Statewide Survey of Insects Found on Coffee in Hawaii

Gabriel A. LeMay,[1] Andrea M. Kawabata,[2] and **RT Curtiss[3]**
[1]UF/IFAS School of Forest, Fisheries, & Geomatics Sciences, University of Florida, Gainesville, Florida 32611, glemay@ufl.edu
[2]Department of Tropical Plant and Soil Sciences, University of Hawaii at Manoa, College of Tropical Agriculture and Human Resources, 79-7381 Mamalahoa Highway, Kealakekua, Hawaii 96750, andreak@hawaii.edu
[3]Tree Fruit Research and Extension Center, Washington State University, 1100 N. Western Ave., Wenatchee, WA 98801, rcurtiss@wsu.edu

Abstract. Hawaii is home to a high number of endemic species, but the state is also considered a hotbed of invasive species. Coffee, like many crops grown in Hawaii, is particularly valuable and susceptible to a number of injurious pest insects not yet established in the islands. A comprehensive statewide survey of insects found on coffee plants has never been undertaken. Cultivated and feral coffee, at 46 sites on the six main Hawaiian Islands, was systematically surveyed for pest and innocuous insects. Surveys identified 152 unique insect species or morphotypes in 12 orders associated with coffee throughout the state. Some are major pests of coffee, such as the coffee berry borer, *Hypothenemus hampei*, while others have little impact on coffee production. This survey identified no new state records but is the first to document the association of many of these insects with coffee plants.

Key words: Invasive species, *Coffea arabica*, coffee berry borer, pest monitoring

Hawaii is particularly susceptible to invasive species, and insects specifically can easily disrupt the fragile ecosystems of the archipelago; when they are freed from competition, they affect the production of commercial crops grown on the islands (Kenis et al. 2008, Wright and Conant 2009). *Coffea arabica*, the only commercially grown coffee species in the state (Kawate et al. 2010), is one of the most economically important crops on the islands. In 2016, the ca. 2,830 harvestable hectares had a production value of $48 million (USDA-NASS 2017). Hawaii grown coffee is at risk of being disrupted by serious insect pests already established in other coffee producing regions of the world. Among the coffee pests not yet found in Hawaii are the coffee white stem borer, *Xylotrechus quadripes* Chevrolat, a cerambycid which feeds on coffee trees internally during the larval stage (Venkatesha 2012), and the coffee leaf miner, *Leucoptera coffeella* (Guérin-Méneville), a moth which feeds on coffee leaves in the larval stage (Orlando 1980).

Trujillo et al. (1995) provided a brief discussion of the invasive coffee pests and diseases that were present in Hawaii at the time; since then, several invasions (i.e., coffee berry borer, *Hypothenemus hampei* (Ferrari)) and pest status updates have occurred (Hawaii Department of Agriculture 2020a, Nelson et al. 2005). Some remain minor issues, while others such as coffee leaf rust, *Hemileia vastatrix,* and the coffee berry borer (CBB) can cause large financial losses (McCook 2006, Leung et al. 2014). Following the first detection on Hawaii Island in 2010

(Burbano et al. 2011), CBB spread to Oahu in 2014 (Hawaii Department of Agriculture 2014), Maui in 2017 (Hawaii Department of Agriculture 2017a), Lanai in 2020 (Gillett et al. 2020), and Kauai in 2020 (Hawaii Department of Agriculture 2020b). In response, the Hawaii Department of Agriculture (HDOA) enacted a quarantine preventing the transportation of coffee plant parts and equipment from an island infested with coffee berry borer to an uninfested island (Hawaii Department of Agriculture 2017b). Prior to CBB introduction, the Hawaii pest management strategic plan for coffee (Kawate et al. 2010) didn't consider it enough of a risk to include in the list of potential threats, though Trujillo et al. (1995) provided a comprehensive description of the pest and cultural controls employed in Central America. Upon discovery of CBB on the Island of Hawaii, an integrated pest management (IPM) program was drafted (Kawabata et al. 2013) and revised several times (Kawabata et al., 2015, 2016, 2017, 2020). An areawide CBB monitoring program was also coordinated by the United States Department of Agriculture's Agricultural Research Service (USDA-ARS) with several other collaborating institutions to document the population dynamics and biology of CBB at commercial, abandoned, and feral sites on Hawaii island (Hamilton et al. 2019, Johnson et al. 2019, Johnson and Manoukis 2020).

The current study was initiated to establish baseline presence of all insects associated with coffee throughout the state and enable early detection of new pests. The results of this study may be used by state quarantine officials and researchers to better understand the complex of insects currently associated with coffee and compare with similar future studies to determine if new invasions have occurred. If confirmed, the presence of a new major coffee pest on the islands would prompt a similar response to that of CBB. Responsiveness is a key component of any biosecurity program, and therefore the surveying of insects on coffee statewide is vital to invasive species control.

Materials and Methods

Area of study. On-farm and feral coffee plants were surveyed for insects on the six most populous Hawaiian Islands. From February 2017 to January 2018, 13 surveys were conducted on Oahu, 12 surveys on Maui, 17 surveys on Kauai, 5 surveys on Molokai, 3 surveys on Lanai, and 23 surveys on Hawaii island for insects associated with coffee plants. Forty-six unique sites spread among the islands (Figure 1) included a mix of managed farms, unmanaged farms, and plots with feral coffee plants to ensure that the widest range of regions were sampled. Latitude and longitude data for each collection site were recorded and associated with specimens. Locations of surveys were chosen to represent multiple coffee growing regions of each island, though on some islands the extent of coffee growing areas was limited and thus so were the number of sites. Survey trips off Hawaii island were typically up to one week in length and timing of sampling at sites varied between 9:00 AM to 5:00 PM to ensure the capture of the broadest range of insects possible.

The sampling period of February 2017 to January 2018 spanned one year to capture the entirety of the Hawaii coffee growing season (Bittenbender and Easton-Smith 2008). Some sites were sampled multiple times throughout the year, while others were only sampled 1–2 times. All coffee plants surveyed were *Coffea arabica*, the most common species grown in the Hawaiian Islands. The cultivar, maturity, and management techniques of plants varied from site to site.

Collection and Identification. Collection methods remained consistent

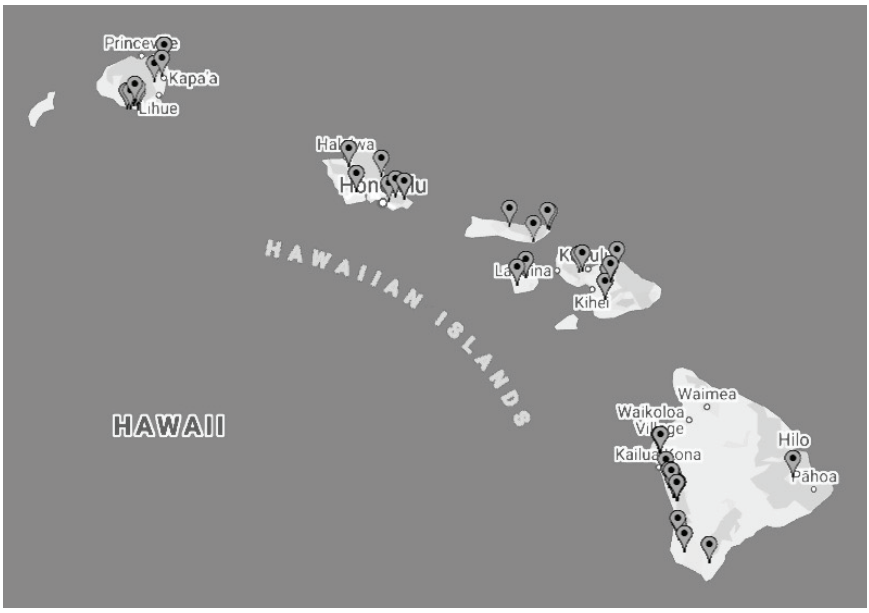

Figure 1. Map of coffee pest survey locations throughout the State of Hawaii.

throughout the study, and approximately followed the Thirty Trees Sampling Method for CBB Monitoring included in the latest CBB IPM plan (Kawabata et al. 2020). Moving in a zig zag pattern across the coffee growing area to gather a representative sample, approximately 12 coffee trees per acre were first selected for brief observation of the leaves, trunk, laterals, and fruit for signs and symptoms of pest infestation. For larger growing areas (>3 acres), multiple smaller plots were chosen for sampling to represent the overall conditions of the growing area. Insects that might not be easily collected with a sweep net, such as scales or CBB, were hand collected during observations. Berry dissections were also done to collect specimens when appropriate signs were observed. After initial observation and hand collection, sweeping of the coffee plant foliage was then performed using a Ward's® Multi-Use canvas insect net (Ward's Science, Rochester, NY), sampling all plants encountered in a new, though similarly spaced, zig zag pattern across the previously observed area.

Collected specimens were prepared for storage by pinning or submerging in 70% ethanol depending on best practices for the species. Specimens were identified to species, if possible, while others were not able to be identified beyond family or genus and are thus considered morphotypes. Identifications were determined by the statewide coffee pest survey technician, Hawaii Department of Agriculture entomologist/taxonomist, or University of Hawaii entomologist. All collected specimens were deposited into the permanent collections of the HDOA in Kailua-Kona, Hawaii.

Disinfestation protocol. Equipment and clothing were washed in hot water with detergent before being transported to an island where coffee berry borer had not been confirmed. Items that could not be washed, such as nets, shears, and boots were cleaned of soil, seeds, and debris before being thoroughly sprayed with 70%

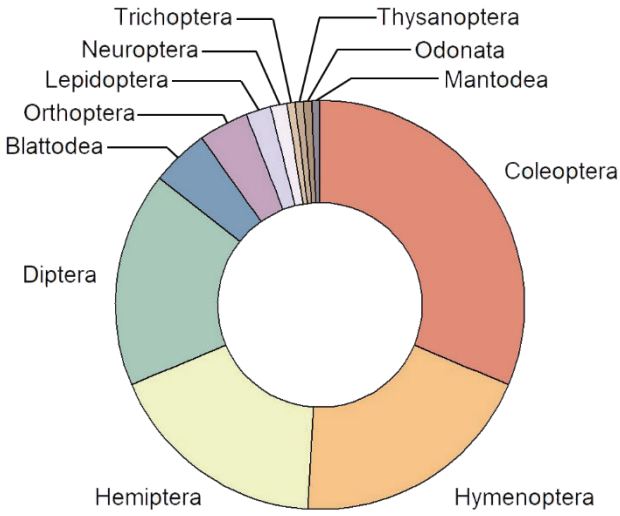

Figure 2. Distribution of orders collected during the year-long survey of insects associated with coffee plants in the State of Hawaii.

ethanol. No collected specimens were transported live between islands.

Results

One hundred fifty-two unique insect species/morphotypes (Table 1; see p. 49) in twelve orders (Figure 2) were found throughout the state. The number of unique species/morphotypes collected per survey ranged between 1 and 22, with a median of 7 (Figure 3). However, the species collected by site and date varied (Appendix 1; in a separare file: http://hdl.handle.net/10125/81749).

Several insect species were identified from a single or few islands and were not found to have statewide distributions on coffee. The most commonly collected species was *Melormenis basalis* (Walker), the West Indian flatid planthopper, which was found in ca. 87% of locations (Figure 4). *Hypothenemus hampei* was only identified from Hawaii island and Oahu, though at the time of the survey it had a limited distribution on Maui. Surveys occurred statewide, but *H. hampei* was only found at ca. 34% of survey locations.

Discussion

This is the first study to evaluate the variety of pest and innocuous insects associated with coffee plants in growing regions of the State of Hawaii. Throughout the one-year survey period, no previously unrecorded species were found. All collected insect specimens are known to occur in the state of Hawaii, but species recorded from single islands may only be present on that island. The comprehensive Bishop Museum species checklist (Nishida 2002) was used to reference present species, but it was last updated April 9, 2002, and does not have the most recent insect locality data.

Among the insect species identified by this survey there are a variety of predators and plant feeding insects, as well as parasitoid and eusocial species. Very few of the collected species are considered pests of *Coffea arabica*, and even fewer

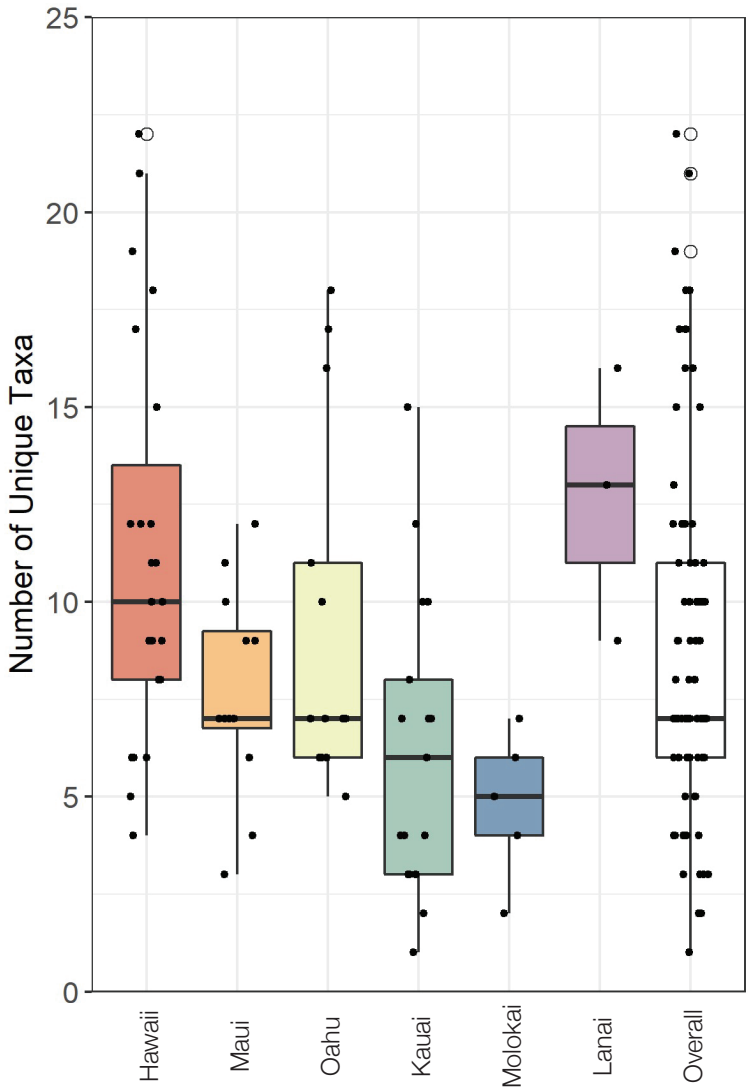

Figure 3. Number of taxa collected per survey, by island and combined for the state overall, during the year-long survey of insects associated with coffee plants in the State of Hawaii.

are considered serious pests of coffee. Among those considered coffee pests are citrus mealybug, *Planococcus citri* (Risso); green scale, *Coccus viridis* (Green); black twig borer, *Xylosandrus compactus* (Eichhoff); and coffee berry borer, *Hypothenemus hampei* (Ferrari). No species collected, except *H. hampei*, are considered primarily dependent on coffee, and *H. hampei* was not identified on any island it was not already known to occur at the time of the survey.

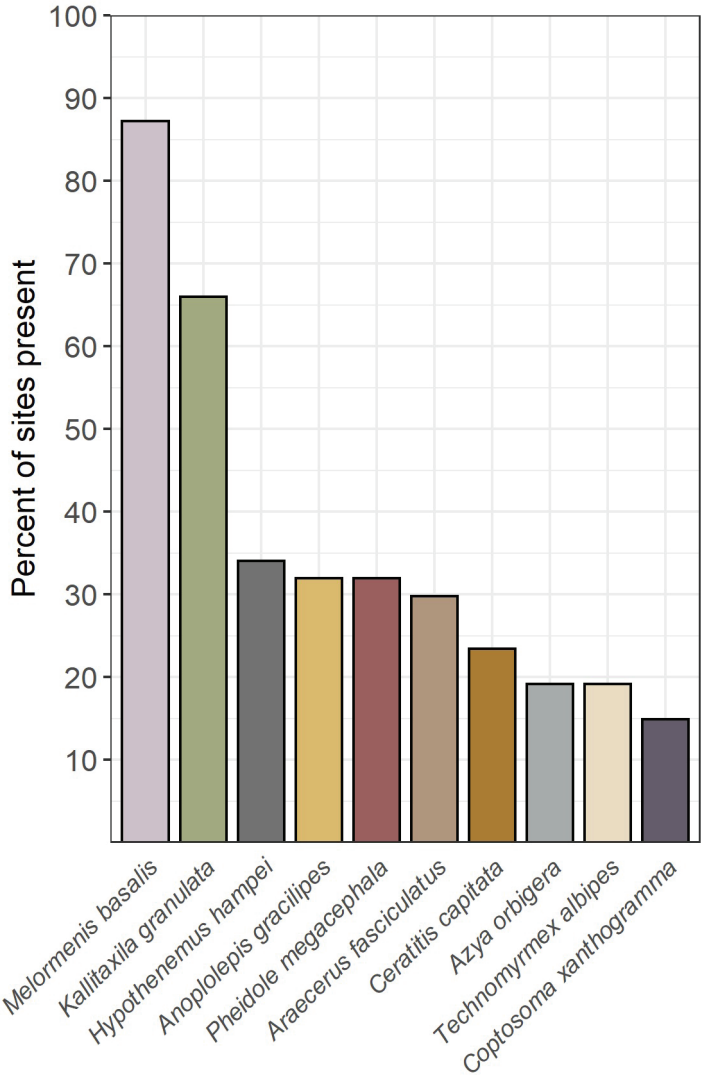

Figure 4. Most frequently collected specimens that were identifiable to species level during the year-long survey of insects associated with coffee plants in the State of Hawaii.

Although this was the first study of its kind in the Hawaiian Islands, and a large number of insects were found to be associated with coffee, there are some inherent limitations. Access to private property was controlled by owner permission, so not all potential sites were available for sampling. Survey methods were restricted to direct collection from plants and sweeping with nets and were not likely to collect underground or wood inhabiting species. In addition, nocturnal insects were unlikely to be captured during our survey period, nor were insects that exhibit strong seasonal population size changes that might have caused low numbers or absence during

sampling times. However, these data still provide a useful comparison for future surveys of insects associated with coffee. Surveys sampling a wider range of coffee farms and feral areas, at more times of the year, are needed to further elucidate the full range of insects that associate with coffee.

Pest surveys are an important component of invasive species monitoring programs. For example, ant and termite surveys have been undertaken in the Hawaiian Islands which have provided insight into localized spreading of pests and the possible reduction of other species (Tong et al. 2017, 2018). Periodically, coordinated surveys similar to the one described herein should be undertaken to determine if new invasions have occurred both in the state and on individual islands. We suggest new comprehensive surveys should occur every five years to balance costs of the survey with the benefit of increased understanding of pest spread and detection of new species. Early detection of pests through surveys is key to management and eradication success. The current study establishes a baseline of insect species associated with coffee in the State of Hawaii and can be used to compare to future monitoring activities.

Acknowledgments

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Table 1. List of specimens collected from *Coffea arabica* plants in the state of Hawaii, sorted phylogenetically by order and then alphabetically by family, genus, and species. Island key: BI (Hawaii, "Big Island"), MA (Maui), LA (Lanai), OA (Oahu), KA (Kauai), MO (Molokai)

Order	Family	Genus	Species	Describer, year	Island
Odonata	Coenagrionidae	Megalagrion	sp.	McLachlan, 1883	KA
Orthoptera	Acrididae	Schistocerca	nitens	Thunberg, 1815	LA
Orthoptera	Acrididae				MO
Orthoptera	Gryllidae				OA
Orthoptera	Tettigoniidae	Elimaea	punctifera	Walker, 1869	KA
Orthoptera	Tettigoniidae	Holochlora	japonica	Brunner, 1878	OA
Orthoptera	Tettigoniidae				BI, LA, OA
Blattodea	Blaberidae	Diploptera	punctata	Eschscholtz, 1822	BI
Blattodea	Blattellidae	Balta	notulata	Stal, 1860	BI
Blattodea	Blattellidae	Balta	sp.	Tepper, 1893	OA
Blattodea	Blattellidae	Blattella	sp.	Caudell, 1903	BI, OA
Blattodea	Blattellidae				BI, MA, LA, KA
Blattodea	Blattidae				BI
Blattodea	Kalotermitidae	Incisitermes	immigrans	Snyder, 1922	BI
Mantodea	Mantidae				BI
Hemiptera	Aphididae				BI, MA
Hemiptera	Cercopidae	Clastroptera	xanthocephala	Germar, 1839	LA
Hemiptera	Cicadellidae	Gyponana	germari	Stal, 1864	BI, MA
Hemiptera	Cicadellidae	Sophonia	rufofascia	Kuoh and Kuoh, 1983	BI
Hemiptera	Cicadellidae				BI
Hemiptera	Cixiidae				BI
Hemiptera	Coccidae	Coccus	viridis	Green, 1889	BI, MA, LA, KA
Hemiptera	Coreidae	Physomerus	grossipes	Fabricius, 1794	BI
Hemiptera	Flatidae	Melormenis	basalis	Walker, 1851	BI, MA, LA, MO, OA, KA
Hemiptera	Flatidae	Siphanta	acuta	Walker, 1851	BI
Hemiptera	Lygaeidae	Nysius	sp.	Dallas, 1852	MA, LA, KA
Hemiptera	Lygaeidae				BI
Hemiptera	Membracidae	Spissistilus	festinus	Say, 1830	KA
Hemiptera	Membracidae	Vanduzeea	segmentata	Fowler, 1895	MA
Hemiptera	Miridae				MA, LA, OA, KA
Hemiptera	Nabidae	Nabis	sp.	Latreille, 1802	MA
Hemiptera	Pentatomidae	Brochymena	quadripustulata	Fabricius, 1775	BI
Hemiptera	Pentatomidae	Nezara	viridula	Linnaeus, 1758	MA, KA
Hemiptera	Plataspidae	Coptosoma	xanthogramma	White, 1842	BI, MA, KA
Hemiptera	Pseudococcidae	Planococcus	citri	Risso, 1813	LA, KA
Hemiptera	Reduviidae	Empicoris	sp.	Wolff, 1811	MA
Hemiptera	Tingidae	Corythucha	gossypii	Fabricius, 1794	BI
Hemiptera	Tingidae	Leptobyrsa	decora	Drake, 1922	BI, MA, OA
Hemiptera	Tingidae	Leptodictya	tabida	Herrich-Schaeffer, 1839	BI
Hemiptera	Tingidae	Teleonemia	scrupulosa	Stal, 1872	BI, MA
Hemiptera	Tingidae				MA
Hemiptera	Tropiduchidae	Kallitaxila	granulata	Stal, 1870	BI, MA, LA, MO, OA, KA
Thysanoptera	Thripidae				BI
Coleoptera	Anthribidae	Araecerus	constans	Perkins, 1900	MA, OA

Table 1. Specimens collected from coffee plants in Hawaii (continued)

Order	Family	Genus	Species	Describer, year	Island
Coleoptera	Anthribidae	Araecerus	fasciculatus	DeGeer, 1775	BI, MA, LA, MO, OA, KA
Coleoptera	Anthribidae	Araecerus	vieillardi	Montrouzier, 1860	BI, LA, KA
Coleoptera	Anthribidae	Araecerus	sp.	Schoenherr, 1823	BI, MA, LA, MO, OA, KA
Coleoptera	Anthribidae				LA, KA
Coleoptera	Bostrichidae	Amphicerus	cornutus	Pallas, 1772	BI
Coleoptera	Bostrichidae	Lyctus	sp.	Fabricius, 1792	BI
Coleoptera	Carabidae				MA
Coleoptera	Cerambycidae	Ceresium	unicolor	Fabricius, 1787	BI
Coleoptera	Cerambycidae	Curtomerus	flavus	Fabricius, 1775	OA
Coleoptera	Cerambycidae	Sybra	alternans	Wiedemann, 1825	BI, OA
Coleoptera	Cerambycidae				MO
Coleoptera	Chrysomelidae	Acanthoscelides	sp.		BI, MA, OA, KA
Coleoptera	Chrysomelidae	Stator	limbatus	Horn, 1873	OA
Coleoptera	Chrysomelidae	Stator	pruininus	Horn, 1873	BI, MA, OA
Coleoptera	Coccinellidae	Azya	orbigera	Mulsant, 1850	BI, OA, KA
Coleoptera	Coccinellidae	Coccinella	septempunctata	Linnaeus, 1758	LA
Coleoptera	Coccinellidae	Coleophora	inaequalis	Fabricius, 1775	BI, LA
Coleoptera	Coccinellidae	Cryptolaemus	montrouzieri	Mulsant, 1853	BI, OA, KA
Coleoptera	Coccinellidae	Curinus	coeruleus	Mulsant, 1850	BI, KA
Coleoptera	Coccinellidae	Diomus	notescens	Blackburn, 1889	MA
Coleoptera	Coccinellidae	Halmus	chalybeus	Boisduval, 1835	BI, MA, LA
Coleoptera	Coccinellidae	Hyperaspis	silvestrii	Weise, 1909	BI, MA
Coleoptera	Coccinellidae	Olla	v-nigrum	Mulsant, 1866	BI, LA, OA
Coleoptera	Coccinellidae	Rhyzobius	forestieri	Mulsant, 1853	BI, MA
Coleoptera	Coccinellidae	Rhyzobius	sp.	Stephens, 1832	MA
Coleoptera	Coccinellidae	Scymnus	sp.	Kugelann 1794	BI
Coleoptera	Coccinellidae				BI, MA, LA, OA, KA
Coleoptera	Curculionidae	Hypothenemus	hampei	Ferrari, 1867	BI, OA
Coleoptera	Curculionidae	Naupactus	godmanni	Crotch, 1867	BI, MA, LA, KA
Coleoptera	Curculionidae	Naupactus	sp.	Dejean, 1821	KA
Coleoptera	Curculionidae	Sitophilus	oryzae sp.	Linnaeus, 1763	BI
Coleoptera	Curculionidae	Stenotrupis	marshallii	Zimmerman, 1938	BI
Coleoptera	Curculionidae	Xyleborus	affinis	Eichhoff, 1867	MA
Coleoptera	Curculionidae	Xylosandrus	compactus	Eichhoff, 1876	BI
Coleoptera	Curculionidae				BI
Coleoptera	Elateridae	Conoderus	sp.	Eschscholtz, 1829	BI
Coleoptera	Elateridae				BI, MO
Coleoptera	Mycetophagidae	Litargus	vestitus	Sharp, 1879	LA
Coleoptera	Nitidulidae	Carpophilus	dimidiatus	Fabricius, 1792	KA
Coleoptera	Nitidulidae	Carpophilus	sp.	Stephens, 1830	BI, OA
Coleoptera	Nitidulidae	Conotelus	sp.	Erichson 1842	BI
Coleoptera	Scarabaeidae	Adoretus	sinicus	Burmeister, 1855	MO
Coleoptera	Scarabaeidae	Protaetia	orientalis	Gory and Percheron, 1833	OA
Coleoptera	Scolytidae				OA
Coleoptera	Silvanidae	Cathartus	quadricollis	Guérin-Méneville 1844	BI, MA, OA
Coleoptera	Silvanidae				BI, MO

Table 1. Specimens collected from coffee plants in Hawaii (continued)

Order	Family	Genus	Species	Describer, year	Island
Neuroptera	Chrysopidae				MA, OA, KA
Neuroptera	Hemerobiidae				BI, MA, LA, OA, KA
Hymenoptera	Agaonidae	Pleistodontes	sp.	Saunders 1882	BI
Hymenoptera	Apidae	Apis	mellifera	Linnaeus, 1758	BI, OA, KA
Hymenoptera	Bethylidae	Cephalonomia	sp.	Westwood, 1833	OA
Hymenoptera	Braconidae				BI, MA, MO, OA, KA
Hymenoptera	Chalcididae	Brachymeria	sp.	Westwood, 1829	OA
Hymenoptera	Crabronidae				BI
Hymenoptera	Eulophidae				BI
Hymenoptera	Eupelmidae				OA
Hymenoptera	Formicidae	Anoplolepis	gracilipes	Smith, 1857	BI, MA, MO, OA, KA
Hymenoptera	Formicidae	Brachymyrmex	obscurior	Forel, 1893	BI, LA, KA
Hymenoptera	Formicidae	Cardiocondyla	obscurior	Wheeler, 1929	BI
Hymenoptera	Formicidae	Ochetellus	glaber	Mayr, 1862	BI
Hymenoptera	Formicidae	Paratrechina	longicornis	Latreille, 1802	LA
Hymenoptera	Formicidae	Pheidole	megacephala	Fabricius, 1793	BI, MA, LA, MO, OA, KA
Hymenoptera	Formicidae	Plagiolepis	alluaudi	Emery, 1894	BI, MA
Hymenoptera	Formicidae	Solenopsis	geminata	Fabricius, 1804	BI, KA
Hymenoptera	Formicidae	Technomyrmex	albipes	Smith, 1861	BI, MO, OA, KA
Hymenoptera	Formicidae	Technomyrmex	difficilis	Perkins, 1899	BI
Hymenoptera	Formicidae	Technomyrmex	obscurior	Wheeler, 1928	BI
Hymenoptera	Formicidae	Tetramorium	simillimum	Smith, 1851	MO
Hymenoptera	Formicidae	Trichomyrmex	destructor	Jerdon, 1851	OA
Hymenoptera	Formicidae	Wasmannia	auropunctata	Roger, 1863	BI
Hymenoptera	Ichneumonidae	Anomalon	californicum	Cresson, 1879	BI
Hymenoptera	Ichneumonidae				BI, MA
Hymenoptera	Pompilidae	Tachypompilus	analis	Fabricius, 1781	OA
Hymenoptera	Pteromalidae				BI, LA, KA
Hymenoptera	Tiphiidae	Tiphia	segregata	Crawford, 1910	OA
Hymenoptera	Vespidae	Polistes	exclamans	Viereck, 1904	KA
Hymenoptera	Vespidae	Polistes	olivaceus	DeGeer, 1773	OA
Hymenoptera	Vespidae				BI
Lepidoptera	Lycaenidae	Zizina	otis	Fabricius, 1787	KA
Lepidoptera	Pieridae	Abaeis	nicippe	Cramer, 1779	KA
Lepidoptera	Pieridae	Pieris	rapae	Linnaeus, 1758	MA, KA
Trichoptera	Hydropsychidae	Cheumatopsyche	pettiti	Banks, 1908	KA
Diptera	Culicidae	Aedes	sp.	Meigen, 1818	KA
Diptera	Dolichopodidae	Austrosciapus	connexus	Walker, 1835	BI
Diptera	Dolichopodidae				BI, MO, OA
Diptera	Dolichopodidae	Chrysosoma	fraternum	Van Duzee, 1933	KA
Diptera	Drosophilidae	Drosophila	suzukii	Matsumura, 1931	BI
Diptera	Drosophilidae	Zaprionus	ghesquierei	Collart, 1937	BI, OA
Diptera	Drosophilidae				BI, LA, MO
Diptera	Lauxaniidae	Homoneura	unguiculata	Kertesz, 1913	BI
Diptera	Lauxaniidae	Homoneura	sp.	Wulp, 1891	BI
Diptera	Lauxaniidae	Poecilominettia	sexseriata	Hendel, 1932	BI

Table 1. Specimens collected from coffee plants in Hawaii (continued)

Order	Family	Genus	Species	Describer, year	Island
Diptera	Lauxaniidae				BI, OA
Diptera	Lonchaeidae				BI, MA, LA, OA, KA
Diptera	Micropezidae	Taeniaptera	angulata	Loew, 1866	BI, MA
Diptera	Muscidae				BI, OA
Diptera	Rhiniidae	Rhinia	apicalis	Wiedemann, 1830	OA
Diptera	Sarcophagidae				BI, LA
Diptera	Sepsidae	Sepsis	biflexuosa	Strobl, 1893	BI
Diptera	Syrphidae	Allograpta	sp.	Osten Sacken, 1875	OA
Diptera	Syrphidae				MA
Diptera	Tephritidae	Bactrocera	cucurbitae	Coquillett, 1899	OA
Diptera	Tephritidae	Bactrocera	dorsalis	Hendel, 1912	BI, MO, OA
Diptera	Tephritidae	Bactrocera	sp.	Macquart, 1835	LA, KA
Diptera	Tephritidae	Ceratitis	capitata	Wiedemann, 1824	BI, OA, KA
Diptera	Tephritidae	Tetreuaresta	obscuriventris	Loew, 1873	MA, OA, KA
Diptera	Ulidiidae	Euxesta	annonae	Fabricius, 1794	BI, MA
Diptera	Ulidiidae	Notogramma	cimiciforme	Loew, 1867	OA