1998. Other than a very heavy spike in mite activity in Mokuleia on the north shore, activity in fall 1999 occurred only in south Oahu as very light complaints. A small cluster of activity was present from Waikiki-Kapiolani Park to Wilhelmina Rise-Maunalani Heights, and a total of nine district/areas reported mite activity in fall 1999.

Most mite activity was reported within the central, south and east urban districts (Figures 7.1-7.4, seasonal totals). The south urban districts of the island showed the highest number of complaints, and the levels of mite activity were highest during the spring, summer and fall. There were a very small number of mite problems around the ports of entry, mainly the airport. 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.

The tick category did not contain enough data to make annual, seasonal mapping very useful. As a result, a description of annual, seasonal mapping results for ticks is not included. Tick activity was mostly reported within the leeward urban districts (Figures 7.5-7.8, seasonal totals). South and west urban districts showed the highest number of complaints, and the levels of tick activity were highest during the winter, summer and

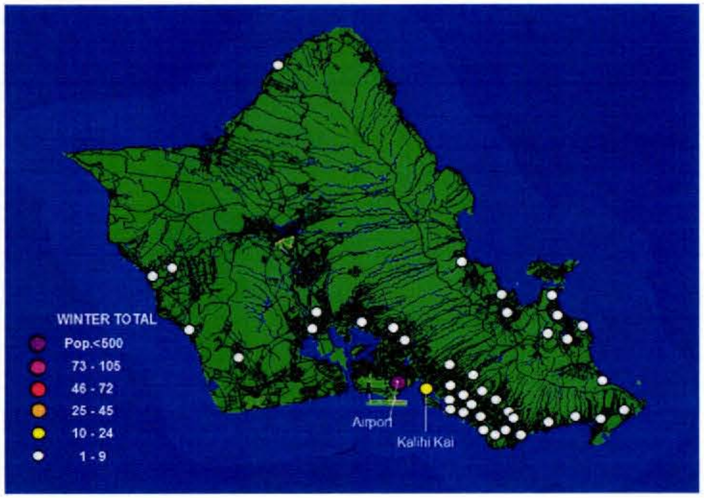

Figure 7.1. Mites, winter total (1990-1999).

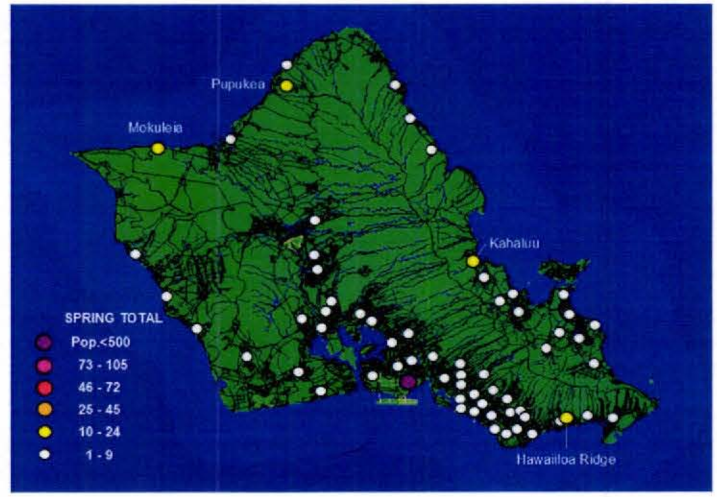

Figure 7.2. Mites, spring total (1990-1999).

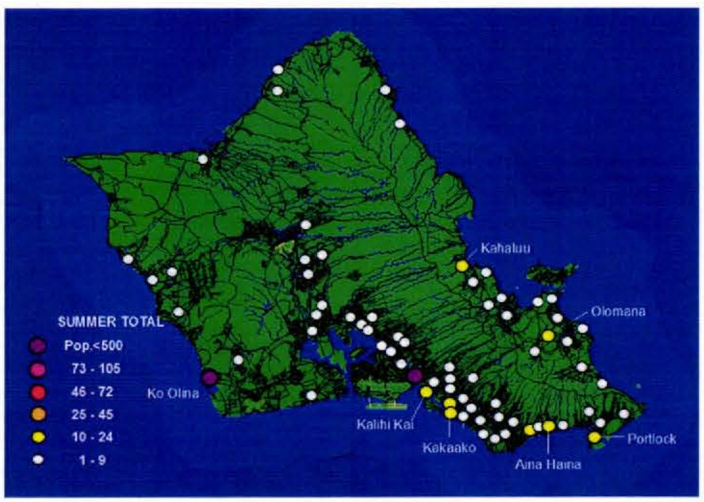

Figure 7.3. Mites, summer total (1990-1999).

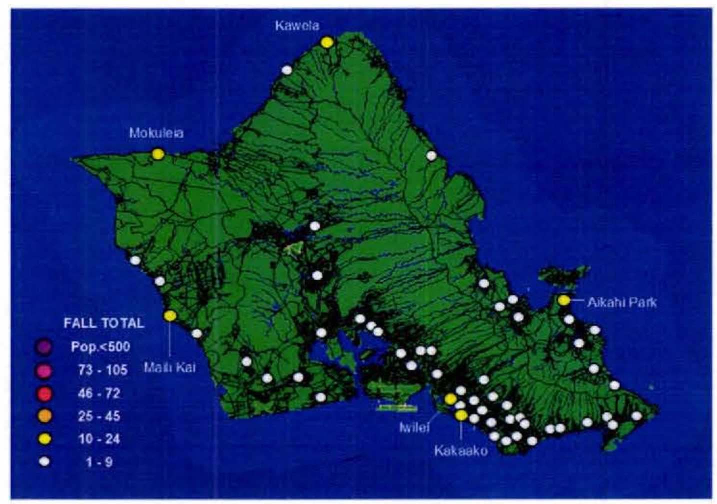

Figure 7.4. Mites, fall total (1990-1999).

Figure 7.5. Ticks, winter total (1990-1999).

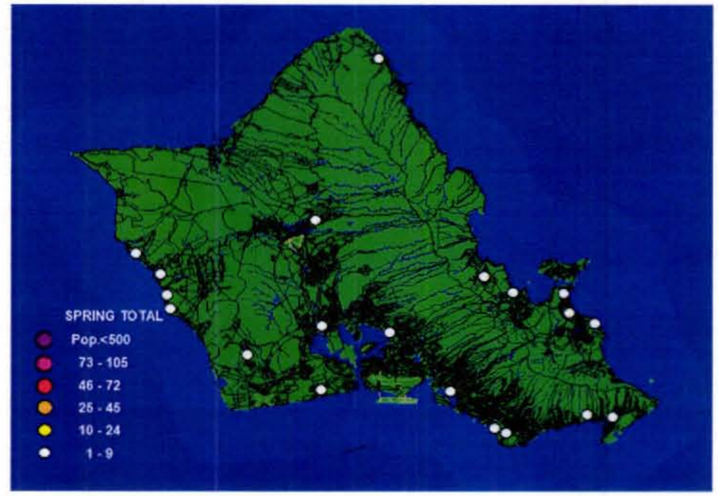

Figure 7.6. Ticks, spring total (1990-1999).

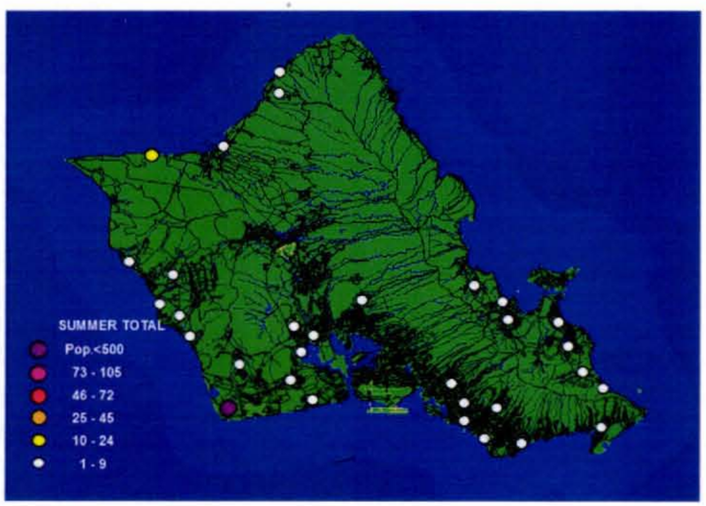

Figure 7.7. Ticks, summer total (1990-1999).

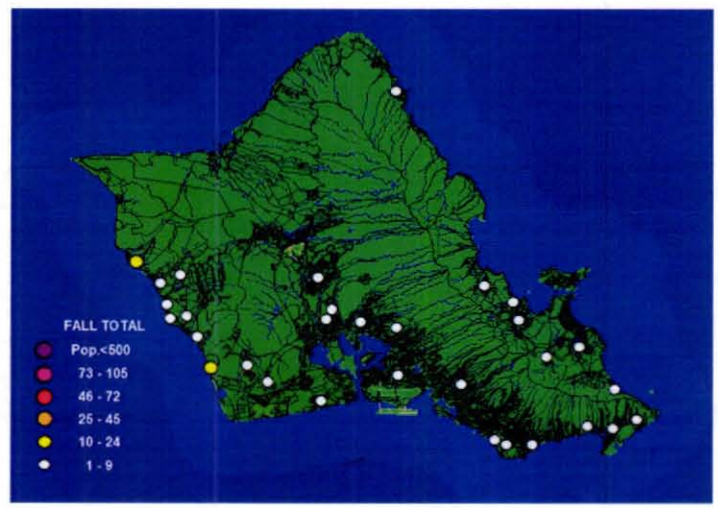

Figure 7.8. Ticks, fall total (1990-1999).

fall. There were very few tick 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 mite species recorded were *Dermatophagoides pteronyssinus* (~32.0%; n = 550), the European house dust mite; *Ornithonyssus bursa* (~11.3%), the tropical fowl mite; *Glycyphagus domesticus* (~10.5%), the grocer's itch mite; *Pyemotes boylei* (~3.1%), the straw itch mite; and *D. farinae* (~2.9%), the American house dust mite (Table 7.1). *Dermatophagoides pteronyssinus* occurrence often overlapped with *G. domesticus*, *D. farinae* and *Cheyletus eruditus*, a predaceous mite; and, although very few *C. eruditus* (~1.3%) cases were recorded, its occurrence was probably much higher and would be found among the *Cheyletus* sp. (~7.3%). Other notable mite species recorded were *Sarcoptes scabiei* (~1.1%), the scabies mite; *Ornithonyssus bacoti* (~0.7%), the tropical rat mite; *Acarus siro* (~0.9%), the grain mite; and *Tyrophagus putrescentiae* (~0.2%), the mold mite. The main sources of mite infestations were house dust, birds, stored food products, fiber-type furniture, dried plant materials and bean pods. Humans and rodents were the sources of infestation for *S. scabiei* and *O. bacoti*, respectively.

Over 19 species of mites were recorded in Vector Control inspections (Table 7.1) with most of the specimens identified being collected by vacuum sampling. Except for

Table 7.1. Mite species occurrence as determined by a sampling of 550 mite-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Acarus siro	0.9	0.5	0	3	0	0	2	0	0	0	0	0	**5**
Arystidae	0.2	0.1	0	0	0	0	0	0	0	0	1	0	**1**
Cheyletus sp.	7.3	4.0	7	0	5	2	1	4	3	8	6	4	**40**
C. eruditus	1.3	0.7	0	0	1	0	1	1	1	0	1	2	**7**
Dermatophagoides sp.	9.5	5.2	2	4	11	15	4	5	10	0	1	0	**52**
D. evansi	0.2	0.1	1	0	0	0	0	0	0	0	0	0	**1**
D. farinae	2.9	1.6	4	3	3	1	0	0	0	2	1	2	**16**
D. pteronyssinus	32.0	17.6	22	18	15	7	15	23	21	17	17	21	**176**
Euroglyphus sp.	0.2	0.1	0	1	0	0	0	0	0	0	0	0	**1**
Feather Mites	0.4	0.2	2	0	0	0	0	0	0	0	0	0	**2**
Glycyphagus sp.	6.5	3.6	10	10	9	0	0	0	1	0	5	1	**36**
Gl. domesticus	10.5	5.8	1	1	4	5	5	9	9	9	8	7	**58**
Grallacheles bakeri	0.4	0.2	0	0	0	0	0	0	0	0	0	2	**2**
Ornithonyssus sp. (=Bird Mites)	7.6	4.2	6	4	5	4	4	5	3	3	6	2	**42**
O. bacoti	0.7	0.4	0	0	1	0	1	0	1	1	0	0	**4**
O. bursa	11.3	6.2	14	6	2	4	6	8	11	0	5	6	**62**
O. sylviarum	0.2	0.1	1	0	0	0	0	0	0	0	0	0	**1**
Oribatida (=Oribatei)	1.6	0.9	2	0	0	0	0	0	2	0	3	2	**9**
Pyemotes sp.	0.5	0.3	3	0	0	0	0	0	0	0	0	0	**3**
P. boylei (=ventricosus)	3.1	1.7	6	2	2	1	2	0	1	0	0	3	**17**
Sarcoptes scabiei	1.1	0.6	0	0	1	0	2	2	1	0	0	0	**6**
Tetranychidae (=*Tetranychus* sp.)	1.1	0.6	1	0	0	1	0	1	1	0	1	1	**6**
Tyrophagus sp.	0.4	0.2	0	0	0	0	1	1	0	0	0	0	**2**
Ty. putrescentiae	0.2	0.1	0	0	0	0	0	0	0	0	1	0	**1**
Total	**100.0**	**55.0**	**82**	**52**	**59**	**40**	**44**	**59**	**65**	**40**	**56**	**53**	**550**

the larger mite species such as *O. bursa* and Tetranychidae, usually *Tetranychus* sp., much of the mite complaints received were due to dermatitis, biting and/or crawling sensations without a visible insect to which to attribute the problem, or the complainant observed mites that could not be visually confirmed by Vector Control Inspectors. If a past or current mite infestation or biting insect problem could not be confirmed, then an environmental cause such as "cable mite" or "paper mite" dermatitis was suspected (Ebeling, 1975; Ikeda, 1982b; Pinto, 1989; Pinto, 1993). This type of problem was not uncommon in business and governmental offices in south Oahu. In some cases, the behavior of the complainant, his or her physical condition, the description of the problem given, and specimen identifications negative for biting mites indicated probable delusions of parasitosis or delusory parasitosis. An extreme example is a case in which the complainant was adamant that mites or bugs were burrowing into the skin, changing colors and jumping or flying from place to place. This individual showed multiple skin sores from which attempts were made to dig out the offending parasites.

Of the mite species recovered from house dust, the five most prevalent listed in their order of occurrence were *D. pteronyssinus*, *G. domesticus*, *D. farinae*, Oribatida, and *C. eruditus*. This differed noticeably from an internal Vector Control Branch memo (Furumizo, 1994) that listed *D. pteronyssinus*, *D. farinae*, *G. domesticus*, *T. putrescentiae* and *A. siro* as the five most common house dust mite species. Two well known itch mite species, *T. putrescentiae* and *A. siro* did not occur as frequently as expected. *Dermatophagoides pteronyssinus* was nearly ubiquitous, *G. domesticus* was usually associated in furniture with a noticeable accumulation of dander or found in dust samples from kitchen areas, and Oribatida were present where indoor planters were located or soil could be tracked in from outdoors.

Unlike Zimmerman (1944) and Erhorn (1931) who reported bird mites were found to be common in nests of English sparrows and/or mynah birds, *O. bursa* infestations were more recently found to be caused by pigeons, doves and Java rice birds roosting or nesting on window ledges, beams or in attic spaces of houses and buildings. The bird activity was often associated with a nearby food source such as a restaurant, uneaten pet food left out, or direct feeding with bird seed, cooked rice or bread. Java rice birds were especially a problem since they would peck through attic vent screens. *Pyemotes boylei* related mite complaints are known from infested koa haole, kiawe and monkeypod (Vaivanijkul and Haramoto, 1969; Ikeda, 1982b; Nishida and Tenorio, 1993; Tenorio and Nishida, 1995) and were also found in this study to occur due to beetle infested dried plant materials such as leis. However, *P. boylei*, also recorded as *P. tritici*, complaints were most often caused by infested koa haole or Formosan koa seed pods around homes or in parks.

The primary tick species recorded was *Rhipicephalus sanguineus* (~100.0%; n = 80), the brown dog tick (Table 7.2). No other established tick species were found to be a public health concern. The main sources of tick infestations were dogs that were taken

Table 7.2. Tick species occurrence as determined by a sampling of 130 tick-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Rhipicephalus sanguineus	100.0	8.0	16	7	3	7	3	11	7	6	9	11	80
Total	**100.0**	**8.0**	**16**	**7**	**3**	**7**	**3**	**11**	**7**	**6**	**9**	**11**	**80**

into a tick infested location or poorly cared for, especially if the dog was relocated on premises, removed from the premises or died.

Human ehrlichiosis has not been reported to occur in Hawaii, but canine ehrlichiosis has been in Hawaii for well over 20 years and is vectored by *R. sanguineus* (Sasaki, 2000). Canine ehrlichiosis is a serious disease in dogs that was the subject of a MidWeek news article in April 2000, "Canine AIDS" (Chapman, 2000). Fortunately, however, it is not known to infect humans (Sasaki, 2000) and no incident of *R. sanguineus* biting a human was recorded in Vector Control inspections. Other important dog related tick species have occasionally been recorded on Oahu, including *Amblyoma americana* (Linnaeus), the lone star tick; *Dermacentor variabilis* (Say), the American dog tick; and *Ixodes pacificus* Cooley & Kohls, the Pacific tick, (Garrett and Haramoto, 1967; Goff, 1987). *Dermacentor variabilis* is of most interest among these tick species since it is likely to be found on man as well as dogs, is a common cause of tick paralysis, and is a vector of Rocky Mountain spotted fever (*Rickettsia rickettsii*) and tularemia (*Francisella tularensis*) (Ebeling, 1975); and was identified in an internal Vector Control Branch memo (Leong, 2000) as the tick found attached to a Tantalus/Round Top resident's ankle two days after returning from a trip to Georgia and New Jersey. The resident was treated with doxycycline soon after the tick was discovered, and no symptoms other than swelling, mild rash and itching were reported.

This survey has determined that mite and tick activity is being maintained in urban areas by human activities. As a result, dermatitis from mite infestations is possible, as well as disease transmission between dogs by ticks, especially along leeward Oahu. The results indicate that community or island-wide educational programs should be carried out in late winter for mites and late spring for ticks, and that residential mite and tick surveys may be concentrated in a limited number of district/areas according to complaints received. Educational activities are currently conducted only on a limited basis during inspections. A broader educational program would help to prevent or reduce mite related respiratory illness in addition to dermatitis, and inform the public on how to prevent the introduction of a human disease carrying tick species together with how to control the tick already present on the island. Inspections conducted in response to complaints have confirmed the practicality of using small-target area surveys since mite infestations were usually restricted to the problem site reported and tick infestations normally occurred within one or two premises of the source.

Geographic analysis can help to target areas and times of the year for more efficient application of mite and tick prevention, control and education programs by continuously tracking mite and tick 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 mite or tick 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 mite or tick 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 mite or tick 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.

CHAPTER 8

Ants, Cockroaches, Centipedes and Wasps

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. Ant, cockroach, centipede and wasp complaints provide the sixth, seventh, eighth and tenth greatest amounts of arthropod pest information available, following mosquito (first), other fly (second), flea (third), bee (fourth), and mite (fifth) and tick (ninth) complaints. The objectives of this study were to conduct a survey of the occurrence of ant, cockroach, centipede and wasp complaints on Oahu over a 10 year period, determine their distribution over time, graphically compare pest occurrence within and between district/areas, and correlate pest occurrence and distribution with season. Ant, cockroach, centipede and wasp data were drawn from inspection reports from 1990-1999, population information was obtained from Hawaii Census and State of Hawaii Data Books, 125 district/area geographic locations were defined, and pest occurrence and distribution were adjusted for population and mapped using ArcView GIS 3.2.

Ant activity was mostly reported within the central, south and east urban districts. South urban districts from Kakaako to Kalani Valley showed some of the highest numbers of complaints. The levels of ant activity were highest during the summer and fall. There were very few ant problems around the ports of entry. The primary ant species recorded were *Monomorium pharaonis* (Linnaeus), the pharaoh ant; *Camponotus variegatus* (F. Smith), the Hawaiian carpenter ant; *Ochetellus glaber* (Mayr), the glaber ant; *Paratrechina longicornis* Latreille, the crazy ant; *Solenopsis geminata* (Fabricius), the tropical fire ant; *Tapinoma melanocephalum* (Fabricius), the tiny yellow house ant; *Anoplolepis longipes* Jerdon, the long-legged ant; *Pheidole megacephala* (Fabricius), the big-headed ant; and *Technomyrmex albipes* (F. Smith), the white-footed ant. The main causes of ant infestations were access to a food source, poor sanitation, openings allowing ants into a structure, and objects providing a bridge onto a structure. Ant populations are being maintained in urban areas as a result of human activities as well as naturally occurring conditions. As a result, injury from bites or stings is possible, especially in the south urban districts from Kakaako to Kalani Valley. The results indicate that educational programs should be carried out in late spring, and that residential ant surveys may be concentrated in a limited number of district/areas.

Reported cockroach activity was mainly found within the central, south and east urban districts. The central and south urban districts of the island showed the highest number of complaints. The levels of cockroach activity were highest during the spring and summer. There were a very small number of cockroach problems around the ports of entry, only in the airport area. The primary cockroach species recorded were *Periplaneta americana* (Linnaeus), the American cockroach; *Blattella germanica* (Linnaeus), the German cockroach; and *Diploptera punctata* (Eschscholtz), the Pacific beetle cockroach. The main causes of cockroach infestations were poor sanitation, garbage accumulation, access to a food source, openings allowing cockroaches into a structure, underground structures high in moisture, leaking plumbing, leaf litter accumulation and potted plants. Cockroach populations are being maintained in urban districts by human activities. As a result, disease transmission is possible, especially in the central and south urban districts of Oahu. The results indicate that educational programs should be carried out in late winter, and that residential cockroach surveys may be concentrated in a limited number of district/areas.

Most centipede activity was reported within the leeward urban districts. South urban districts from Hawaiiloa Ridge to Kalama Valley showed the highest number of complaints. The levels of centipede activity were highest during the winter, summer and fall. There were no centipede problems around the ports of entry. The primary centipede species recorded was *Scolopendra subspinipes* Leach, the large centipede. The main sources of centipede infestations were various ground covers such as wedelia, leaf litter accumulation, red wood chips, gravel, rock piles and wood piles. Undeveloped neighboring properties were also a source of centipede activity. Centipede activity is being maintained in urban areas by human activities as well as naturally occurring conditions. As a result, injury from centipede "bites" is possible, especially from

Hawaiiloa Ridge to Kalama Valley. The results indicate that educational programs should be carried out in late spring, and that residential centipede surveys may be concentrated in a limited number of district/areas.

Wasp activity was fairly well distributed across the island. South, east and central urban districts showed the highest number of complaints, and the levels of wasp activity were highest during the fall. There were few wasp problems around the ports of entry. The primary wasp species recorded was *Polistes* sp., the paper wasp. Paper wasp infestations usually involved several to a dozen or more small to moderate size nests hanging beneath eaves and on walls, and problem sites bordered undeveloped lands or overgrown residential premises on which adult wasps may forage. Wasp activity regularly occurs in urban areas as a result of human activities. As a result, injury from wasp stings is possible, especially along south, east and central Oahu. The results indicate that educational programs should be carried out in late summer, and that residential wasp surveys may be concentrated in a limited number of district/areas.

Introduction

Of the 47 species of ants recorded in Hawaii (Krushelnycky et al., 2005), there are eight species that are or may be considered of public health concern on the island of Oahu (Yamada, 1982; Nishida and Tenorio, 1993; Tenorio and Nishida, 1995). These species are *Monomorium pharaonis* (Linnaeus), the pharaoh ant; *M. floricola* (Jerdon), no common name; *Camponotus variegatus* (F. Smith), the Hawaiian carpenter ant; *Ochetellus glaber* (Mayr), the glaber ant; *Solenopsis geminata* (Fabricius), the tropical fire ant; *Pheidole megacephala* (Fabricius), the big-headed ant; *Linepithema humile* (Mayr), the Argentine ant; and *Pseudomyrmex gracilis mexicanus* (Fabricius), the Mexican ant. These ants were first recorded in Hawaii from 1879 to 1980 (Table 8.1). *Camponotus variegatus, O. glaber* and *Ph. megacephala* are known to bite; and *M. pharaonis, M. floricola, S. geminata* and *Ps. gracilis mexicanus* may bite and/or sting. *Linepithema humile* bites and sprays the wound with a toxic chemical. Other ant species encountered such as *Paratrechina longicornis* Latreille, the crazy ant; *Tapinoma melanocephalum* (Fabricius), the tiny yellow house ant; *Anoplolepis longipes* Jerdon [= *A. gracilipes* (F. Smith)], the long-legged ant; *Technomyrmex albipes* (F. Smith), the white-footed ant; *Plagiolepis alluaudi* Emery, the little yellow ant; and *M. destructor* (Jerdon), the destructive trailing ant, are considered nuisance species. *Solenopsis geminata* and *Ps. gracilis mexicanus* stings and *Li. humile* spray inflict painful burning and may cause severe allergic reactions. Some ants, especially *M. pharaonis*, are important pests in hospitals and have been shown to be potential vectors for pathogenic bacteria (Tenorio and Nishida, 1995; Moreira et al., 2005).

There are 19 species of cockroaches in Hawaii (Tenorio and Nishida, 1995), with eight of these species having been found to occur in homes on Oahu (Toyama, 1982a; Nishida and Tenorio, 1993; Tenorio and Nishida, 1995). The commonly occurring cockroach species are *Blattella germanica* (Linnaeus), the German cockroach;

Table 8.1. Year of first record for ants, cockroaches, centipedes and wasps of public health importance on the island of Oahu.

SPECIES	Year of First Record	Citation	Reference
Ants			
Camponotus variegatus	1879	Smith, 1879	Krushelnycky et al., 2005
Linepithema humile	1940	Zimmerman, 1941	Krushelnycky et al., 2005
Monomorium floricola	1899	Forel, 1899	Perkins and Forel, 1899
M. pharaonis	1913	Gulick, 1913	Krushelnycky et al., 2005
Ochetellus glaber (=Iridomyrmex)	1977	Beardsley, 1980	Krushelnycky et al., 2005
Pheidole megacephala	1879	Smith, 1879	Krushelnycky et al., 2005
Pseudomyrmex gracilis mexicanus	1976	Beardsley, 1979	Krushelnycky et al., 2005
Solenopsis geminata	1879	Smith, 1879	Krushelnycky et al., 2005
Cockroaches			
Blattella germanica	1899	Perkins, 1899	Zimmerman, 1948
Diploptera punctata	1882	Bormans, 1882	Zimmerman, 1948
Leucophaea mederae (=Rhyparobia)	1896 or 1897	Schauinsland, 1897	Zimmerman, 1948
Neostylopyga rhombifolia	1882	Bormans, 1882	Zimmerman, 1948
Periplaneta Americana	1882	Bormans, 1882	Zimmerman, 1948
Pe. Australasiae	1899	Perkins, 1899	Zimmerman, 1948
Pycnoscelus indicus	1822	Eschscholtz, 1822	Zimmerman, 1948
Supella longipalpa	1921	Swezey, 1921	Zimmerman, 1948
Centipedes			
Scolopendra subspinipes	1847	Gervais, 1847	Shelley, 2000
Wasps			
Polistes exclamans	1951	Clagg, 1952	Clagg, 1952
Po. fuscatus aurifer	1879	Smith, 1879	Illingworth, 1923
Po. macaensis	1886	Blackburn and Cameron, 1886	Illingworth, 1923
Po. olivaceous	1935	Swezey, 1936	Swezey, 1936
Sceliphron caementarium	1886	Blackburn and Cameron, 1886	Perkins and Forel, 1899
Vespula pensylvanica	1920	Williams, 1921	Williams, 1921

Periplaneta americana (Linnaeus), the American cockroach; *Supella longipalpa* (Fabricius), the brown-banded cockroach; *Pe. australasiae* (Fabricius), the Australasian cockroach; *Neostylopyga rhombifolia* (Stoll), the harlequin cockroach; *Pycnoscelus indicus* (Linnaeus), burrowing cockroach; *Diploptera punctata* (Eschscholtz), the Pacific beetle cockroach; and *Leucophaea (=Rhyparobia) maderae* (Fabricius), the Madeira cockroach. The majority of these cockroaches were established in Hawaii by the late 1800's (Table 8.1). Cockroaches have been incriminated as mechanical disease vectors by the many pathogenic organisms found on their body or in their gut, feces and vomit, including those causing salmonellosis (*Salmonella*), dysentery (*Shigella dysenteriae* or *Entamoeba histolyica*), poliomyelitis (Poliovirus) and toxoplasmosis (*Toxoplasma*) (Ebeling, 1975; Toyama, 1982a; Nishida and Tenorio, 1993; Tenorio and Nishida, 1995; Fathpour et al., 2003). *Periplaneta americana* and *Pe. australasiae* may bite humans when infestations are especially heavy, and research studies have shown that some people are allergic to *Pe. americana* and *B. germanica*. *Pycnoscelus indicus* damages the underground parts of some plants and is known to be an intermediate host for Manson's eye worm of poultry, and *D. punctata* damages plants, particularly cypress trees, by eating the bark and girdling small branches.

Of at least 12 non-native species of centipedes present in Hawaii (Nishida and Tenorio, 1993; Tenorio and Nishida, 1995), only one species, *Scolopendra subspinipes* Leach, the large centipede, is of medical significance (Komatsu, 1982b; Nishida and Tenorio, 1993; Tenorio and Nishida, 1995). *Scolopendra subspinipes*, reported to be present in Hawaii prior to 1847 and probably arriving in the islands with the Polynesians (Shelley, 2000), can inflict a very painful "bite" with its enlarged first pair of legs and claws that inject venom from poison glands at the base of the legs. The wound can be slow to heal and may be susceptible to infection.

Only seven of nearly 500 non-native wasp species are considered to be of public health importance in Hawaii (Komatsu, 1982a; Nishida and Tenorio, 1993; Tenorio and Nishida, 1995), six of which are present on Oahu. They are *Polistes exclamans* Viereck, the common paper wasp; *Po. olivaceous* (De Geer), the red-brown paper wasp; *Po. fuscatus aurifer* Saussure, the golden paper wasp; *Po. macaensis* (Fabricius), the Macao paper wasp; *Vespula pensylvanica* (Saussure), the Western yellowjacket; and *Sceliphron caementarium* (Drury), a mud-dauber. The common yellowjacket, *V. vulgaris* (Linnaeus), is the seventh medically important wasp and is restricted to the island of Maui. These wasps were recorded in Hawaii beginning in the late 1800's (Table 8.1).

The first year of record for *Po. olivaceous* was difficult to determine from the literature and this wasp was eventually found to be synonymous with *Po. macaensis* which was originally recorded as *Po. hebraeus* (Perkins and Forel, 1899; Illingworth, 1923; Harris, 1979). The important wasp species range from non-aggressive, *S. caementarium*, to very aggressive, *V. pensylvanica*, but they all sting with the possibility of a severe allergic reaction or anaphylactic shock. *Vespula pensylvanica* is especially dangerous due to its highly aggressive nature, tendency to mass attack and the fact that a wasp's stinger is not barbed which allows it to sting repeatedly. As with bees, the severity of reactions to wasp stings varies widely among individuals from localized pain and swelling to the serious and sometimes fatal, systemic reaction.

Results

Ant activity was mostly reported within the central, south and east urban districts (Figures 8.1-8.4, seasonal totals). South urban districts from Kakaako to Kalani Valley along with other lower elevation areas around the perimeter of Oahu showed some of the highest numbers of complaints. The levels of ant activity were highest during the summer and fall. There were very few ant 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.

Reported cockroach activity was mostly found within the central, south and east urban districts (Figures 8.5-8.8, seasonal totals). The central and south urban districts of the island showed the highest number of complaints. The levels of cockroach activity were highest during the spring and summer. There were a very small number of cockroach problems around the ports of entry, only in the airport area. However, the

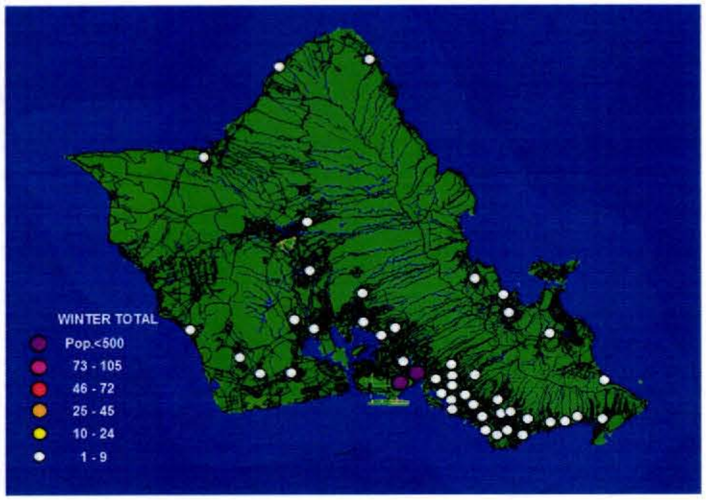

Figure 8.1. Ants, winter total (1990-1999).

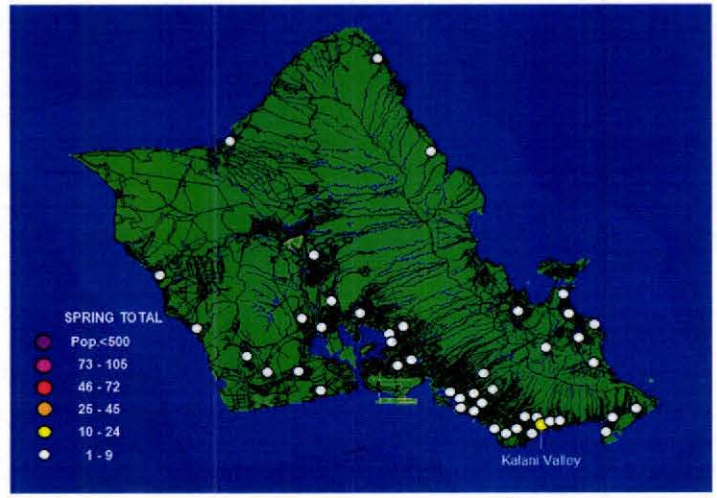

Figure 8.2. Ants, spring total (1990-1999).

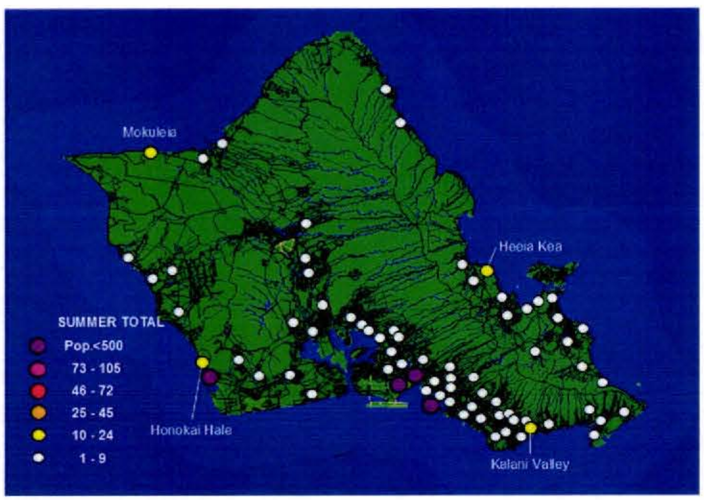

Figure 8.3. Ants, summer total (1990-1999).

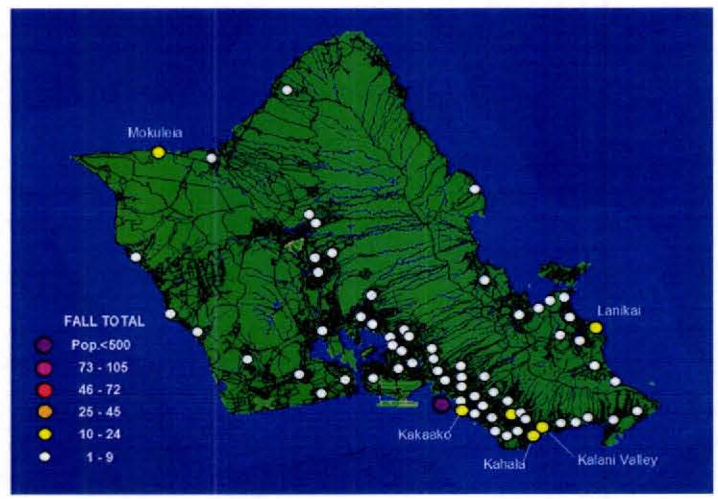

Figure 8.4. Ants, fall total (1990-1999).

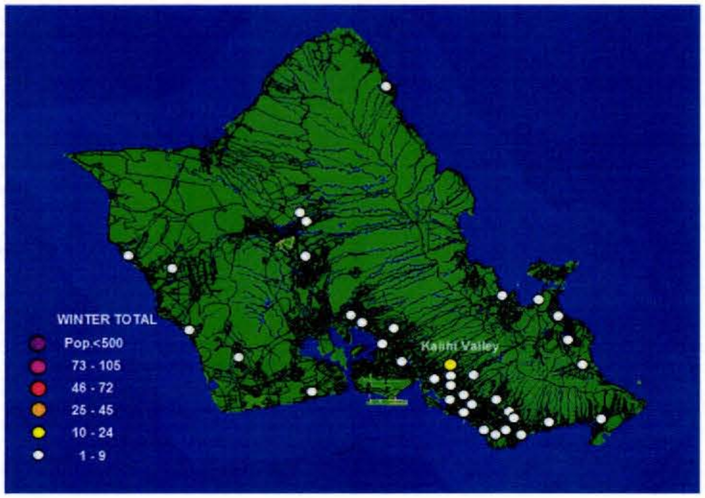

Figure 8.5. Cockroaches, winter total (1990-1999).

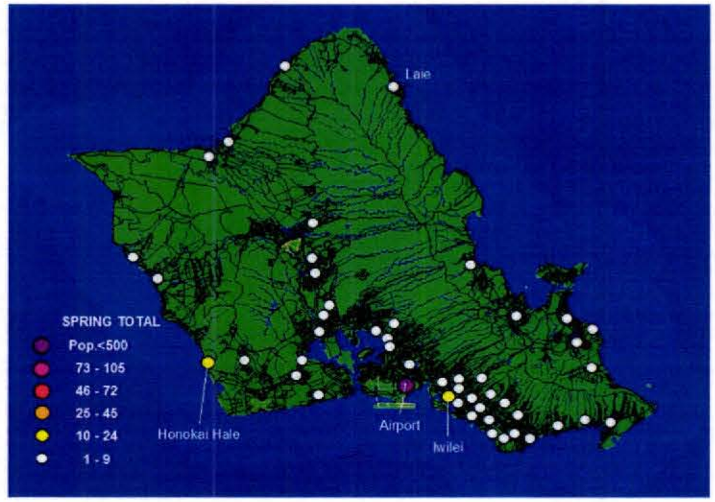

Figure 8.6. Cockroaches, spring total (1990-1999).

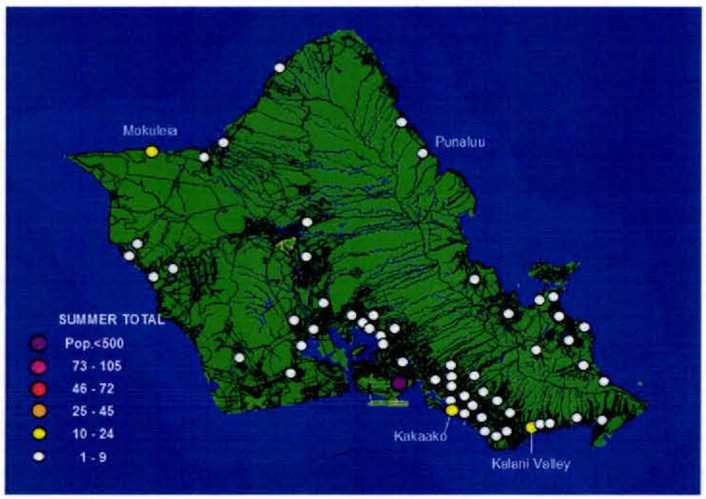

Figure 8.7. Cockroaches, summer total (1990-1999).

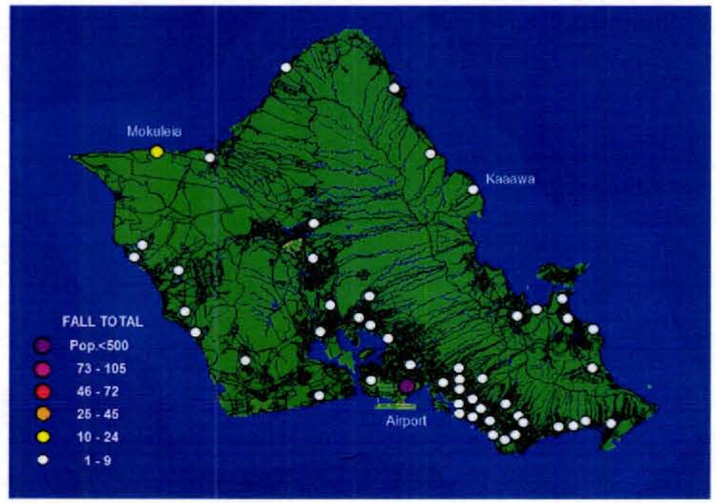

Figure 8.8. Cockroaches, fall total (1990-1999).

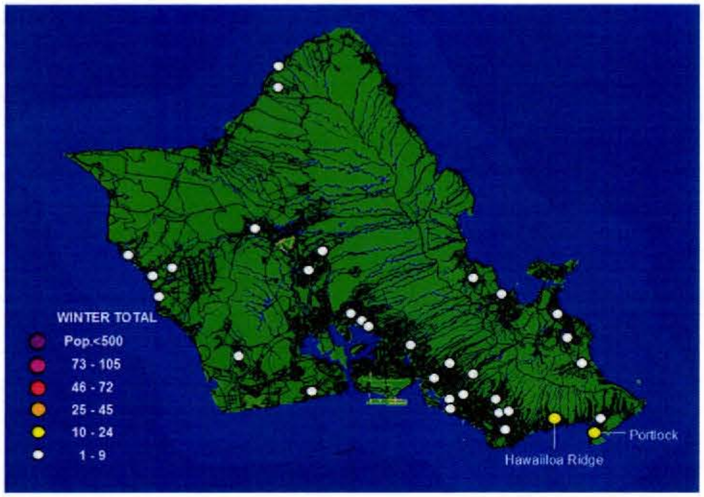

Figure 8.9. Centipedes, winter total (1990-1999).

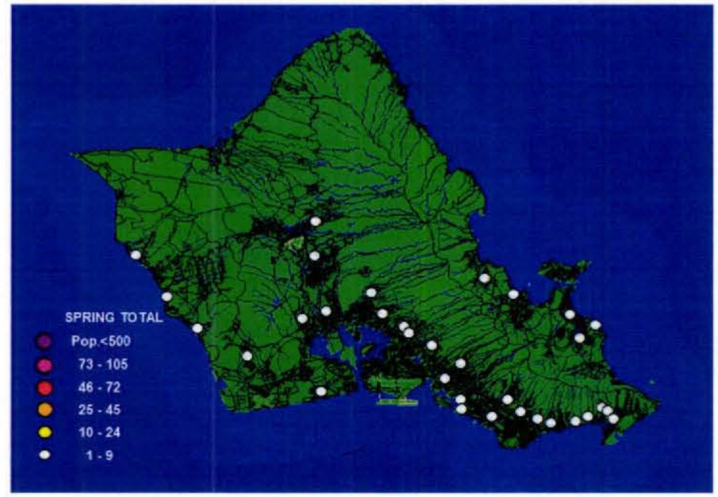

Figure 8.10. Centipedes, spring total (1990-1999).

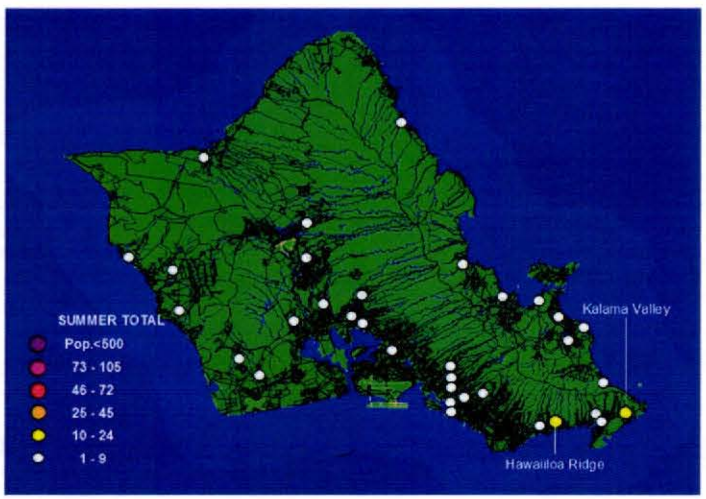

Figure 8.11. Centipedes, summer total (1990-1999).

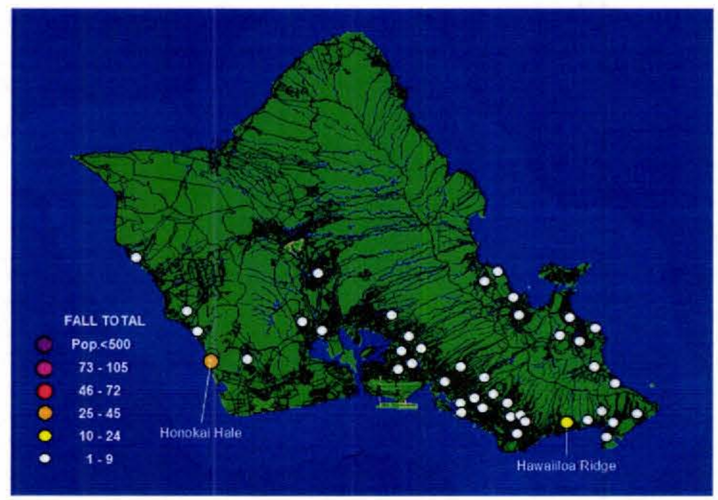

Figure 8.12. Centipedes, fall total (1990-1999).

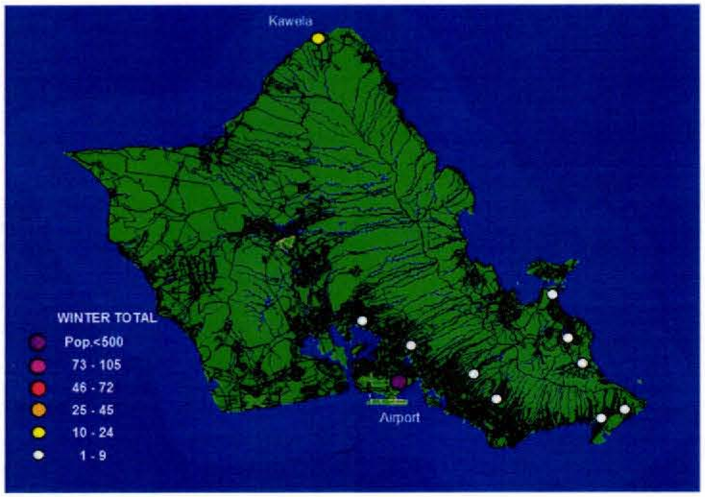

Figure 8.13. Wasps, winter total (1990-1999).

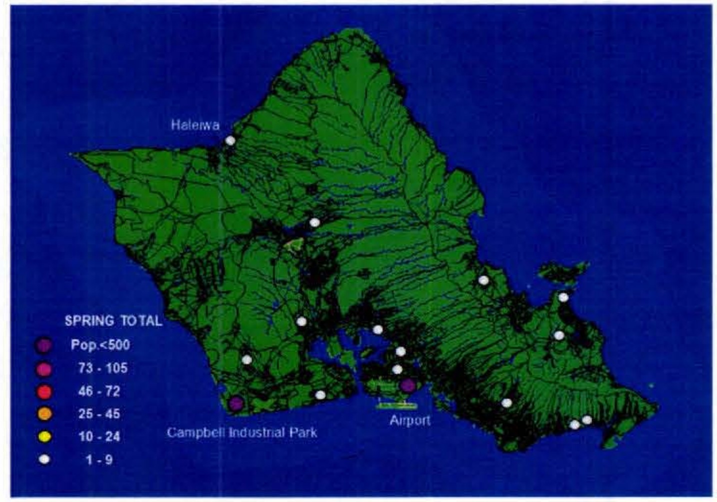

Figure 8.14. Wasps, spring total (1990-1999).

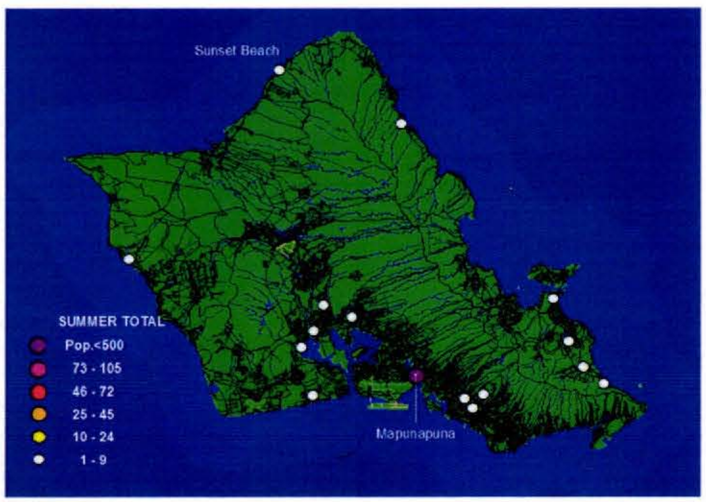

Figure 8.15. Wasps, summer total (1990-1999).

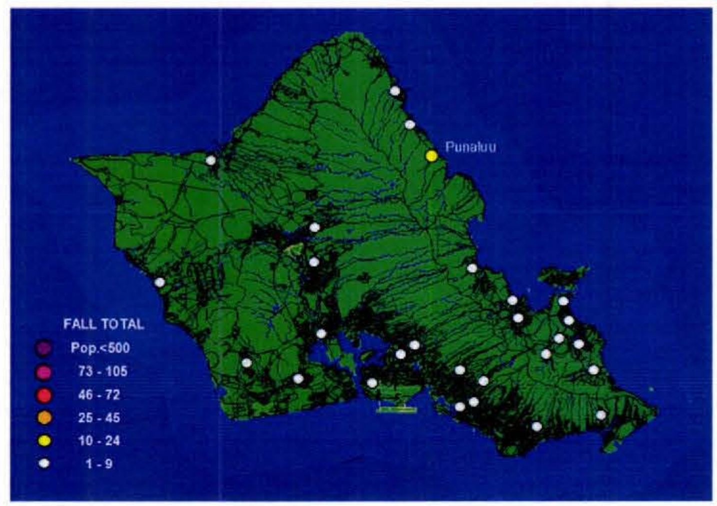

Figure 8.16. Wasps, fall total (1990-1999).

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.

Most centipede activity was reported within the leeward urban districts (Figures 8.9-8.12, seasonal totals). South urban districts from Hawaiiloa Ridge to Kalama Valley showed the highest number of complaints, and the spring total showed a line of activity along south and central district/areas bordering undeveloped lands. The levels of centipede activity were highest during the winter, summer and fall. There were no centipede problems around the ports of entry.

Wasp activity was fairly well distributed across the island (Figures 8.13-8.16, seasonal totals). South, east and central urban districts showed the highest number of complaints, and the levels of wasp activity were highest during the fall. There were few wasp 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 ant species recorded were *Monomorium pharaonis* (~15.9%; n = 517), the pharaoh ant; *Camponotus variegatus* (~15.7%), the Hawaiian carpenter ant;

Ochetellus glaber (~15.5%), the glaber ant; *Paratrechina longicornis* (~10.8%), the crazy ant; *Solenopsis geminata* (~9.9%), the tropical fire ant; *Tapinoma melanocephalum* (~8.7%), the tiny yellow house ant; *Anoplolepis longipes* (~8.3%), the long-legged ant; *Pheidole megacephala* (~5.4%), the big-headed ant; and *Technomyrmex albipes* (~4.8%), the white-footed ant (Table 8.2). Few *Pseudomyrmex gracilis mexicanus* (~2.9%), Mexican ant; *Plagiolepis alluaudi* (~0.8%), little yellow ant; and *M. destructor* (~0.4%), destructive trailing ant, cases were recorded. The main causes of ant infestations were access to a human or natural food source, poor sanitation, openings allowing ants into a structure, and objects, plants and trees providing a bridge onto a structure. In general, ants were usually found in classrooms, kitchens and bathrooms feeding on exposed food, food crumbs and food waste, or drinking water. *Monomorium pharaonis* was often found around electrical or telephone wiring contacts; and, like *O. glaber*, *Pa. longicornis*, *Ta. melanocephalum*, *A. longipes* and *Te. albipes*, would invade a structure through doors, windows, wall openings and floor openings from established nests on the immediate exterior premises or on a neighboring property. *Ochetellus glaber* and *Te. albipes* were found in large numbers tending plant-sucking insects on trees and shrubs just outside or touching a building. In one case, *Te. albipes* traveled to a house along a telephone pole's vine-wrapped wires from a heavily infested, vacant property nearby. *Camponotus variegatus* was always established indoors in an isolated hollow space such as a range hood, hollow-core door or wall void, while *S. geminata* and *Ph. megacephala* were normally outdoor pests. *Solenopsis geminata* was especially a concern since it was often the species found infesting school playgrounds and public parks in addition to yards

Table 8.2. Ant species occurrence as determined by a sampling of 495 ant-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Anoplolepis longipes	8.3	4.3	2	3	3	3	5	13	6	4	1	3	**43**
Camponotus variegatus	15.7	8.1	23	16	9	5	11	8	4	2	2	1	**81**
Hypoponera punctatissima	0.2	0.1	0	0	0	0	1	0	0	0	0	0	**1**
Leptogenys falcigera	0.2	0.1	0	0	1	0	0	0	0	0	0	0	**1**
Monomorium sp.	0.4	0.2	0	0	1	0	0	0	0	0	0	1	**2**
M. destructor	0.4	0.2	0	0	0	0	0	0	0	0	2	0	**2**
M. pharaonis	15.9	8.2	22	14	7	7	5	11	6	5	4	1	**82**
Ochetellus glaber (=Iridomyrmex)	15.5	8.0	15	11	9	5	6	11	11	4	3	5	**80**
Paratrechina bourbonica	0.2	0.1	0	0	0	0	0	0	0	0	1	0	**1**
Pa. longicornis	10.8	5.6	5	4	11	5	4	11	9	3	3	1	**56**
Pheidole megacephala	5.4	2.8	6	4	4	2	2	4	1	2	2	1	**28**
Plagiolepis alluaudi	0.8	0.4	0	1	1	0	0	0	1	0	0	1	**4**
Pseudomyrmex gracilis mexicanus	2.9	1.5	2	1	2	1	1	0	4	1	1	2	**15**
Solenopsis geminata	9.9	5.1	3	6	5	5	3	8	7	4	4	6	**51**
Tapinoma melanocephalum	8.7	4.5	12	5	8	4	4	5	2	2	1	2	**45**
Technomyrmex albipes	4.8	2.5	0	0	0	0	1	1	2	3	9	9	**25**
Total	**100.0**	**51.7**	**90**	**65**	**61**	**37**	**43**	**72**	**53**	**30**	**33**	**33**	**517**

in the drier areas of the island. Ant populations are being maintained in urban areas as a result of human activities as well as naturally occurring conditions. As a result, injury from bites or stings is possible, especially in the south urban districts from Kakaako to Kalani Valley and in the drier areas of the island. The results indicate that community or island-wide educational programs should be carried out in late spring, and that residential ant surveys may be concentrated in a limited number of district/areas according to complaints received.

The primary cockroach species recorded were *Periplaneta americana* (~50.4%; n = 230), the American cockroach; *Blattella germanica* (~33.0%), the German cockroach; and *Diploptera punctata* (~10.4%), the Pacific beetle cockroach (Table 8.3). A small number of *Neostylopyga rhombifolia* (~2.2%), harlequin cockroach; *Supella longipalpa* (~1.3%), brown-banded cockroach; *Pycnoscelus indicus* (~0.9%), burrowing cockroach; and *Pe. australasiae* (~0.4%), Australasian cockroach, cases were recorded. The main causes of cockroach infestations were poor sanitation, garbage accumulation, access to a human or pet food source, openings allowing cockroaches into a structure, underground structures high in moisture such as the sanitary sewer and utility boxes, leaking plumbing, leaf litter accumulation, and potted plants. Poorly maintained rental apartment buildings, low-income housing and single family dwellings were found with moderate to very heavy *Pe. americana* or *B. germanica* infestations mainly in the kitchen and bathrooms as well as in garbage container or dumpster enclosures. Garbage accumulation and exposed human or pet food were often present inside and outside of

Table 8.3. Cockroach species occurrence as determined by a sampling of 445 cockroach-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Balta sp.	0.4	0.1	0	0	0	1	0	0	0	0	0	0	**1**
Blattella germanica	33.0	7.6	1	15	12	3	5	5	13	5	3	14	**76**
Diploptera punctata	10.4	2.4	7	3	0	2	2	2	3	0	1	4	**24**
Euthyrrhapha pacifica	0.4	0.1	0	0	0	0	0	0	0	0	0	1	**1**
Neostylopyga rhombifolia	2.2	0.5	1	1	0	0	1	1	0	0	1	0	**5**
Periplaneta sp.	0.4	0.1	1	0	0	0	0	0	0	0	0	0	**1**
Pe. Americana	50.4	11.6	18	10	6	6	6	11	24	15	10	10	**116**
Pe. Australasiae	0.4	0.1	0	0	1	0	0	0	0	0	0	0	**1**
Pycnoscelus indicus	0.9	0.2	1	0	0	0	0	0	1	0	0	0	**2**
Supella longipalpa	1.3	0.3	0	0	0	0	0	0	1	1	0	1	**3**
Total	**100.0**	**23.0**	**29**	**29**	**19**	**12**	**14**	**19**	**42**	**21**	**15**	**30**	**230**

Table 8.4. Centipede species occurrence as determined by a sampling of 221 centipede-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Scolopendra subspinipes	100.0	7.1	5	17	11	7	5	11	5	3	2	5	**71**
Total	**100.0**	**7.1**	**5**	**17**	**11**	**7**	**5**	**11**	**5**	**3**	**2**	**5**	**71**

the buildings in these situations. Openings beneath doors, window screens in disrepair, and holes in indoor and exterior walls and flooring allowed the cockroaches into the structures and to infest multiple units in a building via wall voids and attic spaces. *Periplaneta americana* preferred the high moisture conditions found in sanitary sewers, utility boxes, and kitchens and bathrooms with leaking plumbing. *Diploptera punctata* was generally an outdoor pest found beneath leaf litter accumulation and around the base of plants, but they would enter homes both in potted plants and through openings beneath doors. Cockroach populations are being maintained in urban districts by human activities. As a result, disease transmission is possible, especially in the central and south urban districts of Oahu. The results indicate that community or island-wide educational programs should be carried out in late winter, and that residential cockroach surveys may be concentrated in a limited number of district/areas according to complaints received.

The primary centipede species recorded was *Scolopendra subspinipes* (~100.0%; n = 71), the large centipede (Table 8.4). No other centipede species were found to be a public health concern. The main sources of centipede infestations were various ground covers such as wedelia (*Wedelia trilobata*), leaf litter accumulation, red wood chips, gravel, rock piles and wood piles. Undeveloped neighboring properties were also a source of centipede activity. These sites provided habitats for various insects, worms and slugs on which centipedes feed in addition to protective cover. Heavy rains have been known to flood the centipedes out of their low-lying homes and up into nearby human dwellings. Centipede activity is being maintained in urban areas by human activities as well as naturally occurring conditions. As a result, injury from centipede "bites" is possible, especially from Hawaiiloa Ridge to Kalama Valley. The results indicate that community or island-wide educational programs should be carried out in late spring, and that residential centipede surveys may be concentrated in a limited number of district/ areas according to complaints received.

The primary wasp species recorded was *Polistes* sp. (~93.2%; n = 59), the paper wasp (Table 8.5). A few cases involving *Po. olivaceous* (~3.4%), the red-brown paper wasp; *Sceliphron caementarium* (1.7%), a mud-dauber; and *Liris opulenta* (~1.7%), a sphecid wasp, were recorded. Specific species identification of paper wasps was not often done since, in addition to the potential for Inspectors to be stung during specimen collecting, the abatement recommendations for treatment and removal of the wasps and nests were the same for all of the species. Paper wasp infestations usually involved several to a dozen or more small to moderate size nests hanging beneath eaves and on walls, and problem sites bordered undeveloped lands or overgrown residential premises on which adult wasps may forage for caterpillars, other insects, honeydew and juices of fruits (Komatsu, 1982; Tenorio and Nishida, 1995). Infestations involving a large number of nests normally occurred on single structures that were not being properly maintained. Wasp activity regularly occurs in urban areas as a result of human activities. As a result, injury from wasp stings is possible, especially along south, east and central Oahu. The results indicate that community or island-wide educational programs should

Table 8.5. Wasp species occurrence as determined by a sampling of 75 wasp-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Liris opulenta	1.7	0.1	0	0	0	0	0	0	0	0	1	0	**1**
Polistes sp.	93.2	5.5	9	8	7	5	5	4	7	6	3	1	**55**
P. olivaceous	3.4	0.2	0	1	0	0	0	1	0	0	0	0	**2**
Sceliphron caementarium	1.7	0.1	1	0	0	0	0	0	0	0	0	0	**1**
Total	**100.0**	**5.9**	**10**	**9**	**7**	**5**	**5**	**5**	**7**	**6**	**4**	**1**	**59**

be carried out in late summer, and that residential wasp surveys may be concentrated in a limited number of district/areas according to complaints received.

Educational activities for ant, cockroach, centipede and wasp complaints are currently conducted only on a limited basis during inspections. A more comprehensive educational program would better inform the public and help to reduce the potential for pest related illness and injury. Inspections conducted in response to complaints have confirmed the practicality of using small-target area surveys to reach the people who most need the information since ant, cockroach, centipede and wasp infestations were usually restricted to the problem site reported or occurred within one or two premises of the source. Moreover, conducting presentations on these pests as well as other pests of public health importance in public schools and recreation centers would not only benefit the schools and parks affected, but also provide avenues to disseminate pest prevention and control information to the community.

Geographic analysis will help to target areas and times of the year for more efficient application of ant, cockroach, centipede and wasp prevention, control and education programs by continuously tracking pest 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 pest 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 ant, cockroach, centipede or wasp 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 pest 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.

APPENDIX A

Remaining Pest Groups: Less frequently occurring pest complaints to very minor or anomalous reports. Many of the pest species listed here range from non-public health related or nuisance pests to those of mild health concern. However, species such as *Latrodectus geometricus* and *Loxosceles rufescens* are of serious health concern due to their toxic venom.

Table A.1. Spider species occurrence as determined by a sampling of 64 spider-related inspection reports. Although reported in complaints, *Loxosceles reclusa* is not known to occur in Hawaii.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Argiope appensa	2.7	0.1	0	0	1	0	0	0	0	0	0	0	1
Common House Spider	13.5	0.5	0	0	0	1	1	1	2	0	0	0	5
Gasteracantha mammosa	5.4	0.2	0	0	1	0	1	0	0	0	0	0	2
Heteropoda venatoria	2.7	0.1	0	1	0	0	0	0	0	0	0	0	1
Latrodectus geometricus	45.9	1.7	1	2	2	0	2	6	3	1	0	0	17
Loxosceles reclusa	5.4	0.2	0	0	0	0	0	2	0	0	0	0	2
Lx. rufescens	2.7	0.1	0	0	0	1	0	0	0	0	0	0	1
Lycosidae (=Wolf Spider)	5.4	0.2	1	1	0	0	0	0	0	0	0	0	2
Pholcidae	8.1	0.3	2	0	1	0	0	0	0	0	0	0	3
Salticidae (=Jumping Spider)	5.4	0.2	1	1	0	0	0	0	0	0	0	0	2
Zosis geniculatus	2.7	0.1	0	0	0	0	0	0	0	0	0	1	1
Total	**100.0**	**3.7**	**5**	**5**	**5**	**2**	**4**	**9**	**5**	**1**	**0**	**1**	**37**

Table A.2. Lice species occurrence as determined by a sampling of 50 lice-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Pediculus humanus capitis	100.0	0.5	2	0	1	0	0	1	0	1	0	0	5
Total	**100.0**	**0.5**	**2**	**0**	**1**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**5**

Table A.3. Gnat species occurrence as determined by a sampling of 52 gnat-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Sciaridae (=Fungus Gnat)	100.0	0.9	0	2	0	1	0	0	2	2	2	0	9
Total	**100.0**	**0.9**	**0**	**2**	**0**	**1**	**0**	**0**	**2**	**2**	**2**	**0**	**9**

Table A.4. Bed bug species occurrence as determined by a sampling of 31 bed bug-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Cimex lectularius	100.0	1.4	3	1	0	1	1	2	0	1	1	4	**14**
Total	**100.0**	**1.4**	**3**	**1**	**0**	**1**	**1**	**2**	**0**	**1**	**1**	**4**	**14**

Table A.5. Scorpion species occurrence as determined by a sampling of 29 scorpion-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Isometrus maculatus	100.0	1.2	3	1	1	0	2	1	3	0	0	1	**12**
Total	**100.0**	**1.2**	**3**	**1**	**1**	**0**	**2**	**1**	**3**	**0**	**0**	**1**	**12**

Table A.6. Termite species occurrence as determined by a sampling of 15 termite-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Coptotermes formosanus	33.3	0.1	0	0	0	0	1	0	0	0	0	0	**1**
Cryptotermes brevis	66.7	0.2	0	2	0	0	0	0	0	0	0	0	**2**
Total	**100.0**	**0.3**	**0**	**2**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**3**

Table A.7. Beetle species occurrence as determined by a sampling of 16 beetle-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Ananca bicolor	7.1	0.1	0	0	0	0	0	0	0	0	1	0	**1**
Carabidae	7.1	0.1	0	0	0	0	0	1	0	0	0	0	**1**
Carpophilus humeralis (=Urophorus)	7.1	0.1	0	1	0	0	0	0	0	0	0	0	**1**
Lasioderma serricorne	28.6	0.4	0	2	0	1	1	0	0	0	0	0	**4**
Rhyzopertha dominica	7.1	0.1	0	0	0	1	0	0	0	0	0	0	**1**
Sitophilus oryzae	7.1	0.1	0	0	0	1	0	0	0	0	0	0	**1**
Stegobium paniceum	7.1	0.1	0	0	0	0	0	1	0	0	0	0	**1**
Tribolium castaneum	7.1	0.1	0	0	0	1	0	0	0	0	0	0	**1**
Tricorynus herbarium (=Book Beetle)	21.4	0.3	0	0	0	1	2	0	0	0	0	0	**3**
Total	**100.0**	**1.4**	**0**	**3**	**0**	**5**	**3**	**2**	**0**	**0**	**1**	**0**	**14**

Table A.8. Millipede species occurrence as determined by a sampling of 11 millipede-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Trigoniulus lumbricinus	100.0	0.1	0	1	0	0	0	0	0	0	0	0	1
Total	**100.0**	**0.1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**

Table A.9. Moth species occurrence as determined by a sampling of six moth-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Plodia interpunctella	66.7	0.2	0	1	0	0	1	0	0	0	0	0	2
Spodoptera mauritia	33.3	0.1	0	0	0	0	0	0	0	1	0	0	1
Total	**100.0**	**0.3**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**3**

Table A.10. Whitefly species occurrence as determined by a sampling of six whitefly-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Aleyrodidae	100.0	0.3	0	1	1	0	0	0	0	0	0	1	3
Total	**100.0**	**0.3**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**3**

Table A.11. Midge species occurrence as determined by a sampling of six midge-related inspection reports.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Chironomidae	100.0	0.2	0	0	1	0	0	1	0	0	0	0	2
Total	**100.0**	**0.2**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**2**

Table A.12. Miscellaneous species occurrence as determined by a sampling of 599 inspection reports related to complaints about bugs, insects and something biting.

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Mosquitoes													
Aedes albopictus	3.2	1.9	4	2	1	1	3	1	1	3	0	3	**19**
Culex quinquefasciatus	0.5	0.3	1	0	1	0	0	0	0	1	0	0	**3**
Wyeomyia mitchellii	0.2	0.1	0	0	0	0	0	0	0	1	0	0	**1**
Flies													
Diptera (=Flies)	0.2	0.1	0	1	0	0	0	0	0	0	0	0	**1**
Chrysomya megacephala	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Chrysomya rufifacies	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Drosophila spp.	2.0	1.2	2	0	3	2	1	1	0	1	0	2	**12**
Hermetia illucens	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Musca domestica	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Musca sorbens	0.3	0.2	0	0	0	0	1	0	1	0	0	0	**2**
Ophyra chalcogaster	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Phaenicia cuprina	0.3	0.2	1	0	0	0	0	0	0	1	0	0	**2**
Phoridae	0.7	0.4	2	0	2	0	0	0	0	0	0	0	**4**
Psychodidae	0.3	0.2	0	1	0	0	1	0	0	0	0	0	**2**
Sarcophagidae	0.2	0.1	0	0	0	0	0	0	0	1	0	0	**1**
Sciaridae	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Tricharaea occidua	0.2	0.1	0	0	0	0	0	1	0	0	0	0	**1**
Fleas													
Siphonaptera (=Fleas)	0.2	0.1	0	0	0	0	0	0	0	0	1	0	**1**
Ctenocephalides canis	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Ctenocephalides felis	1.8	1.1	0	3	0	3	3	0	1	0	0	1	**11**
Xenopsylla cheopis	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Bees													
Apis mellifera	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Xylocopa sonorina	0.2	0.1	0	0	0	0	1	0	0	0	0	0	**1**
Mites													
Acari (=Stored Food Mites)	0.5	0.3	0	0	0	2	0	0	1	0	0	0	**3**
Acarus siro	0.2	0.1	0	0	1	0	0	0	0	0	0	0	**1**
Arystidae	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Cheyletus sp.	3.8	2.3	2	1	0	1	3	3	1	6	3	3	**23**
Cheyletus eruditus	0.7	0.4	0	0	0	0	1	0	1	1	1	0	**4**
Dermatophagoides sp.	5.7	3.4	1	5	1	12	8	2	4	0	1	0	**34**
Dermatophagoides evansi	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Dermatophagoides farinae	0.8	0.5	0	0	0	0	0	0	0	1	3	1	**5**
Dermatophagoides pteronyssinus	17.9	10.7	12	9	6	13	7	6	13	17	14	10	**107**
Eriophyidae (=Gall Mites)	0.2	0.1	0	1	0	0	0	0	0	0	0	0	**1**
Euroglyphus sp.	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Feather Mites	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Glycyphagus sp.	2.7	1.6	2	6	1	4	0	0	0	0	2	1	**16**
Glycyphagus domesticus	7.0	4.2	0	0	1	4	5	3	6	12	6	5	**42**
Grallacheles bakeri	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Laelaps echidninus	0.2	0.1	1	0	0	0	0	0	0	0	0	0	**1**
Ornithonyssus sp. (=Bird Mites)	1.5	0.9	1	1	0	1	1	3	0	0	0	2	**9**
Ornithonyssus bacoti	0.2	0.1	0	0	1	0	0	0	0	0	0	0	**1**
Ornithonyssus bursa	2.8	1.7	7	2	0	1	4	1	1	1	0	0	**17**
Ornithonyssus sylviarum	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Oribatida (=Oribatei, Soil Mites)	0.5	0.3	0	0	0	0	1	0	0	1	1	0	**3**
Pyemotes sp.	0.2	0.1	0	0	0	0	0	0	0	0	0	1	**1**
Pyemotes boylei (=ventricosus)	1.2	0.7	0	1	0	1	1	1	1	1	1	0	**7**

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Sarcoptes scabiei	0.3	0.2	0	2	0	0	0	0	0	0	0	0	**2**
Tenuipalpidae	0.2	0.1	0	0	0	0	0	0	0	0	0	1	**1**
Tetranychidae (=*Tetranychus* sp.)	0.3	0.2	0	0	0	0	0	1	0	0	0	1	**2**
Tyrophagus sp.	0.3	0.2	0	1	1	0	0	0	0	0	0	0	**2**
Tyrophagus putrescentiae	0.8	0.5	0	0	0	2	1	0	0	2	0	0	**5**
Ticks													
Rhipicephalus sanguineus	0.7	0.4	0	0	0	0	0	0	1	3	0	0	**4**
Ants													
Formicidae (=Ants)	0.7	0.4	1	1	2	0	0	0	0	0	0	0	**4**
Anoplolepis longipes	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Camponotus variegatus	1.0	0.6	1	0	0	0	1	2	2	0	0	0	**6**
Cardiocendyla "a"	0.2	0.1	0	0	0	1	0	0	0	0	0	0	**1**
Hypoponera punctatissima	0.2	0.1	0	0	0	0	1	0	0	0	0	0	**1**
Leptogenys falcigera	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Monomorium sp.	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Monomorium destructor	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Monomorium pharaonis	0.5	0.3	1	1	0	1	0	0	0	0	0	0	**3**
Ochetellus glaber (=Iridomyrmex)	1.7	1.0	1	0	2	2	0	0	2	3	0	0	**10**
Paratrechina bourbonica	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Paratrechina longicornis	0.3	0.2	0	0	1	1	0	0	0	0	0	0	**2**
Pheidole megacephala	1.3	0.8	0	0	1	1	1	1	0	1	3	0	**8**
Plagiolepis alluaudi	0.2	0.1	0	0	0	0	0	0	0	0	0	1	**1**
Pseudomyrmex gracilis mexicanus	0.2	0.1	0	0	0	1	0	0	0	0	0	0	**1**
Solenopsis geminata	0.2	0.1	0	0	0	0	1	0	0	0	0	0	**1**
Tapinoma melanocephalum	2.2	1.3	1	3	0	2	2	1	0	2	2	0	**13**
Technomyrmex albipes	0.2	0.1	0	0	0	0	0	0	0	0	0	1	**1**

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Cockroaches													
Blattaria (=Cockroaches)	0.5	0.3	1	0	0	0	1	0	0	1	0	0	**3**
Balta sp.	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Blattella germanica	0.2	0.1	0	0	0	0	1	0	0	0	0	0	**1**
Diploptera punctata	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Euthyrrhapha pacifica	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Neostylopyga rhombifolia	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Periplaneta sp.	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Periplaneta Americana	1.0	0.6	1	0	0	0	3	0	0	0	0	2	**6**
Periplaneta Australasiae	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Pycnoscelus indicus	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Supella longipalpa	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Centipedes													
Scolopendra subspinipes	0.2	0.1	0	0	0	0	1	0	0	0	0	0	**1**
Wasps													
Hymenoptera (=Wasps)	0.2	0.1	0	0	0	0	1	0	0	0	0	0	**1**
Ampulex compressa	0.2	0.1	0	0	0	0	0	0	1	0	0	0	**1**
Chrysidoidea	0.2	0.1	0	1	0	0	0	0	0	0	0	0	**1**
Comperia merceti (=Roach Parasite)	1.3	0.8	1	0	0	2	0	2	2	0	0	1	**8**
Liris opulenta	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Polistes sp.	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Polistes olivaceous	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Sceliphron caementarium	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Spiders													
Araneae (=Spiders)	0.7	0.4	0	0	0	2	0	1	1	0	0	0	**4**
Argiope appensa	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Common House Spider	0.3	0.2	0	0	0	1	0	1	0	0	0	0	**2**
Gasteracantha mammosa	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Heteropoda venatoria	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Latrodectus geometricus	0.2	0.1	0	0	0	0	0	0	1	0	0	0	**1**
Loxosceles reclusa	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Loxosceles rufescens	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Lycosidae (=Wolf Spider)	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Pholcidae	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Salticidae (=Jumping Spider)	0.2	0.1	1	0	0	0	0	0	0	0	0	0	**1**
Zosis geniculatus	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Lice													
Pediculus humanus capitis	0.5	0.3	0	0	0	0	0	0	2	0	1	0	**3**
Pthirus pubis	0.2	0.1	1	0	0	0	0	0	0	0	0	0	**1**
Gnats													
Sciaridae (=Fungus Gnat)	2.8	1.7	1	1	3	1	4	1	2	4	0	0	**17**
Bradysia tritici	0.2	0.1	0	0	0	1	0	0	0	0	0	0	**1**
Bed Bugs													
Cimex lectularius	1.5	0.9	3	0	1	0	0	2	2	1	0	0	**9**
Scorpions													
Isometrus maculatus	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Termites													
Isoptera	0.2	0.1	0	0	0	0	1	0	0	0	0	0	**1**
Coptotermes formosanus	0.2	0.1	0	0	1	0	0	0	0	0	0	0	**1**
Cryptotermes brevis (=Drywood Termites)	0.2	0.1	0	0	0	0	1	0	0	0	0	0	**1**
Beetles													
Coleoptera	0.2	0.1	0	0	0	0	0	0	0	1	0	0	**1**

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Adoretus sinicus (=Chinese Rose Beetle)	0.3	0.2	0	0	1	0	0	1	0	0	0	0	**2**
Alphitobius diaperinus	0.2	0.1	1	0	0	0	0	0	0	0	0	0	**1**
Ananca bicolor (=Red-Black False Blister Beetle)	0.5	0.3	0	1	0	1	0	0	1	0	0	0	**3**
Anthrenus sp. (=Carpet Beetle)	0.3	0.2	1	1	0	0	0	0	0	0	0	0	**2**
Anthribidae	0.2	0.1	0	0	0	0	0	0	0	1	0	0	**1**
Carabidae	0.2	0.1	0	0	0	0	0	0	0	1	0	0	**1**
Carpophilus sp.	0.3	0.2	0	0	0	0	0	1	0	0	1	0	**2**
Carpophilus humeralis (=*Urophorus)*	0.5	0.3	1	0	1	1	0	0	0	0	0	0	**3**
Coccinellidae (=Lady Bugs)	0.8	0.5	4	0	1	0	0	0	0	0	0	0	**5**
Curculionidae	0.2	0.1	0	0	1	0	0	0	0	0	0	0	**1**
Dermestidae	0.2	0.1	0	0	0	0	0	0	0	0	1	0	**1**
Esbia bicola	0.3	0.2	0	0	0	0	0	0	2	0	0	0	**2**
Gnathaphanus picipes	0.2	0.1	0	0	0	0	0	0	0	1	0	0	**1**
Lasioderma serricorne	1.8	1.1	1	1	1	4	0	2	1	0	1	0	**11**
Rhyzopertha dominica	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Sitophilus oryzae	0.2	0.1	0	0	0	1	0	0	0	0	0	0	**1**
Staphylinidae (=Rove Beetles)	0.2	0.1	0	0	0	0	1	0	0	0	0	0	**1**
Stegobium paniceum	0.3	0.2	0	0	1	0	0	0	0	1	0	0	**2**
Tribolium castaneum	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Tricorynus herbarium (=Book Beetle)	0.3	0.2	0	0	0	1	0	0	0	1	0	0	**2**
Wood Boring Beetle	0.3	0.2	0	0	1	0	1	0	0	0	0	0	**2**
Millipedes													
Diplopoda (=Millipedes)	0.7	0.4	0	0	1	1	1	0	0	1	0	0	**4**
Trigoniulus lumbricinus	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Moths													
Agrotis ipsilon	0.2	0.1	0	1	0	0	0	0	0	0	0	0	**1**
Common Yard Moths (=Cutworms)	0.7	0.4	0	0	2	0	1	0	0	1	0	0	**4**
Peridroma saucia	0.3	0.2	2	0	0	0	0	0	0	0	0	0	**2**
Phereoeca allutella (=Casebearer)	0.3	0.2	0	0	1	0	1	0	0	0	0	0	**2**
Plodia interpunctella	0.2	0.1	1	0	0	0	0	0	0	0	0	0	**1**
Spodoptera mauritia	0.3	0.2	0	0	1	0	0	1	0	0	0	0	**2**
Whiteflies													
Aleyrodidae	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Midges													
Ceratopogonidae (=Biting Midge)	0.0	0.0	0	0	0	0	0	0	0	0	0	0	**0**
Chironomidae (=Midges)	1.2	0.7	0	2	2	1	0	0	0	2	0	0	**7**
Dasineura mangiferae	0.7	0.4	0	0	4	0	0	0	0	0	0	0	**4**
Plant Midge	0.8	0.5	0	0	4	0	0	0	1	0	0	0	**5**
Psyllids													
Heteropsylla sp.	2.8	1.7	8	4	0	0	0	1	3	0	1	0	**17**
Psocoptera													
Barklice	0.2	0.1	1	0	0	0	0	0	0	0	0	0	**1**
Psocidae (=Booklice)	2.2	1.3	1	4	1	1	2	1	0	1	0	2	**13**
Leaf Hoppers													
Cicadellidae (=Leaf Hopper)	0.7	0.4	0	1	1	0	1	1	0	0	0	0	**4**
Pseudoscorpion													
Pseudoscorpiones	0.2	0.1	0	0	1	0	0	0	0	0	0	0	**1**
Antlions													
Myrmeleontidae	0.2	0.1	0	0	1	0	0	0	0	0	0	0	**1**
Sowbugs													
Sowbugs	0.2	0.1	0	0	0	1	0	0	0	0	0	0	**1**

SPECIES	%	Mean	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Total
Butterflies													
Butterflies	0.2	0.1	0	0	0	0	0	1	0	0	0	0	**1**
Grasshoppers													
Acrididae	0.2	0.1	0	0	0	0	0	1	0	0	0	0	**1**
Caddisflies													
Trichoptera	0.2	0.1	0	0	0	0	0	0	1	0	0	0	**1**
Aphids													
Aphididae (=Aphids, Plant Lice)	0.7	0.4	0	2	0	0	0	0	1	1	0	0	**4**
Earwigs													
Dermaptera	0.2	0.1	0	0	0	0	0	0	0	0	0	1	**1**
Chinch Bugs													
Blissus insularis (=Chinch Bug)	0.2	0.1	0	0	0	1	0	0	0	0	0	0	**1**
Mealybugs													
Pseudococcidae	0.2	0.1	0	0	0	0	1	0	0	0	0	0	**1**
Crickets													
Gryllidae	0.2	0.1	0	0	0	0	1	0	0	0	0	0	**1**
Gryllus bimaculatus	0.2	0.1	0	0	0	0	0	0	0	1	0	0	**1**
Springtails													
Collembola	0.2	0.1	0	0	0	0	0	0	0	0	1	0	**1**
Bristleworms													
Polychaeta	0.2	0.1	0	0	0	0	1	0	0	0	0	0	**1**
Earthworms													
Oligochaeta	0.2	0.1	0	0	0	0	0	0	0	1	0	0	**1**
Total	**100.0**	**59.8**	**71**	**60**	**56**	**76**	**72**	**44**	**57**	**79**	**44**	**39**	**598**

APPENDIX B

Table B.1. District/area geographic locations established for the island of Oahu together with their community populations.

DISTRICT/AREA	CENSUS 1990	EST. POP 1991	EST. POP 1992	EST. POP 1993	EST. POP 1994	CENSUS 1995	EST. POP 1996	EST. POP 1997	EST. POP 1998	EST. POP 1999	CENSUS 2000
Airport	22	23	23	23	23	23	23	23	24	24	24
Kalihi Kai	2253	2153	2053	1953	1854	1754	1665	1576	1487	1398	1309
Sand Island	408	385	361	338	315	291	270	248	227	205	184
Downtown	8301	8474	8646	8818	8991	9163	9384	9605	9826	10047	10269
Nuuanu/Dowsett Highlands	10693	10650	10607	10564	10521	10478	10494	10510	10526	10542	10558
Kakaako	1147	1443	1739	2034	2330	2626	2932	3239	3545	3852	4159
Punchbowl/Pauoa/Pacific Hts.	19007	18989	18970	18952	18933	18915	19002	19089	19176	19263	19350
Ala Moana	10986	11127	11268	11409	11550	11691	11895	12099	12303	12507	12711
Makiki/Punahou	21112	21016	20921	20825	20730	20634	20655	20675	20695	20716	20736
Makiki Hts./Tantalus/Round Top	4487	4415	4343	4271	4199	4127	4079	4031	3982	3934	3886
Waikiki/Kapiolani Park	20190	20122	20053	19984	19916	19847	19890	19933	19975	20018	20061
McCully/Moiliili	28551	28263	27976	27688	27400	27112	26979	26845	26712	26578	26445
Kapahulu/Diamond Head	13370	13226	13082	12938	12795	12651	12579	12507	12436	12364	12293
Manoa/Woodlawn	18500	18489	18478	18468	18457	18446	18538	18630	18722	18814	18906
Saint Louis Heights	5431	5344	5257	5169	5082	4995	4937	4878	4820	4762	4704
Kaimuki/Waialae	14093	13976	13859	13742	13625	13508	13468	13428	13387	13347	13307
Palolo/Palolo Valley	12838	12814	12790	12767	12743	12719	12766	12814	12861	12908	12955
Wilhelmina Rise/Maunalani Hts.	6468	6472	6476	6480	6484	6488	6529	6569	6609	6649	6689
Kahala	7742	7705	7667	7630	7592	7555	7560	7565	7571	7576	7581
Waialae Nui	1645	1635	1625	1615	1605	1595	1595	1594	1593	1592	1591
Kalani Valley	781	775	770	764	758	753	751	750	749	747	746
Waialae Iki	3169	3205	3241	3277	3313	3349	3403	3457	3511	3565	3619
Wailupe	604	602	600	598	596	593	595	596	597	599	600
Aina Haina	4071	4092	4113	4134	4155	4176	4220	4264	4308	4352	4396

DISTRICT/AREA	CENSUS 1990	EST. POP 1991	EST. POP 1992	EST. POP 1993	EST. POP 1994	CENSUS 1995	EST. POP 1996	EST. POP 1997	EST. POP 1998	EST. POP 1999	CENSUS 2000
Hawailloa Ridge	850	868	885	903	920	937	960	982	1005	1027	1050
Niu Valley	2413	2410	2407	2405	2402	2399	2410	2421	2432	2442	2453
Kuliouou	3379	3363	3347	3331	3316	3300	3302	3305	3308	3310	3313
Hahaione Valley	2667	2678	2690	2702	2714	2726	2753	2780	2807	2834	2861
Mariners Ridge	1474	1480	1487	1493	1500	1507	1522	1537	1551	1566	1581
Hawaii Kai	18030	17936	17842	17749	17655	17561	17566	17571	17576	17581	17586
Portlock	1674	1666	1657	1649	1641	1633	1633	1634	1635	1636	1637
Queens Gate/Kalama Valley	3588	3618	3648	3678	3708	3739	3789	3840	3890	3941	3991
Makapuu	10	10	11	11	12	12	12	13	13	14	14
Waimanalo Beach	3724	3755	3785	3816	3847	3877	3855	3833	3811	3789	3767
Waimanalo/Bellows AFB	4932	5061	5190	5318	5447	5576	5629	5682	5735	5788	5841
Lanikai	2413	2451	2489	2527	2565	2603	2606	2609	2611	2614	2617
Enchanted Lake/Keolu Hills	13360	13428	13495	13563	13631	13698	13580	13461	13342	13224	13105
Olomana/Pohakupu	2651	2693	2735	2777	2819	2861	2864	2867	2871	2874	2877
Maunawili	2217	2209	2202	2194	2186	2179	2141	2104	2067	2029	1992
Kawainui Marsh	153	153	152	152	151	150	148	145	142	140	137
Kailua	17358	17465	17572	17679	17787	17894	17758	17621	17485	17349	17213
Kaneohe Marine Corps Air Station	11662	11761	11860	11959	12058	12158	12091	12025	11959	11893	11827
Oneawa H/Kalaheo HS/Aikahi P	3728	3748	3768	3788	3808	3827	3795	3763	3731	3698	3666
Yacht Club Knolls & Terrace/Keaalu	1603	1624	1645	1667	1688	1709	1707	1705	1704	1702	1700
Keaalu/Mahinui/Kokokahi	1527	1547	1567	1588	1608	1628	1626	1624	1622	1621	1619
Kaneohe	23091	23152	23213	23273	23334	23395	23137	22880	22622	22365	22107
Heeia	11029	11119	11209	11299	11388	11478	11412	11346	11279	11213	11147
Haiku Village/Haiku Plantations	3041	3053	3066	3078	3090	3103	3073	3043	3013	2983	2953
Heeia Kea	1253	1297	1340	1383	1427	1470	1494	1517	1541	1564	1588
Ahuimanu	8689	8729	8769	8809	8849	8889	8808	8727	8646	8565	8484
Kahaluu/Waihee Valley	2849	2873	2897	2921	2944	2968	2952	2935	2919	2902	2886
Waiahole/Waikane	818	824	830	837	843	849	844	839	834	829	824
Kaaawa	1561	1595	1629	1663	1697	1730	1747	1764	1782	1799	1816
Punaluu	911	950	989	1028	1067	1105	1134	1162	1191	1219	1247

DISTRICT/AREA	CENSUS 1990	EST. POP 1991	EST. POP 1992	EST. POP 1993	EST. POP 1994	CENSUS 1995	EST. POP 1996	EST. POP 1997	EST. POP 1998	EST. POP 1999	CENSUS 2000
Hauula	3430	3472	3513	3555	3596	3638	3643	3648	3654	3659	3664
Laie	5768	5700	5633	5565	5498	5431	5306	5181	5057	4932	4807
Kahuku	2386	2417	2448	2479	2511	2542	2548	2554	2560	2566	2572
Kawela	408	433	458	484	509	534	554	575	595	615	636
Waialee/Sunset Beach/Waimea	3067	3013	2958	2904	2849	2795	2846	2897	2948	2998	3049
Pupukea	1751	1777	1802	1828	1854	1880	1887	1894	1901	1908	1916
Haleiwa	4641	4579	4517	4455	4393	4331	4438	4544	4650	4757	4863
Waialua	4891	4796	4702	4607	4513	4418	4489	4559	4630	4700	4771
Mokuleia	908	897	886	875	864	854	876	899	922	944	967
Helemano Plantation/Poamoho	324	361	398	435	471	508	509	511	512	513	514
Whitmore Village	3811	4003	4194	4385	4576	4768	4644	4520	4396	4273	4149
Schofield Barracks Military Reservation	19597	19738	19880	20021	20163	20304	19189	18073	16958	15842	14727
Wheeler Army Airfield	2600	2730	2861	2991	3121	3252	3167	3083	2998	2914	2829
Wahiawa	17386	17905	18424	18942	19461	19980	19214	18448	17683	16917	16151
Waipio Acres	4351	4489	4627	4764	4902	5040	5101	5161	5221	5282	5342
Mililani Town	30293	30506	30718	30930	31142	31355	30968	30580	30193	29806	29419
Mililani Mauka	15	1003	1992	2980	3969	4957	6026	7094	8163	9231	10300
Panaikauahi/Waiawa	0	0	0	0	0	0	0	0	0	0	0
Kipapa	20	21	22	22	23	24	24	25	25	25	26
Waipio/Crestview/Seaview	11867	11997	12127	12257	12387	12517	12417	12316	12215	12114	12013
Makaha/Waianae	9538	9397	9257	9116	8976	8835	8847	8859	8871	8883	8895
Makaha Valley	1303	1345	1387	1430	1472	1514	1591	1668	1745	1822	1899
Waianae	5246	5312	5379	5445	5512	5579	5762	5944	6127	6310	6493
Waianae Valley/Lualualei	3735	3768	3801	3834	3868	3901	4014	4126	4239	4352	4465
Maili	4499	4463	4427	4391	4354	4318	4360	4403	4445	4488	4530
Maili Kai	1957	2010	2062	2114	2166	2218	2320	2422	2523	2625	2727
Nanakuli/Mikilua/Lualualei	3232	3279	3325	3371	3417	3464	3583	3702	3821	3941	4060
Nanakuli	7709	7754	7800	7846	7892	7937	8142	8347	8552	8757	8962
Kahe Pt/Nanakai Garden/Honokai Hale	246	345	443	541	639	738	839	940	1041	1142	1244
Ko Olina	63	106	149	192	235	278	323	368	413	458	504

DISTRICT/AREA	CENSUS 1990	EST. POP 1991	EST. POP 1992	EST. POP 1993	EST. POP 1994	CENSUS 1995	EST. POP 1996	EST. POP 1997	EST. POP 1998	EST. POP 1999	CENSUS 2000
Campbell Industrial Park	28	26	25	23	21	20	17	15	13	10	8
Makakilo	9748	10178	10609	11040	11470	11901	12169	12436	12703	12971	13238
Barbers Point Naval Air Station	4524	4259	3994	3728	3463	3198	2819	2440	2061	1682	1303
Kapolei	1104	1858	2611	3365	4118	4872	5664	6457	7249	8042	8834
Ewa	6550	7627	8703	9780	10857	11933	12964	13995	15026	16057	17088
Ewa Beach	13647	14014	14382	14749	15117	15484	15604	15724	15843	15963	16083
Puuloa	5759	5631	5502	5373	5245	5116	4860	4603	4347	4090	3834
West Loch Fairways	356	635	913	1192	1471	1750	2044	2338	2633	2927	3221
West Loch Estates	748	903	1058	1213	1368	1523	1676	1828	1980	2133	2285
Honouliuli	3911	3990	4069	4147	4226	4305	4310	4316	4321	4327	4332
Waipahu	31371	31838	32305	32773	33240	33708	33574	33441	33308	33175	33042
Village Park/Royal Kunia	7407	7875	8343	8810	9278	9746	10101	10456	10811	11166	11521
Kunia	806	800	793	787	780	774	750	727	704	680	657
Waikele	26	686	1345	2005	2665	3325	4038	4750	5463	6176	6889
Pearl City	21929	21986	22042	22099	22156	22212	21827	21442	21057	20672	20287
Pacific Palisades	7313	7340	7366	7393	7420	7447	7327	7207	7087	6967	6847
Waiau	8268	8333	8398	8463	8528	8593	8495	8397	8299	8201	8103
Waimalu	5830	5915	6000	6086	6171	6256	6230	6203	6177	6150	6124
Newtown	3943	4011	4079	4148	4216	4284	4278	4272	4265	4259	4252
Royal Summit	2021	2056	2091	2126	2161	2196	2193	2189	2186	2183	2179
Pearlridge	4421	4442	4463	4485	4506	4527	4460	4393	4326	4259	4192
Aiea	7593	7622	7652	7681	7711	7740	7617	7495	7372	7250	7127
Aiea Heights	5689	5747	5806	5864	5923	5981	5929	5876	5824	5771	5719
Halawa	3080	3110	3141	3171	3202	3232	3202	3172	3143	3113	3083
Halawa Heights	4518	4563	4608	4653	4699	4744	4701	4658	4614	4571	4528
Halawa Valley	1115	1162	1208	1255	1301	1348	1375	1403	1431	1458	1486
Pearl Harbor/Hickam Air Force Base	14734	14508	14282	14056	13830	13604	13060	12516	11971	11427	10883
Foster Village	5189	5267	5345	5423	5501	5579	5558	5537	5515	5494	5473
Salt Lake/Naval Housing	7915	7805	7695	7584	7474	7363	7295	7227	7159	7091	7023
Salt Lake	22177	22248	22318	22389	22459	22530	22725	22920	23115	23310	23505

DISTRICT/AREA	CENSUS 1990	EST. POP 1991	EST. POP 1992	EST. POP 1993	EST. POP 1994	CENSUS 1995	EST. POP 1996	EST. POP 1997	EST. POP 1998	EST. POP 1999	CENSUS 2000
Aliamanu	10202	9915	9628	9341	9054	8767	8532	8298	8063	7829	7594
Red Hill	3042	3009	2976	2942	2909	2875	2858	2841	2824	2807	2790
Mapunapuna	36	34	33	31	29	28	26	25	23	22	20
Moanalua Valley	2494	2469	2444	2420	2395	2371	2360	2349	2338	2327	2316
Moanalua	4400	4353	4305	4257	4209	4161	4137	4113	4089	4065	4041
Fort Shafter	2952	2817	2682	2547	2412	2277	2156	2035	1914	1794	1673
Kalihi	23999	23951	23903	23855	23807	23759	23844	23929	24014	24099	24183
Kalihi Valley	17413	17374	17336	17298	17259	17221	17279	17337	17395	17453	17511
Kamehameha Heights/Alewa Heights	9356	9213	9069	8926	8783	8640	8546	8453	8360	8266	8173
Iwilei	1660	1620	1580	1539	1499	1459	1427	1396	1364	1333	1301
Liliha/Puunui	20835	20717	20600	20483	20366	20249	20245	20242	20239	20236	20233
DISTRICT/AREA TOTALS	**831676**	**838432**	**845189**	**851945**	**858701**	**865457**	**866455**	**867453**	**868451**	**869449**	**870447**
PERCENTAGE OF ISLAND TOTALS	**99.46%**	**99.44%**	**99.43%**	**99.42%**	**99.40%**	**99.39%**	**99.38%**	**99.37%**	**99.37%**	**99.36%**	**99.35%**
OAHU ISLAND DISTRICT/AREA TOTALS	**836231**	**843137**	**850043**	**856949**	**863855**	**870761**	**871840**	**872919**	**873998**	**875077**	**876156**

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Table B.2. District/area geographic locations established for the island of Oahu together with their census tract:block divisions.

DISTRICT/AREA	TRACT:BLOCKS
Airport	71:1000-1002; 72:9001-9018
Kalihi Kai	59:1003-1006, 1010-1015, 2006-2017, 2020-2022
Sand Island	57:9000s
Downtown	39:1001-1005, 1012-1014, 1015/2; 40:All; 41:2004-2006; 42:1002-1007; 51:1002-1006; 52:All
Nuuanu/Dowsett Highlands	42:1000-1001; 43:1003-1007; 45:1000-1013, 1015-1016, 2000-2015; 46:1000-1011, 2000-2003, 2006-2007, 2015-2017; 47:1003-1005, 1009-1010; 50:1002-1003, 1006-1007, 2002-2005; 51:1000-1001
Kakaako	38:1000s, 2000-2018; 39:1000, 1006-1011, 1015/2, 1016-1017; 41:2017-2020
Punchbowl/Pauoa/Pacific Hts.	34.03:All; 35:3000-3004; 41:1000s, 2000-2003, 2007-2016; 1008; 43:1000-1002, 1008-1013, 2000s; 44:1000-1005, 1007, 1014, 2000s; 45:1014
Ala Moana	35:1004-1006, 2006-2012, 3005-3008; 36.01:All; 36.02:All; 37:All; 38:2019
Makiki/Punahou	27.02:1001/4, 1015-1016, 2003-2013; 34.04:All; 34.05:All; 34.06:All; 34.07:All; 35:1000-1003, 2000-2005, 3000-3004
Makiki Hts./Tantalus/Round Top	30:1001*1/4, 4000-4002; 32:All; 33:All; 44:1006, 1008-1013
Waikiki/Kapiolani Park	17:1005, 1006/2, 1007-1008; 18.01:All; 18.02:All; 19.01:All; 19.02:All; 20.01:All; 20.02:All
McCully/Moiliili	22:All; 23:1000s, 2001-2008; 24.01:All; 24.02:All; 25:All; 26:All; 35:1007-1008
Kapahulu/Diamond Head	6:1004-1010, 1013, 1023-1025; 15:All; 16:All; 17:1000-1004, 1006/2, 1009-1018; 21:1003, 1006-1007, 2000s
Manoa/Woodlawn	23:2000; 27.01:1000s, 2001, 3003-3004; 27.02:1000, 1001*3/4, 1002-1014, 1017-1019, 2000-2002, 2014-2016; 29:All; 30:1001*3/4, 1000s, 2000s, 3000s; 31.01:All; 31.02:All
Saint Louis Heights	12.01:1017/2; 21:1001-1002; 27.01:2000, 3000-3002; 28:All
Kaimuki/Waialae	6:1000*2/7, 1001*2/5, 1002-1003; 7:1001*2/3, 1002-1013, 1014/2, 1015-1016, 2000s; 8:All; 13:All, 14:All; 21:1000, 1004-1005
Palolo/Palolo Valley	10:All; 11:All; 12.01:1000*2/3, 1017/2, 1028*3/4, 1000s; 12.02:All
Wilhelmina Rise/Maunalani Hts.	9.02:All; 9.03:1000*2/3, 1002-2000s; 12.01:1000/3, 1028/4
Kahala	4.01:1000*5/13, 1001, 1005-1012; 5:1000s-5000s; 6:1000*5/7, 1001*3/5, 1011-1012, 1014-1022; 7:1000, 1001/3, 1014/2; 9.01:All; 9.03:1000/3, 1001
Waialae Nui	4.01:1000*8/13, 1002-1004
Kalani Valley	4.02:1002/4, 1003; 5:6002/2, 6003-6008
Waialae Iki	4.02:1000-1001, 1002*3/4, 1004-1020, 2000s; 5:6000-6002/2
Wailupe	3.02:1012*4/5, 1013-1015, 2007/2, 2008-2009
Aina Haina	3.01:1000/2, 1003-1021; 3.02:1000/2, 1002-1011, 1012/5, 2000-2007/2
Hawaiiloa Ridge	3.01:1000/2, 1001-1002, 1022-1023; 3.02:1001

DISTRICT/AREA	TRACT:BLOCKS
Niu Valley	2:1014-1015, 2000s; 3.02:1000/2
Kuliouou	2:1000-1013, 3000-3002
Hahalone Valley	1.06:1000/2, 1001-1008, 2000/3, 2001-2002
Mariners Ridge	1.06:2000/3, 3000/2, 3002-3003
Hawaii Kai	1.04:All; 1.05:1000s, 2000s, 3001-3004; 1.06:1000/2, 1009-1010, 2000/3, 3000/2, 3001; 1.07:All; 1.08:All; 1.09:All
Portlock	1.02:All
Queens Gate/Kalama Valley	1.05:3000, 3005; 1.10:1000s, 2006-2010
Makapuu	1.10:2000-2005; 113.02:1000-1001, 1022-1031
Waimanalo Beach	113.02:1002-1011, 1014-1021, 2001-2027
Waimanalo/Bellows AFB	113.01:All; 113.02:1012-1013, 2000
Lanikai	111.06:1001-1002; 112.01:2000, 9000; 112.02:All
Enchanted Lake/Keolu Hills	110:1019; 111.03:1000s; 111.04:All; 111.06:All-1001-1002
Olomana/Pohakupu	110:1001-1016, 1020; 111.03:2000s
Maunawili	110:1017-1018, 1021-1022, All-2000
Kawainui Marsh	110:1000, 2000
Kailua	109.03:All; 109.04:All; 109.05:All; 111.05:All; 112.01:1004-1021, 2001-2023
Kaneohe Marine Corps Air Station	108.01:All; 108.02:All
Oneawa H/Kalaheo HS/Aikahi P	109.01:All; 112.01:1000-1003
Yacht Club Knolls & Terrace/Keaalu	107.01:1000*14/15, 1001-1007, 1008/3
Keaalu/Mahinui/Kokokahi	107.01:1000/15, 1008*2/3, 1014*2/3, 2000s
Kaneohe	103.02:All; 105.03:All; 105.04:1006-1007, 2000s; 106.01:All; 106.02:All; 107.01:1014/3; 107.02:All
Heeia	103.06:1005-1008, 9002-9003, 9013-9014; 105.04:1000-1005; 105.05:All; 105.06:1000s-2000s, 3000
Haiku Village/Haiku Plantations	103.06:9001, 9004-9012; 105.06:3001-3006
Heeia Kea	103.05:1002-1004, 2000-2009, 2011-2013; 103.06:1000-1001
Ahuimanu	103.03:1011/5, 9013-9016; 103.05:1000-1001, 1005-1021, 2010; 103.06:1002-1004, 2000s, 9000, 9015-9021
Kahaluu/Waihee Valley	103.03:1000-1010, 1011*4/5, 1012, 2000/4, 2001-2011
Waiahole/Waikane	103.03:2000*3/4, 9004-9012
Kaaawa	102.01:2000s, 9001*4/11, 9009-9013; 103.03:9000-9003
Punaluu	102.01:9001*7/11, 9002-9008
Hauula	102.01:1000s, 9000; 102.02:3031/3, 3032-3040, 9004-9006

DISTRICT/AREA	TRACT:BLOCKS
Laie	102.02:1000-1001, 1002/2, 1004-1021, 2000s, 3000-3030, 3031*2/3, 9000/3, 9001-9003
Kahuku	101:1000s, 9000-9003, 9005*16/25, 9016-9018; 102.02:1002/2, 1003, 9000*2/3
Kawela	101:9005*9/25, 9007-9010, 9019-9031
Waialee/Sunset Beach/Waimea	100:1000-1007, 2004*8/31, 9000*2/9, 9001-9002; 101:2000*1/5, 3000s, 3015*7/10
Pupukea	101:2000*4/5, 2001-2003, 2004*23/31, 2005-2010, 3015*3/10
Haleiwa	99.02:All; 100:1008-1041, 9000*4/9, 9003-9013, 9017-9033, 9035-9037, 9051
Waialua	99.01:1000s-3000s, 9001-9002, 9003*4/7, 9004*2/5, 9005-9010, 9022/4
Mokuleia	99.01:9003*3/7, 9004*3/5, 9011-9021, 9022*3/4, 9023-9028
Helemano Plantation/Poamoho	91:2000s, 9012; 100:9000*3/9, 9014-9016, 9034, 9038-9043, 9045-9050
Whitmore Village	91:1000s, 9000, 9003-9011, 9014-9016
Schofield Barracks Military Reservation	86.03:4000-4004, 4007-4010; 91:9013; 95.01:All; 95.02:All; 95.03:All; 95.04:All; 95.05:9000s; 99.01:9000
Wheeler Army Airfield	89.05:9000, 9002-9004, 90:9005-9006
Wahiawa	90:9002; 92:All; 93:All; 94:All
Waipio Acres	89.07:9006, 9013; 89.15:1000-1003, 1007-1000s, 2000s; 89.16:9013/5, 9040-9044
Mililani Town	89.06:All: 89.07:1000s, 9000-9005, 9007-9012; 89.08:All; 89.09:All; 89.15:1004-1006; 89.17:All; 89.18:All-9000-9002/30
Mililani Mauka	89.16:9000-9012, 9013*4/5, 9015-9038
Panaikauahi/Waiawa	89.19:1000, 1004-1010
Kipapa	89.18:9002/30 or 89.20:1009
Waipio/Crestview/Seaview	89.20:1006-1008, 1010-1023, 2000s; 89.21:1002-1023; 89.23:All
Makaha/Waianae	97.01:1000-1004, 1012-1014, 1016, 9011*14/33, 9012; 98.01:9013-9014, 9033-9038; 98.02:All
Makaha Valley	98.01:9000/2, 9015-9032
Waianae	97.01:1005-1011, 2000s, 9011*10/33, 9013-9014, 9015*2/3, 9016; 97.02:1000*2/3, 1002*17/21, 1003-1026, 9041-9057, 9061-9062
Waianae Valley/Lualualei	97.01:9000-9010, 9011*9/33; 97.02:1000/3, 1002*4/21, 9000-9040, 9058-9060
Maili	96.03:1000-1005, 1006*3/13, 2000s, 9000*2/53, 9001-9002
Maili Kai	96.03:1006*10/13, 1007-1017, 9000*24/53, 9003-9007
Nanakuli/Mikilua/Lualualei	96.03:3000, 9000*27/53, 9008; 96.04:1001-1019, 9032-9038, 9040
Nanakuli	96.01:1000s-2000s, 9003, 9007-9016; 96.04:1020-1026, 2000s
Kahe Pt/Nanakai Garden/Honokai Hale	86.03:9017; 86.09:1001/2, 1003-1006
Ko Olina	86.09:1001/2, 1002; 86.10:All
Campbell Industrial Park	85:1005-1008, 1011-1015, 1017-1023; 86.09:1007-1008

DISTRICT/AREA	TRACT:BLOCKS
Makakilo	86.03:2000s-3000s, 9021-9022; 86.04:1000s-2000s, 9000-9002
Barbers Point Naval Air Station	85:1000-1004, 1009-1010, 1024-1025
Kapolei	86.06:1000-1008, 1011-All; 86.07:All; 86.08:All
Ewa	84.01:All; 84.03:1000/4; 84.04:All; 86.05:1000s-3000s, 9005/2, 9016
Ewa Beach	83.01:9004; 83.02:All; 84.02:All; 84.03:1000*3/4, 1003-1011
Puuloa	83.01:1000, 1006-1009, 9000-9003
West Loch Fairways	83.01:1001/2; 86.05:9009-9015
West Loch Estates	83.01:1001/2, 1002-1004; 87.03:9001-9006
Honouliuli	86.05:9002-9004, 9005/2, 9008
Waipahu	87.01:1000s, 2014, 3000s-4000s; 87.02:All; 87.03:1000s-3000s, 9000; 88:All; 89.12:1002-1013; 89.13:All; 89.14:All
Village Park/Royal Kunia	89.05:1000s-4000s, 9010
Kunia	86.03:1000s, 4005-4006; 89.05:9001, 9005-9006, 9011-9013
Waikele	89.12:1000-1001; 89.22:1002, 1004-1018
Pearl City	78.04:All; 78.10:9000-9001; 80.01:1003-1007, 2000s, 9002; 80.02:1005-1011, 2000s; 80.03:All; 80.06:All; 80.07:All
Pacific Palisades	80.05:All
Waiau	78.05:1000s; 78.10:1000, 1002-1004, 1005/3; 80.01:1000-1002; 80.02:1000-1004, 1012-1016
Waimalu	78.06:1007-1012; 78.07:1001, 1003-1004; 78.08:1003, 1005*7/10, 2000s; 78.09:2000*18/38, 2004-2006
Newtown	78.05:2000-2001; 78.09:2000*3/38, 2001-2003; 78.10:1005*2/3, 1006-1007, 2000s
Royal Summit	78.09:1000s, 2000*17/38; 78.10:1001/2
Pearlridge	78.02:All; 78.06:1000-1006, 2000s
Aiea	74:9000-9001; 75.04:1000-1001; 77.01:2003-2004, 2006-2009, 2012, 3000s; 77.02:1011-1012, 2014; 78.07:1000, 1002, 2000, 3000; 78.08:1000-1002, 1004, 1005*3/10, 1006-1008
Aiea Heights	77.01:1000s, 2000-2002, 2005; 77.02:1000-1010, 2000-2013, 2015-2018
Halawa	75.04:1002-1009, 1012; 75.05:1000-1002, 1007
Halawa Heights	75.02:1000-1001, 1022-1024; 75.03:1000s, 2000*14/21, 2001-2007, 2010; 77.01:2010-2011; 77.02:2019-2021
Halawa Valley	75.02:1002-1008, 1029-1035, 1037; 75.03:2000*7/21
Pearl Harbor/Hickam Air Force Base	70:3000s; 71:1003-1006; 72:9019-9023; 73:All; 74:9002-9004, 9018-9029
Salt Lake/Naval Housing	69:All; 70:1000-1005, 2000-2003; 74:9005-9017, 9030-9031; 75.04:1010-1011, 1013; 75.05:1011-1012
Salt Lake	68.02:All; 68.05:All; 68.06:All; 68.08:All; 68.09:All
Aliamanu	68.04:All; 75.06:All
Red Hill	67.02:All; 75.02:1036, 1038-1040

DISTRICT/AREA	TRACT:BLOCKS
Mapunapuna	68.03:1000-1002, 1004-1017
Moanalua Valley	67.01:1000-1003, 1004/2, 1005-1010; 3003/2, 3004-3005
Foster Village	75.04:1014-1015; 75.05:1003-1006, 1008-1010, 2000s-2001
Moanalua	67.01:1004/2, 2000s, 3000-3002, 3003/2, 3006
Fort Shafter	66:All; 68.03:1003; 72:9000
Kalihi	56:1000-1011, 2000-2007; 57:1000s; 58:All; 59:1000-1002, 1007-1009, 2000-2005, 2018-2019; 60:All; 61:All; 62.01:All; 62.02:All; 63.01:2002/3
Kalihi Valley	63.01:1000s, 2000-2001, 2002*2/3, 2003-2005; 63.02:All; 64.01:All; 64.02:All; 65:All
Kamehameha Heights/Alewa Heights	47:2000*5/6, 2001-2009, 2010*3/5; 48:All
Iwilei	57:2000s
Liliha/Puunui	46:1012, 2004-2005, 2008-2014, 3000s; 47:1000-1002, 1006-1008, 2000*1/6, 2010*2/5; 49:All; 50:1000-1001, 1004-1006, 2000-2001; 53:All; 54:All; 55:All; 56:1012, 2008-2017, 3000s

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