Journal of Insect Science, 2026, **26**, ieag033
DOI: https://doi.org/10.1093/jisesa/ieag033
Research

An interdisciplinary approach to investigating an invasive insect pest: tracking, phenology, and genetics of the Queensland longhorn beetle, *Acalolepta aesthetica* (Cerambycidae: Lamiinae)

Matthew S. Siderhurst*[,1], Sheina B. Sim*[,1], Jason D. K. Dzurisin[2], Franny K. Brewer[3], Jade Miyashiro[3], Stacy G. Chun[4], Nicole D. Miller[5], Theodore J. Yoder[5], Anika L. Hurst[1], Renee L. Corpuz[1], Keena M. Curbelo[1], and Stephanie Gayle[1]

[1]United States Department of Agriculture, Agricultural Research Service, Daniel K. Inouye U.S. Pacific Basin Agricultural Research Center, Hilo, HI, USA
[2]Center for the Environmental Management of Military Lands, Colorado State University, Fort Collins, CO, USA
[3]Big Island Invasive Species Committee, Hilo, HI, USA
[4]Plant Pest Control Branch, Division of Plant Industry, Hawaii Department of Agriculture, Hilo HI, USA
[5]Eastern Mennonite University, Department of Biology, Harrisonburg, VA, USA

*Corresponding authors. Matthew S. Siderhurst, USDA ARS PBARC, 64 Nowelo St., Hilo, HI 96720, USA (Email: matthew.siderhurst@usda.gov); Sheina B. Sim, USDA ARS PBARC, 64 Nowelo St., Hilo, HI 96720, USA (Email: sheina.sim@usda.gov).

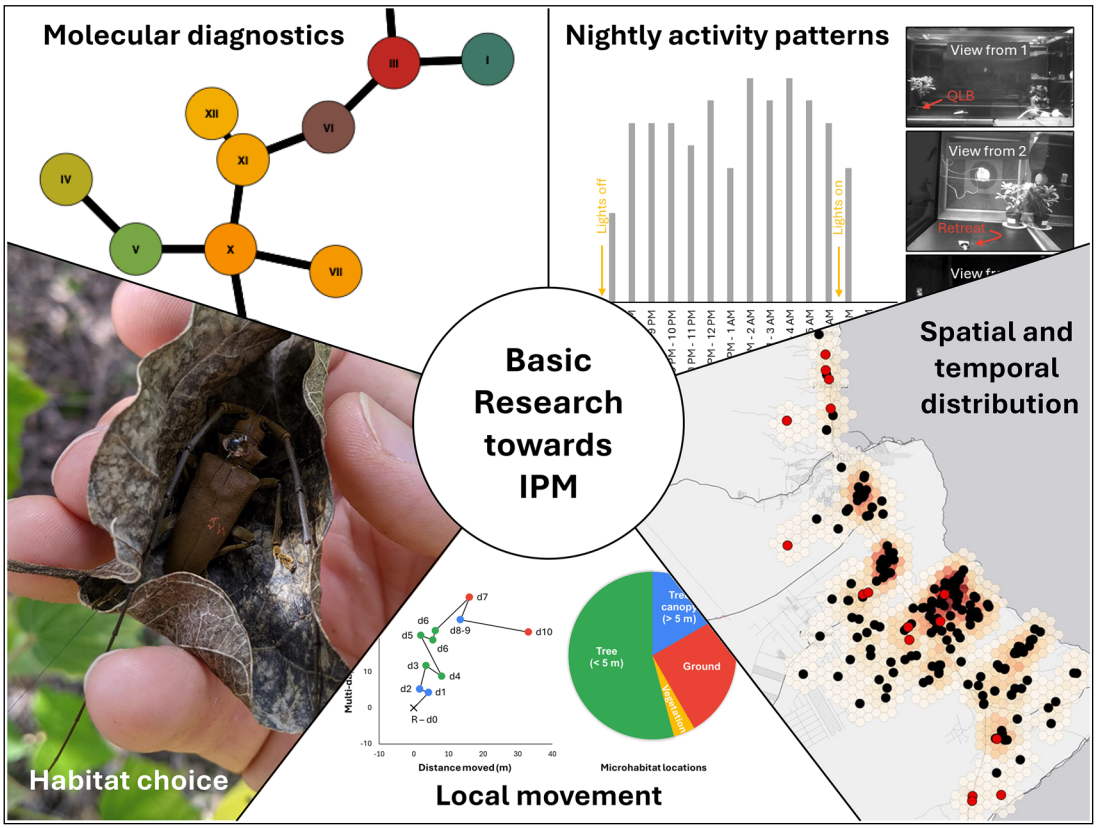
Subject Editor: Flavius Balacenoiu

The Queensland longhorn beetle (QLB), *Acalolepta aesthetica* (Olliff), was first detected in the Puna District of Hawai'i Island in 2009 and has since been observed to attack high value specialty crops such as cacao (*Theobroma cacao*), breadfruit (*Artocarpus altilis*), and citrus (*Citrus* spp.), as well as the culturally important kukui, *Aleurites moluccanus*. Endemic to the Australian states of Queensland and New South Wales, QLB had no pest status before introduction into Hawai'i. To address the lack of basic biological data on QLB, we conducted four pilot experiments to support pest management efforts. These included sequencing the CO1 region of the mitochondrial genome, observing beetle behavior in both a laboratory wind tunnel during scotophase and in the field using harmonic radar tracking, and obtaining QLB spatial distribution data through a citizen science web-based reporting application hosted by ArcGIS Online. Our results place QLB in a phylogenetic context, which will allow the development of diagnostic tools to differentiate QLB from other longhorn beetles. Behavioral observations suggest that QLB are largely sedentary, move mostly by walking with rare flights, and spend most of their time in trees. Citizen science reports suggest QLB populations are highest in May-July, beetle locations are largely restricted to elevations under 500 m, and population expansions are mostly occurring along the coast. These data combined can be applied to pest management efforts for this important and invasive agricultural pest. Further, we hope this interdisciplinary approach can serve as a framework for research response efforts to invasive insects generally.

Keywords: haplotype network analysis, harmonic radar, wind tunnel, citizen science

Received: 28 January 2026. **Revised:** 11 March 2026. **Accepted:** 18 March 2026
Published by Oxford University Press on behalf of Entomological Society of America 2026.
This work is written by (a) US Government employee(s) and is in the public domain in the US.

Graphical abstract



Introduction

Threats from invasive insects are increasing globally due to an increase in the transportation of people and goods (Hulme 2021, Venette and Hutchison 2021). If insects have minimal human impacts in their native range, there is often little impetus to study them, until the insect is introduced into a nonendemic habitat or niche where the species can radiate into a new adaptive zone. In many instances, invading insects are not known as pests in their endemic range and therefore, little information about the biology of the species may be recorded. An example of this, which impacts Hawai'i, can be seen with the little fire ant which received relatively little study until it was spread outside of its native range (Wetterer and Porter 2003). Considered one of the 100 worst invasive species (Lowe et al. 2000), this ant is a disturbance specialist in the rain forests of south America where it is abundant but does not show the negative ecological and economic impacts observed outside its native range (Wetterer and Porter 2003, Tennant 2021). Another example comes from the invasive beetle *Agrilus planipennis* (emerald ash borer), which received minimal research before it was discovered in the United States in 2002 and Moscow, Russia in 2003 (Sun et al. 2024). This lack of information can be a major impediment to agencies managing invasive species responses as the basic life histories, behaviors, and ecological impacts are being studied simultaneously with eradication or control measure implementation. Ideally, sufficient biological data would be available to inform activities such as optimal trap placement, setting the size of quarantine areas, limiting the movement of host materials, focusing pest surveys on appropriate microhabitats, and related control and surveillance responses.

For insects that negatively impact agriculture or forestry, initial studies often include rearing individuals in laboratory settings to determine life cycle and host range. Trapping insects in effected areas is also common, and if available, these efforts can be aided by the use of species-specific attractants. However, as noted by Tobin et al. (2015), "…for many invasive alien species, especially for those that are not economically important in their native range, research on pheromone identification has been insufficient and so sensitive monitoring tools may not be immediately available." Thus, attractant-based trapping can be ineffective making studying insect movement (both local and longer-range dispersal), location in the environment (feeding, resting, and aggregation sites, etc.), and phenology quite difficult.

The Queensland longhorn beetle (QLB), *Acalolepta aesthetica* (Olliff), is a polyphagous tree-boring cerambycid species that is invasive in Hawai'i (Fig. 1). The beetle is native to eastern Australia and was first collected from the Puna district of Hawai'i Island in 2009 (Matsunaga and Chun 2018). The adult beetles grow up to 4.5 cm in length and feed on a number of live hosts including ulu (breadfruit; *Artocarpus altilis*), kukui (candlenut; *Aleurites moluccanus*), trumpet tree (*Cecropia obtusifolia*), queen sago palm (*Cycas circinalis*), Citrus spp., and cacao (*Theobroma cacao*) among others (Matsunaga and Chun 2018, Miles 2022, Sofaer et al. 2025). Very little is known about QLB from the time prior to its discovery in

Fig. 1. Male *Acalolepta aesthetica*. Characteristic of other members of the beetle family *Cerambycidae*, male and female *A. aesthetica* have long segmented antennae. Photo credit: S.B. Sim.

Hawai'i as it does not appear to negatively impact plants in its Australian home range. Following the discovery of QLB in Hawai'i, attempts have been made to find an attractant that could be used as a monitoring tool. Four cerambycid aggregation-sex pheromones known to attract lamiine beetles were largely ineffective in attracting QLB (Collignon et al. 2019). Thus, trapping is largely ineffectual for studying QLB movement behavior and range expansion.

Cerambycids are important both ecologically, as components of forest ecosystems (Haack and Byler 1993, Grove 2002, Teale and Castello 2011, Ulyshen 2016), and economically, primarily because of negative impacts on forestry, ornamental trees, and orchards (Haack et al. 2010, Parry and Teale 2011). The movement of plants and wooden commercial products provide a method for cryptic cerambycid larvae to spread into new habitats (Haack 2006). Notable examples of invasive cerambycids include the Asian longhorn beetle, *Anoplophora glabripennis*, and the citrus longhorn beetle, *Anoplophora chinensis*. Control and eradication measures for cerambycids, particularly *Anoplophora*, include employing biocontrol agents, insecticides, and host removal together with other activities such as pheromone trapping to monitor populations and public outreach (Smith et al. 2009, Marchioro and Faccoli 2021, Keena et al. 2026). These methods are strengthened by sound biological data on the pest being targeted.

In light of the dearth of biological information available on QLB, this study aimed to use a diverse range of research tools to provide data that can inform and support ongoing surveillance and control measures for this invasive pest. Four research approaches were used: (i) phylogenetic analysis to determine QLB relatedness to other cerambycid species (potentially providing an identification tool), (ii) scotophase activity monitoring using infrared cameras, (iii) harmonic radar tracking of tagged QLB to provide ecological and vegetation usage data, (iv) a citizen science reporting project aimed at assessing spatial-temporal range of QLB.

Materials and Methods

Phylogenetic Analysis

To place *A. aesthetica* in a phylogenetic context, Study 1 used a haplotype network analysis with *A. aesthetica* beetles collected on Hawai'i Island, closely related cerambycid species for which there was publicly available barcode sequence, and one locally sourced weevil *Rhabdoscelus obscurus* (Coleoptera: Curculionidae) to serve as an outgroup. To obtain CO1 sequences from locally collected beetles, total genomic DNA was extracted using the QIAGEN DNeasy Blood and Tissue Column Kit (QIAGEN, Hilden, Germany) automated using a QIAcube (QIAGEN, Hilden, Germany) for 18 individuals submitted by local Hawaii Island residents and a representative beetle from the species *Phoracantha semipunctata* (Coleoptera: Cerambycidae), *Xystrocera globosa* (Coleoptera: Cerambycidae), *Phagiohammus spinipennis* (Coleoptera: Cerambycidae), and *Lagocheirus obsoletus* (Coleoptera: Cerambycidae). A 710 bp region of the mitochondrial gene cytochrome oxidase 1, also known as the barcode of life region, of the genome was amplified using the Folmer primers LCO1490: 5′-GGTCAACAAATCATAAAGATATTGG-3′ and HCO2198: 5′-TAAACTTCAGGGTGACCAAAAAATCA-3′ (citation). Polymerase chain reaction (PCR) amplifications were performed in reactions consisting of 12.5 µl Q5 Hot Start High-Fidelty 2X Master Mix (New England Biolabs, Ipswich, Massachusetts, USA), 0.5 µl of 10 mmol forward and reverse primers, of 0.5 to 2 ng of template genomic DNA, and raised to a final volume of 25 µl with nuclease-free water. Thermal cycling was performed under the following conditions: initial denaturation at 98 °C for 30 s; 35 cycles at 98 °C for 10 s 59 °C for 10 s, 72 °C for 10 s; and a final extension of 72 °C for 2 min. Amplified products were then purified using SPRI beads and served as the input to separate forward and reverse Big Dye reactions using BigDye Terminator v3.1 (Thermo Fisher Scientific, Waltham, Massachussetts, USA) followed by purification using BigDye Xterminator (Thermo Fisher Scientific, Waltham, Massachusetts, United States). Chain-termination sequencing of all products was performed using a Genetic Analyzer 3500 (Thermo Fisher Scientific, Waltham, Massachusetts, United States). Forward and reverse sequences were aligned to form one consensus per individual using Geneious Prime v2020.1 (https://www.geneious.com). An alignment between *A. aesthetica* and publicly available Cerambycidae sequences *Anoplophora chinensis* (GenBank accession: AB439191.1), *Anoplophora glabripennis* (AB439154.1), *Arhopalus* sp. (KY357781.1), *Acalolepta grossescapus* (FJ559016.1), *Acalolepta* sp. (MK704500.1), *Acalolepta formosana* (FJ559004.1), *Monochamus sutor* (KY773689.1), *and Monochamus saltuarius* (JN087435.1) was performed and trimmed to 600 bp for analysis using Geneious Prime v2025.2.2. Bootstrapped (replicates = 10,000) neighbor-joining network analysis was performed using the 'read.dna', 'dist.dna', 'nj', and 'boot.phylo' functions of the R package ape (Paradis and Schliep 2019). The rooted tree was visualized using the 'plot.phylo' function.

Scotophase Activity Observations

Study 2 (conducted 14 May to 5 June 2021) was designed to assess the nightly activity of wild caught QLB in a laboratory wind tunnel. The glass/metal wind tunnel was comprised of a 0.9 × 0.9 × 2.8 m rectangular glass arena equipped with inlet and exit fans that produced a laminar air flow (Jang et al. 1997). Two potted plants were placed in the wind tunnel, one at each end. Two digital infrared cameras (D-Link DCS-942L, Taipei, Taiwan) were positioned inside the wind tunnel, one at each end secured to existing metal shelves (Fig. 2C to D). Tape was

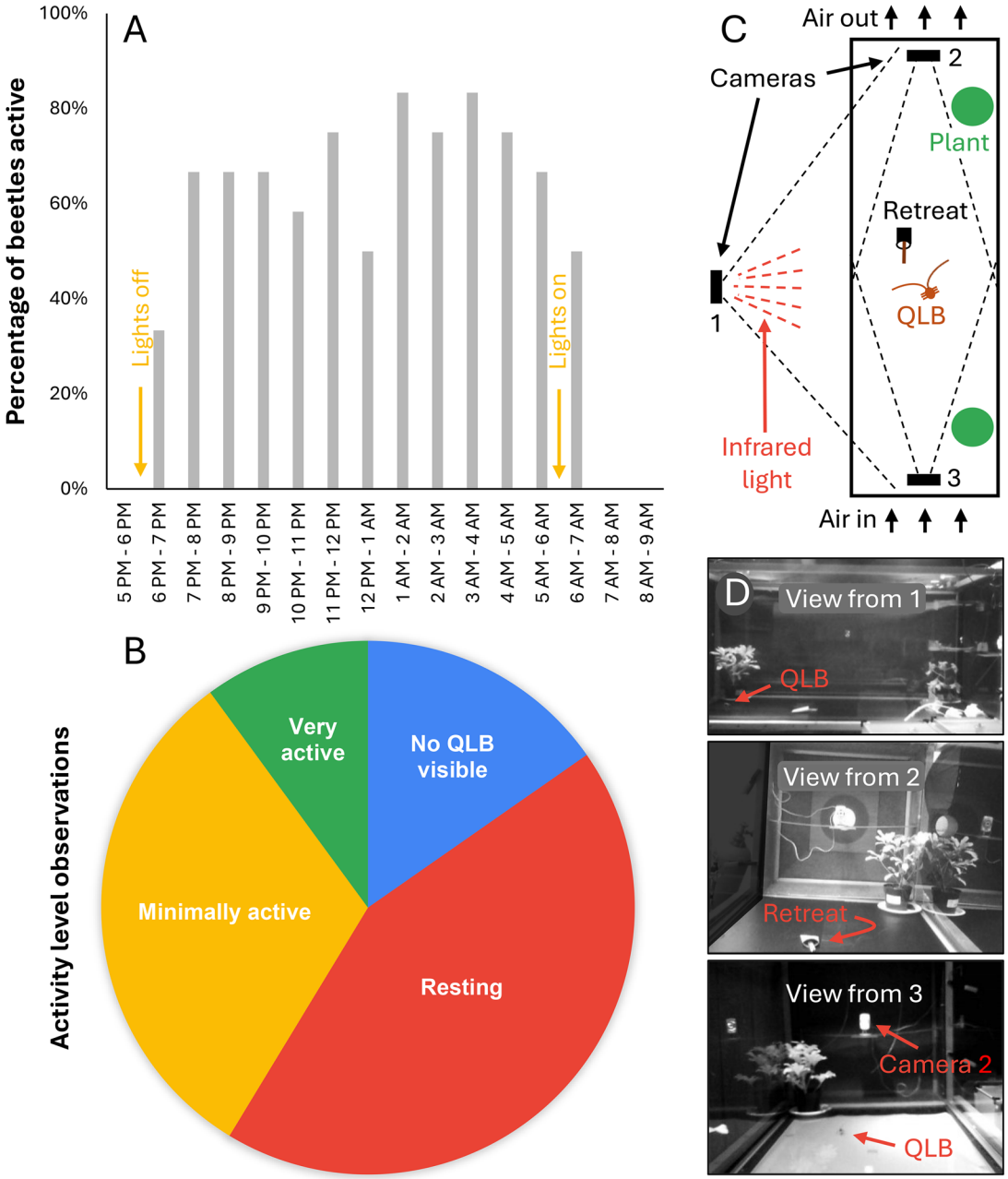


Fig. 2. *Acalolepta aesthetica* scotophase activity observations. The bar graph shows the percentage of beetles active during one hour time intervals A). The pie chart summarizes beetle activity levels B). The layout of the wind tunnel with the camera, plant, and retreat positions illustrated is shown in the top right C). Camera fields of view are illustrated by the black dashed lines. Example images from each of the three cameras are shown in the bottom right D).

placed over the built-in infrared LEDs of both cameras so that they did not washout ('blind') the images from the other. A third camera with uncovered LEDs (providing infrared illumination) was positioned along one side of the tunnel. Additionally, two 96 LED infrared lamps (Model 80AIR, Yeshizhuanjia, China) were affixed above the wind tunnel to provide further illumination. The 15-h observation period started at 5 PM (lights off at 6 PM) and ended at 9 AM (lights on at 6 AM). Room temperature was 26 to 28 °C. Beetles were introduced into the wind tunnel in cardboard tubes stapled closed at one end and had a short stick inserted in the other end. The nightly activity patterns of 14 QLB were observed during the course of this experiment. Recorded video footage was viewed and observed beetle movement behaviors were characterized as either resting, walking, or flying. Activity levels were also scored using a four-point scale (0 = no activity–beetle not visible; 1 = no activity–beetle visible but stationary; 2 = minimal active–intermittent movement; 3 = very active–near constant movement).

Field Tracking

Dipole HR tags used for tracking were fabricated by attaching two 8.25 cm lengths of superelastic nitinol wire (0.076 mm dia., Malin Co., Brookpark, Ohio, United States) using conductive

silver paint (GC Electronics, Rockford, Illinois, United States) onto each of the leads of the Schottky diode (RECCO AB, Lindigo, Sweden) (Siderhurst et al. 2025). All beetles were wild caught. Beetles were tagged both in the lab before transport to the field or on the back of a truck in the field. Tags were attached to the pronotum in a longitudinal orientation (Fig. 3A to C) using a UV activated adhesive (Bondic, Niagara Falls, New York, United States) (Siderhurst et al. 2025). Care was taken not to glue the elytra or the head during tag attachment. Several tagged QLB were released into the wind tunnel described in Study 2 to determine if tagged QLB were flight capable. Beetles were marked with orange paint pens to aid identification. Following the tag attachment, beetles were carefully inspected for damage and any beetles that showed signs of damage were not released into the field for tracking.

Study 3 (conducted 10 to 21 December 2020) was designed to assess the movements of QLB over a multi-day period. Five QLB were fitted with harmonic radar tags and tracked over a period of several days in a stand of Kukui trees (~1,800 m^2), *Aleurites moluccanus* (L.), at Kamehameha Schools Hawai'i Campus (19.6114579, −155.0490436). Tagged QLB were released onto tree trunks (height of ~1 m) during the early evening after sunset on 10 August 2020 with temperatures approximately 21 to 22 °C. Tracking a released beetle was accomplished with four searchers, each equipped with a RECCO transceiver. When possible, an attempt was made to follow the beetle visually once it took flight. Once a tentative direction of flight was determined, vegetation along the trajectory of the flight path was swept with a RECCO transceiver. Care was taken to space out the searchers to avoid false-positive signals from nearby transceivers. Beetles were generally located within 5 min of taking flight. At most locations, the tagged beetle was visually located. QLB releases were spaced out in time so as to allow the tracking team to concentrate search efforts on one individual at a time and to lower the chance of confusing two tagged beetles. After release, QLB locations were determined by a once daily search (with the exception of 11 December when two searches were conducted). GPS coordinates were recorded for each QLB location.

Study 4 (conducted 3 June 2021) was designed to assess the movements of QLB during a single evening. Four QLB were fitted with harmonic radar tags and release at the same site as Study 3. Beetles were released at 6:45 PM onto tree trunks (height ~1 m) and located every ~15 mins from 7 PM to 11 PM using the methodology previously described.

Citizen Science Mapping

Study 5 was designed to support early detection and spatial monitoring of QLB by using a web-based reporting application developed using ArcGIS Online (Esri, Redlands, California, United States). The application, titled the *Hawai'i Queensland Longhorn Beetle Reporter*, was constructed using the GeoForm configurable app template and enabled users to submit reports directly into a hosted feature layer. The form collected information including the date of observation, geographic location (selected via an interactive map or device GPS), host plant species, infestation characteristics (eg severity and life stage), the reporting agency, and a photograph of the specimen. Categorical fields were constrained by coded value domains to ensure consistency in data entry.

Results

Phylogenetic Analysis

Mitochondrial haplotype sequencing revealed no variation in the QLB sequenced (Fig. 4). Haplotype network analysis between QLB and closely related cerambycids revealed that QLB was most similar to other *Acalolepta* species followed by other species in the tribe Monochamini being slightly less similar but still strongly related. Cerambycids in the sub-family Lamiini which includes economically important species such as *Anoplophora glabripennis* and *Anoplophora chinensis* were the most phylogenetically distant among the sequences analyzed.

Scotophase Activity Observations

No beetle activity was observed in the wind tunnel before the fluorescent room lights were switched off at 6 PM (Fig. 2A). Additionally, no beetle activity was observed outside the first hour following lights on at 6 AM. Two beetles were completely inactive throughout the observation period. The percentage of

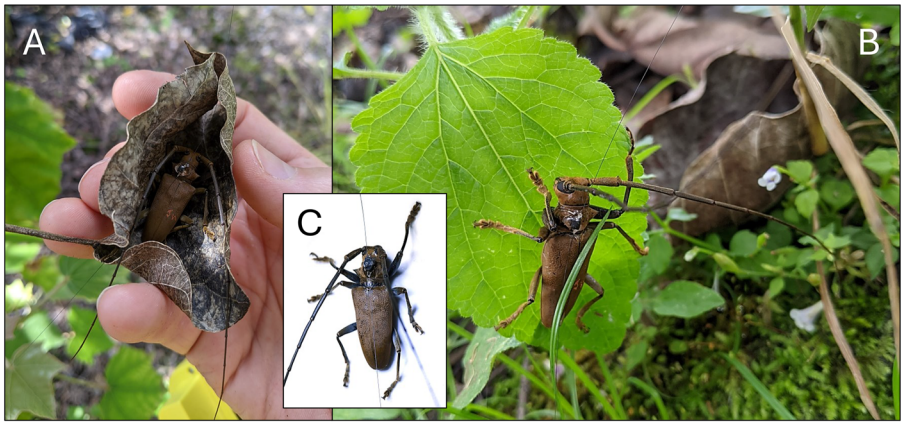


Fig. 3. Examples of *Acalolepta aesthetica* with harmonic radar tags attached: a beetle that was found hiding in a dead leaf A), a beetle that was found in the open B), and a beetle in the lab C). Photo credits: M.S. Siderhurst and S.B. Sim.

Fig. 4. Neighbor-joining network estimated using CO1 haplotypes for Cerambycidae collected on Hawai'i Island rooted using a locally collected weevil (*Rhabdoscelus obscurus*) as an outgroup. Network was bootstrapped using 10,000 replicates. Nodes with dark asterisks have > 95% bootstrap support. Species names with an asterisk after were locally collected and sequenced cerambycids.

QLB that showed active movement during an hourly block ranged from a low of 33% in the first hour after lights out to a peak of 83% in the period after midnight (Fig. 2A). For the 15-h observation period, beetles were observed to be active (activity score of 2 to 3) for 6 ± 1 h (mean ± SE) and inactive (activity score of 0 to 1) for 9 ± 1 h. The proportion of beetle observations at different activity levels is shown in Fig. 2B. The vast majority of beetle movements were by walking with only four QLB flight bouts observed. In three of these instances, flights were observed in the period just after the beetle emerged from the cardboard tube (retreat). The remaining flight bout was observed ~2 h before lights on.

Field Tracking

Initial wind tunnel testing showed that tagged QLB were flight capable. Several tagged beetles flew when disturbed or were approached by the researchers. Further, tagged QLB were observed to move without apparent constraints by the nitinol wire tag antenna (which was observed to bend when the beetles encountered obstacles) or the affixed diode.

Study 3 successfully tracked five QLB over a period of multiple days. The two longest beetle movement paths are shown in Fig. 5A to B. The other three beetles either one took one step (2 beetles) or stayed in the release tree (1 beetle). Individual beetles were followed for varying periods of time ranging from 1 to 10 d. In four instances tracking ended with the discovery of a detached (lost) tag. The fifth beetle (the smallest released) was not detected after the second tracking day, and no tag was recovered. QLB path lengths (sum of all observed steps) range from 2 to 80.7 m with a mean of 30 ± 14 m (± SE). Distance from the release point ranged from 2 to 39.3 m with a mean of 18 ± 7 m (± SE). Beetles moved at an average rate of 5 ± 1 m/d (mean ± SE). QLB were most often located in trees with a majority of tree observations below 5 m (Fig. 5C). Most beetles located in the tree canopy were not sighted visually but were instead detected by HR signal only (several beetles were sighted either by climbing the trees or from the ground). Three beetle locations were particularly cryptic and finding these beetles would have been very difficult without the HR signal detection. These locations included two where QLB were under or inside dead leaves and one where the beetle was found over a piece of tarp (Fig. 3A).

Study 4 successfully tracked four QLB over a roughly four-hour period on a single night. The two longest beetle movement paths are shown in Fig. 5D to E. The other two beetles stayed in the release trees in one case moving into tree foliage fairly low in the tree and in the other moving into the tree canopy (> 5 m). QLB path lengths (sum of all observed steps) ranged from several meters (horizontal movement) to 32 m. Distance from the release point ranged from several meters to 21.0 m. Similar to observations from Study 3, QLB were most often located in trees with a majority of tree observations below 5 m (Fig. 5F). Two of beetles are presumed to have flown during the tracking period, although this was not observed directly, due to rapid transitions into the tree canopy. The other two beetles likely did not fly, again based on the movement progress observed.

Citizen Science Mapping

A total of 380 records were submitted between 5 April 2020 and 15 September 2025. Each submission was reviewed individually by a subject matter expert. Attached photographs were evaluated, and records were annotated with a species identification, reviewer initials, and the date of verification. Of the 373 submissions, 211 were confirmed as *A. aesthetica*. Reports lacking sufficient photographic evidence or depicting non-target species were excluded from analysis. Verified records were exported to ArcGIS Pro (version 3.5.2) for spatial and temporal analysis. Annual subsets were created for the years 2020 to 2025, with observations classified as either new (reported in the focal year) or cumulative (reported in prior years) (Fig. 6). The Calculate Density tool was applied to each year's dataset using 1 km hexagonal bins and a 2 km neighborhood size. Resulting density surfaces were symbolized with a sequential color ramp and overlaid with point data to visualize clustering and the geographic progression of reported infestations (Fig. 6).

Reports of beetle finds were highest in May to July and lowest in December-February (Fig. 7A). The highest number of reports were received in the first 2 yr of the project (2020 to

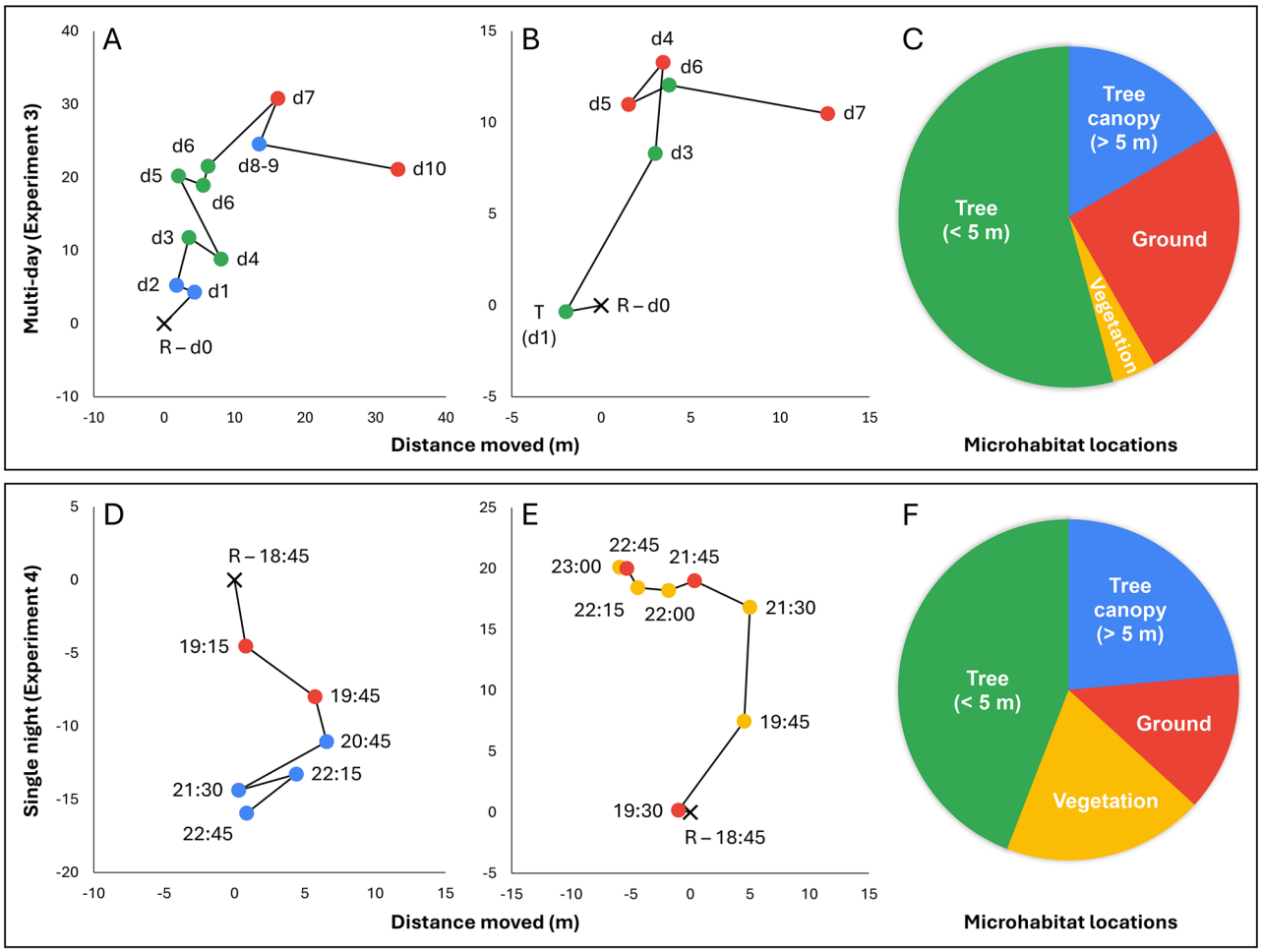


Fig. 5. *Acalolepta aesthetica* tracks obtained by locating tagged individuals using harmonic radar. A to B) show representative tracks of two beetles followed over the course of several days while D to E) show the tracks of two beetles followed for one evening. C) and F) show summaries of where beetles were located (all beetle observations). R = release point, colored dots in A), B), D), and E) correspond to color coded locations noted in C) and F).

2021, roughly 50 to 60 reports/yr), with reports decreasing thereafter (roughly 20 to 30 reports/yr). The number of QLB reports decreased with increasing elevation (Fig. 7B). Roughly 2/3rds of all reports were from below 150 m, while 93% were from under 300 m. After the first year of report collection (2020), 23 ± 7% (mean ± SE) of all reports constituted range expansions beyond what was documented from previous years (Fig. 7C). In 2021 and 2022, the QLB range, based on public reports, expanded both inland (higher elevations) and along the coast (Fig. 6). For 2023 and 2025, QLB range expansion was mostly observed to be moving along the coast with less inland movement.

Discussion

Results from this interdisciplinary research provide information about multiple aspects of QLB biology that are relevant to improving existing surveillance and control methods. The sequencing analysis (Study 1) place QLB in a phylogenetic context which will allow the development of diagnostic tools to differentiate QLB from other longhorn beetles. Laboratory and field observations of QLB (Studies 2 to 4) suggest that beetles are largely sedentary, move mostly by walking with rare flights, and spend most of their time in trees. Finally, citizen science reports (Study 5) provided information on QLB annual population fluctuations, abundance by elevation, and range expansion.

Genetic analysis based on 600 bp of the mitochondrial gene cytochrome oxidase 1 (CO1) sequence suggests *A. aesthetica* is more closely related to beetle species in the cerambycid tribe Monochamini, none of which are on Hawai'i Island, than to locally present cerambycids (Fig. 4). Though bootstrap support for these relationships are low, the lack of CO1 sequence diversity in Hawaii Island QLB maximizes its utility as a diagnostic locus.

Wind tunnel observations suggest that QLB are mostly nocturnally active as no beetle movements were observed before broad spectrum bioassay lighting was switched off (infrared illumination continued) (Fig. 2A). This is consistent with reports that most lamiines are nocturnal or crepuscular (Monné et al. 2017) and mirrors behavior observed using cameras in the wild (Torres-Vila et al. 2024). QLB do not appear to have a distinct activity peak but instead are somewhat uniformly active (roughly 60% to 80% of beetles showed some activity during an hourly block) throughout scotophase. The observed QLB spent more time resting and hiding than engaged in movement (Fig. 2B). Periods of high activity, including flight bouts, were rare.

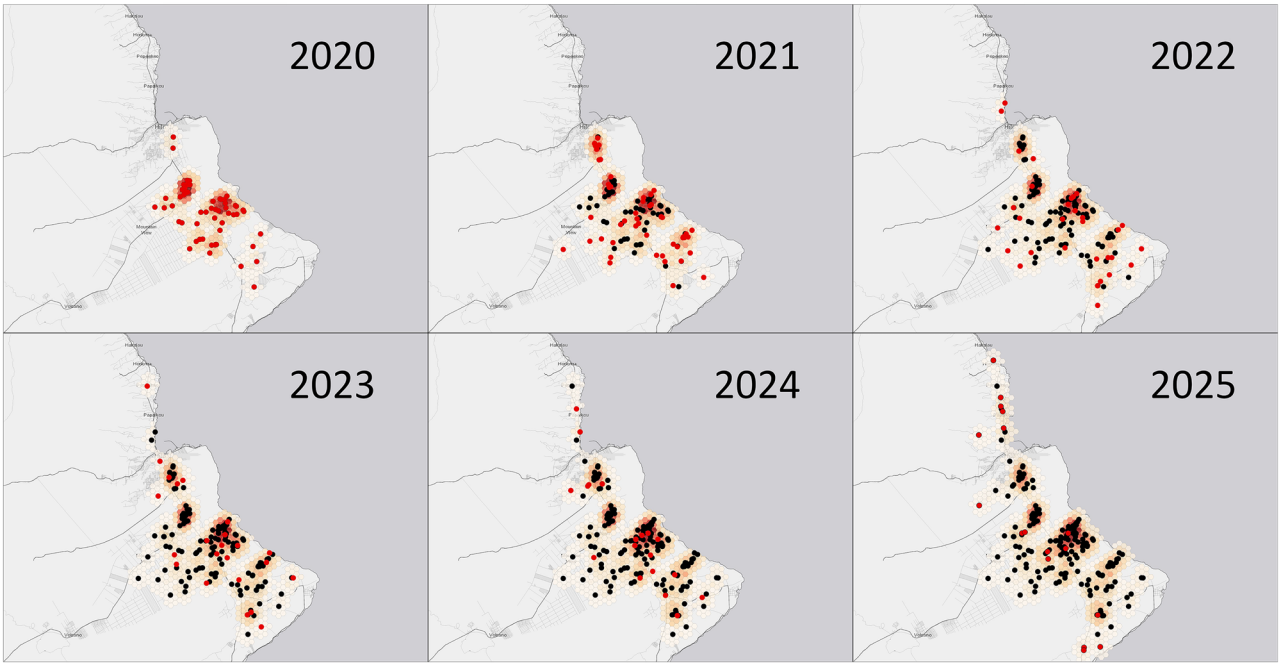


Fig. 6. *Acalolepta aesthetica* locations on the east side of Hawai'i Island shown by year as reported by the public. Red dots indicate QLB find locations reported in the year listed in the top right corner of each panel. Black dots indicate locations from previous years.

Field tracking using harmonic radar showed most QLB movements were confined to the roughly 1,800 m^2 of the Kukui tree stand. Sweeps of the surrounding grassy areas and nearby vegetation failed to find beetles that had moved beyond the immediate vicinity of the Kukui. Taken together, the wind tunnel observations and field tracking suggest that QLB are fairly sedentary (spending an appreciable amount of time not moving), do much of their movement by walking with occasional flight bouts, and are cryptic in their behavior (either blending in with the natural vegetation or actively hiding). Kukui is reported to be a preferred QLB host, and this study supports that conclusion as the majority of beetle microhabitat locations were in Kukui trees (Fig. 5C and F). QLB were found on the trunks of trees, on branches and on leaves.

QLB movement distances reported in this study are in two dimensions (beetle microhabitat height was not addressed) and therefore underestimate the total distances that beetles are moving in the environment. Modifications to the search protocol could likely yield height estimates by relating transceiver signal attenuation settings and signal strength to tag distance. The movement distances observed in this study are general agreement with previous harmonic radar tracking of the cerambycids *Anoplophora glabripennis* (Williams et al. 2004) and *Monochamus alternatus* (Zhang et al. 2020). Williams et al. (2004) reported daily movement rates of ~2 to 4 m/d while Zhang et al. (2020) found that no tagged beetles moved beyond 20 m from the release site during the first week of tracking and not beyond 70 m during the second week.

Utilizing citizen scientists to monitor invasive species (Gallo and Waitt 2011, Johnson et al. 2020, Pawson et al. 2020, Encarnação et al. 2021, Howard et al. 2022) and insects in particular (Caley et al. 2020, Marchante et al. 2024, Roy et al. 2024, Sheard et al. 2024) has become an increasingly important tool for scientists and management agencies attempting to mitigate the effects of introduced organisms. However, there are some complicating factors in using reports from the general public, such as variations in pest awareness over time and spatial and temporal mismatches between human spheres of activity of invasive species distribution. With those limitations acknowledged, documentation of QLB observations do allow a rough delimitation of beetle populations on the east side of Hawai'i Island, potential habitat suitability limitations (elevation and temperature), and how these populations expand over time. Only one beetle was reported from a location over 500 m in elevation which may represent a habitat limitation. During the 6 yr of this study, the average monthly temperature for May to July (months with highest QLB reports) near the highest elevation location report a range from 19.1 to 20.6 °C (weather station at 19.548, −155.127, 561 m elevation). For comparison, the average monthly temperature at the Hilo airport (19.717, −115.051, 12 m elevation) for the same time period ranged from 26.8 to 29.5 °C. Both elevation and temperature are known to affect cerambycid ranges (Koutroumpa et al. 2013, Zhang et al. 2025). Additional empirical studies are needed to determine QLB physiological limits more fully.

It has long been recognized that basic ecological research supports pest insect management and eradication measures (Walter 2003, Liebhold et al. 2016). The sequencing analysis (Study 1) can be used to develop diagnostics to accurately identify invasive beetle species. Data related to the spatial and temporal distribution of QLB at the field level (Studies 2 to 3) can inform where to inspect for pest presence, where to apply insecticides, and how cultural practices might be changed to decrease negative QLB impacts. Additionally, the larger scale spatial and temporal distribution (Study 4) informs the optimal timing for QLB population surveillance and suppression (beginning in April), where to look for range expansion on Hawai'i Island

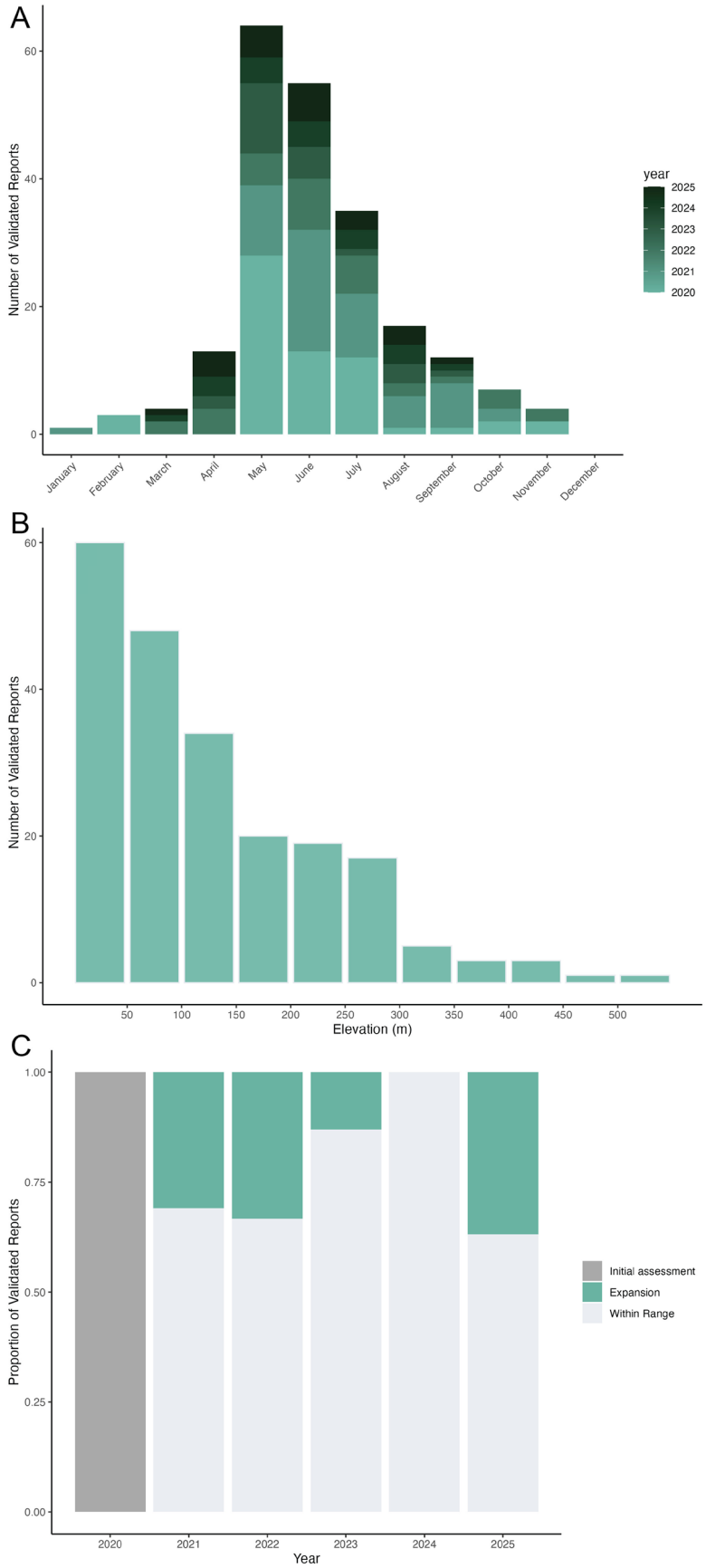


Fig. 7. *Acalolepta aesthetica* locations reported by the public shown by month A), by elevation B), and by range expansion status C). Over the 6 yr of this study, beetles were reported most often in May and the least in December A). Ninety-three percent of all reports were at elevations under 300 m B). From 2021 to 2025, 23 ± 7% (mean ± SE) of all reports constituted range expansions C). All reports which included a beetle photo were validated visually. Of 373 reports between 5 April 2020 and 16 July 2025, 215 (56.6%) reports were identified as QLB.

(in lower elevation, warmer areas) and potential incursions on other islands. Together these studies can be used to inform QLB pest management efforts and more broadly we hope this interdisciplinary approach can serve as a framework for research response efforts to invasive insects.

Acknowledgements

We would like to thank Kamehameha Schools Hawai'i Campus for allowing us to track tagged beetles on their property and Amberly Buer and Charmaine Sylva for sample collection support. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture (USDA). USDA is an equal-opportunity employer.

Author Contributions

Matthew Samuel Siderhurst (Conceptualization [equal], Data curation [equal], Formal analysis [equal], Investigation [equal], Methodology [equal], Resources [equal], Supervision [equal], Visualization [equal], Writing—original draft [equal]), Sheina Sim (Conceptualization [equal], Data curation [equal], Funding acquisition [equal], Investigation [equal], Methodology [equal], Project administration [equal], Resources [equal], Supervision [equal], Visualization [equal], Writing—original draft [equal]), Jason Dzurisin (Data curation [equal], Formal analysis [equal], Investigation [equal], Methodology [equal], Visualization [equal], Writing—original draft [equal]), Franny Brewer (Investigation [equal], Writing—review & editing [equal]), Jade Miyashiro (Investigation [equal], Writing—review & editing [equal]), Stacey Chun (Investigation [equal], Writing—review & editing [equal]), Nicole Miller (Investigation [equal], Writing—review & editing [equal]), Theodore Yoder (Investigation [equal], Writing—review & editing [equal]), Anika Hurst (Investigation [equal], Writing—review & editing [equal]), Renee Corpuz (Investigation [equal], Writing—review & editing [equal]), Keena Curbelo (Investigation [equal], Writing—review & editing [equal]), and Stephanie M Gayle (Investigation [equal], Writing—review & editing [equal])

Funding

This research was supported by funding from the U.S. Department of Agriculture, Agricultural Research Service appropriated projects 'Advancing Molecular Pest Management, Diagnostics, and Eradication of Fruit Flies and Invasive Species' (2040-22430-028-000-D) and 'Development of New and Improved Surveillance, Detection, Control, and Management Technologies for Fruit Flies and Invasive Pests of Tropical and Subtropical Crops' (2040-22430-027-000-D).

Conflicts of Interest

None declared.

Data Availability

The data that support the findings of this study are available from the USDA, National Agricultural Library, Ag Data Commons. There are no restrictions on data availability.

References

Caley P, Welvaert M, Barry SC. 2020. Crowd surveillance: estimating citizen science reporting probabilities for insects of biosecurity concern: implications for plant biosecurity surveillance. *J. Pest Sci.* 93:543–550.

Collignon RM, Siderhurst MS, Millar JG, et al. (2019) Response of invasive longhorn beetles (Coleoptera: Lamiinae) to known cerambycid aggregation-sex pheromones in the Puna District of Hawaii Island.

Encarnação J, Teodósio MA, Morais P. 2021. Citizen science and biological invasions: a review. *Front. Environ. Sci.* 8:602980.

Gallo T, Waitt D. 2011. Creating a successful citizen science model to detect and report invasive species. *BioScience* 61:459–465.

Grove SJ. 2002. Saproxylic insect ecology and the sustainable management of forests. *Annu. Rev. Ecol. Syst.* 33:1–23.

Haack RA. 2006. Exotic bark-and wood-boring coleoptera in the United States: recent establishments and interceptions. *Can. J. For. Res.* 36:269–288.

Haack RA, Byler JW. 1993. Insects and pathogens: regulators of forest ecosystems. *J. For.* 91:32–37.

Haack RA, Hérard F, Sun J, et al. 2010. Managing invasive populations of Asian longhorned beetle and citrus longhorned beetle: a worldwide perspective. *Annu. Rev. Entomol.* 55:521–546.

Howard L, Van Rees CB, Dahlquist Z, et al. 2022. A review of invasive species reporting apps for citizen science and opportunities for innovation. *NB.* 71:165–188.

Hulme PE. 2021. Unwelcome exchange: international trade as a direct and indirect driver of biological invasions worldwide. *One Earth* 4:666–679.

Jang EB, Carvalho LA, Stark JD. 1997. Attraction of female oriental fruit fly, *bactrocera dorsalis*, to volatile semiochemicals from leaves and extracts of a nonhost plant, panax (*polyscias guilfoylei*) in laboratory and olfactometer assays. *J. Chem. Ecol.* 23:1389–1401.

Johnson BA, Mader AD, Dasgupta R, et al. 2020. Citizen science and invasive alien species: an analysis of citizen science initiatives using information and communications technology (ICT) to collect invasive alien species observations. *Glob. Ecol. Conserv.* 21:e00812.

Keena MA, Trotter , RTIII Roe AD, et al. 2026. New insights on the ecology, economics, and management of *anoplophora* longhorned beetles (coleoptera: Cerambycidae: Lamiinae). *Curr. For. Rep.* 12:7.

Koutroumpa FA, Rougon D, Bertheau C, et al. 2013. Evolutionary relationships within European *monochamus* (coleoptera: Cerambycidae) highlight the role of altitude in species delineation. *Biol. J. Linn. Soc. Lond.* 109:354–376.

Liebhold AM, Berec L, Brockerhoff EG, et al. 2016. Eradication of invading insect populations: from concepts to applications. *Annu. Rev. Entomol.* 61:335–352.

Lowe S, Browne M, Boudjelas S, et al. (2000) 100 of the world's worst invasive alien species: a selection from the global invasive species database. Invasive Species Specialist Group Auckland.

Marchante E, López-Núnez FA, Duarte LN, et al. 2024. The role of citizen science in biodiversity monitoring: when invasive species and insects meet: biological invasions and global insect decline (ed. *Elsevier* 291–314.

Marchioro M, Faccoli M. 2021. Successful eradication of the asian longhorn beetle, *anoplophora glabripennis*, from North-Eastern Italy: protocol, techniques and results. *Insects* 12:877.

Matsunaga JN, Chun SG. (2018) New pest advisory: *Acalolepta aesthetica* (Oellif), a longhorned beetle (Coleoptera: Cerambycidae): Hawai'i Department of Agriculture, Honolulu, HI, USA.

Miles BJ. (2022) *Characterization of Queensland Longhorn Beetle (Acalolepta Aesthetica Olliff) Distribution, Host Selection Preference, and Environmental Correlations in Puna District, Hawai'i County, Hawai'i, Vol.* Masters: University of Hawai'i at Hilo, Hilo, HI.

Monné ML, Monné MA, Wang Q. (2017) *General morphology, classication, and biology of Cerambycidae: Cerambycidae of the world: biology and pest management* (ed. by Wang Q) CRC Press.

Paradis E, Schliep K. 2019. ape 5.0: an environment for modern phylogenetics and evolutionary analyses in R. *Bioinformatics* 35:526–528. https://doi.org/10.1093/bioinformatics/bty633

Parry D, Teale S (2011) *Alien invasions: the effects of introduced species on forest structure and function: forest health: an integrated perspective* (ed. by Castello JD & Teale SA) Cambridge University Press, pp. 115–162.

Pawson S, Sullivan J, Grant A. 2020. Expanding general surveillance of invasive species by integrating citizens as both observers and identifiers. *J. Pest Sci.* 93:1155–1166.

Roy HE, Martinou AF, Pocock MJ, et al. 2024. The global reach of citizen science for monitoring insects. *One Earth* 7:552–557.

Sheard JK, Adriaens T, Bowler DE, et al. 2024. Emerging technologies in citizen science and potential for insect monitoring. *Philos. Trans. R Soc. Lond. B Biol. Sci.* 379:20230106.

Siderhurst MS, Ladizinsky N, Hurst AL, et al. 2025. Harmonic radar tags for insect tracking: lightweight, low-cost, and accessible. *J. Vis. Exp.* 219:e67812. https://doi.org/10.3791/67812

Smith MJ, Turgeon JJ, De Groot P, et al. 2009. Asian longhorned beetle *anoplophora glabripennis* (motschulsky): lessons learned and opportunities to improve the process of eradication and management. *Am. Entomol.* 55:21–25.

Sofaer HR, Miles BJ, Zarders JA, et al. 2025. Host preferences of non-native *acalolepta aesthetica* (coleoptera: Cerambycidae) on the island of hawai'i. *Agri. For. Entomol.*

Sun J, Koski T-M, Wickham JD, et al. 2024. Emerald ash borer management and research: decades of damage and still expanding. *Annu. Rev. Entomol.* 69:239–258.

Teale S & Castello J, eds. (2011) *Regulators and terminators: the importance of biotic factors to a healthy forest*. Cambridge University Press.

Tennant LE. (2021) The ecology of *Wasmannia auropunctata* in primary tropical rainforest in Costa Rica and Panama: Exotic ants (ed. CRC Press), pp. 80-90.

Tobin PC, Liebhold AM, Roberts EA, et al. (2015) Estimating spread rates of non-native species: the gypsy moth as a case study: Pest risk modelling and mapping for invasive alien species (ed. CABI Wallingford UK, pp. 131–144.

Torres-Vila LM, López-Calvo R, Ponce-Escudero F, et al. 2024. Phototrap-assessed diel activity of *cerambyx cerdo* and *cerambyx welensii* sympatric populations in the wild: does extreme drought boost diurnality? *Agri. For. Entomol.* 26:485–495.

Ulyshen MD. 2016. Wood decomposition as influenced by invertebrates. *Biol. Rev. Camb. Philos. Soc.* 91:70–85.

Venette RC & Hutchison WD (2021) Invasive insect species: global challenges, strategies & opportunities, Vol. 1: *Front Insect Sci*, p. 650520.

Walter GH. (2003) *Insect pest management and ecological research*. Cambridge.

Wetterer JK, Porter SD. (2003) The little fire ant, *Wasmannia auropunctata*: distribution, impact and control.

Williams DW, Li G, Gao R. 2004. Tracking movements of individual *anoplophora glabripennis* (coleoptera: Cerambycidae) adults: application of harmonic radar. *Environ. Entomol.* 33:644–649.

Zhang L, Wang P, Xie GL, et al. 2025. Assessing the potential distribution of *pseudoechthistatus* (coleoptera: Cerambycidae) in China under climate change using species distribution models. *Ecol. Evol.* 15:e71303.

Zhang ZY, Zha YP, Cai SS, et al. 2020. Application of harmonic radar to analyze dispersal behavior of the japanese pine sawyer beetle, *monochamus alternatus* (coleoptera: Cerambycidae). *Entomol. Res.* 50:50–58.