New Records and Accounts

First Record of the Coffee Berry Borer, *Hypothenemus hampei* (Ferrari, 1867), on the Hawaiian Island of Lanai (Coleoptera: Curculionidae: Scolytinae)

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Abstract. A survey for scolytine bark and ambrosia beetles undertaken on the entomologically understudied Hawaiian island of Lanai revealed for the first time the presence there of the coffee berry borer, *Hypothenemus hampei* (Ferrari, 1867), a serious exotic pest of cultivated coffee. Lanai is chronologically the fourth Hawaiian island on which *H. hampei* has been found, following its initial detection on the island of Hawaii, followed by Oahu then Maui. We present the new records from Lanai in detail, together with a map of collecting sites and photographs of an adult specimen, demonstrating that the beetle is now widespread on Lanai, occurring at high and low elevations, and in both mesic and xeric environments.

Key words: Bark beetle, *Coffea arabica*, Hawaii, invasive species, crop pest, Maui Nui

In the past decade there has been an increased interest in bark and ambrosia beetles (Coleoptera: Curculionidae: Scolytinae) in the Hawaiian Islands, primarily because of the potential or actual status of a number of species as pests of plants of economic, conservation, and cultural importance. Recently two serious scolytine-associated threats have arisen in Hawaii. First the fungal disease known as "rapid ohia death" caused by fungi of the genus *Ceratocystis* Ellis & Halst. (Ceratocystidaceae), the transmission of which has been associated with scolytine beetles (Kawabata et al. 2017, Barnes et al. 2018, Roy et al. 2018) and poses a serious threat to *Metrosideros polymorpha* Gaudich. (Myrtaceae), one of the most widespread and iconic native tree species across the archipelago. And second, the arrival of the invasive "coffee berry borer" (CBB), *Hypothenemus hampei* (Ferrari, 1867), on the islands—a serious global pest of cultivated coffee (Burbano et al. 2011) (Figure 1). Consequently, the monitoring and documentation of the distribution and composition of bark beetle communities across the state has become increasingly important (Gillett and Rubinoff 2017, Gillett et al. 2019a).

CBB is native to tropical Africa but has dispersed to most coffee-growing regions of the world and is now the most widespread and destructive pest of the

Figure 1. Dorsal and lateral views of an adult female specimen of *Hypothenemus hampei* (Ferrari, 1867), the coffee berry borer, from Munro Trail, Lanai. Length of specimen: 1.6 mm. Photograph by C.P.D.T. Gillett.

crop, causing an estimated half a billion dollars annually through damage to yield and quality (Vega et al. 2015, Chapman et al. 2015). CBB-infested berries can typically be recognized by a c. 1 mm bore hole at the very tip of the berry made by a female beetle to gain access to the inside of the berry, in which she lays up to 50 eggs in endosperm tissue (the "bean"), on which the larvae develop. The beetle poses a serious challenge to coffee production in Hawaii, where it is currently managed through monitoring, field sanitation, strip-pruning, and application of the entomophagic fungus *Beauveria bassiana* (Aristizábal et al. 2017, Aristizábal 2018). Potential biological controls against CBB are under investigation, including the eulophid parasitoid wasp *Phymastichus coffea* (Hymenoptera: Eulophidae) (Yousuf et al., in review)

CBB was first reported from the Hawaiian Islands in 2010, when it was recorded from the South Kona District on the leeward side of the island of Hawaii, the most important coffee growing area of the islands (Burbano et al. 2011). Subsequently, CBB was reported in 2014 from Waialua, Oahu (Hawaii Department of Agriculture 2014), and then in 2016 it was discovered infesting coffee cherries in Hana, Maui (Hawaii Department of Agriculture 2016), before being also found in Kipahulu, Ulupalakua, and Haiku on the island. Our initial detection of CBB on Lanai in July 2020 was the subject of a press release announcement by the state Department of Agriculture (2020a). Less than two months after CBB was found on Lanai, it was found on the island of Kauai, as reported in September 2020 (Hawaii Department of Agriculture 2020b). Kauai is the second largest producer of coffee in the Hawaiian Islands.

The island of Lanai is the sixth-largest Hawaiian island in area and the smallest inhabited one that is publicly accessible. It is part of the Maui Nui island complex, which in the past was a single, larger island containing the current high islands

of Maui, Molokai, Lanai, and Kahoolawe (Price and Elliott-Fisk 2004). Lanai has a reputation for having been ecologically devastated, in part owing to the previously widespread intensive pineapple cultivation that took place there, and for which the island is well known, combined with the negative effects brought about by the introduction of many exotic animals and plants (Hobdy 1993). However, vestiges of native biotopes persist, including the most extensive area of lowland dry forest remaining in the Hawaiian Islands at the Kanepuu Preserve (The Nature Conservancy 2011), and mesic and "cloud" forest on the highest part of the island, along the Lanai Hale volcanic ridge (Liebherr 2009). Whilst coffee is not a significant commercial crop in Lanai, coffee plants are grown and harvested in some agricultural lots near the island's airport, and there have been coffee plants at private residential properties throughout Lanai City for years, in addition to "feral" plants around the outskirts of the town (KKB, personal observation).

Hitherto, a total of 13 species of Scolytinae had been recorded from Lanai. Of these, seven are species endemic to the Hawaiian Islands, and the remainder, including two species of *Hypothenemus*, are exotic, adventive species (Nishida 2002).

This article aims to formally record CBB from Lanai for the first time, resulting from recent sampling for bark and ambrosia beetles undertaken on the island in July and August 2020. We present the detailed new records here and discuss the circumstances in which the specimens were collected. We include a map of localities and photographs of an adult specimen from Lanai to aid identification.

Materials and Methods

During July 2020 we sampled for Scolytinae on Lanai as an integral part of an ongoing survey for bark and ambrosia beetles across the Hawaiian Islands that aimwws to contribute to knowledge of their biogeography and evolution (Gillett et al. 2018, 2019b, 2020). We employed Lindgren funnel trapping (Figures 2–4) and/or manual searching of host plants at a total of four sites on the island, varying in elevation between 407 and 1025 masl and encompassing both xeric and mesic/"cloud" forest habitats. Traps were deployed in forested areas containing mixed communities of native and non-native trees and were each baited with approximately 150 ml of an ethanol-methanol solvent lure containing between 40 and 50% ethanol and 50 and 55% methanol (Klean-Strip® Denatured Alcohol), and

Figure 2. Lindgren funnel trap deployed on the native plant *Freycinetia arborea* in mesic / "cloud" forest alongside Munro Trail on Lanaihale, Lanai, July 2020. Photograph by C.P.D.T. Gillett.

Figure 3. Lindgren funnel trap deployed in dryland forest at The Nature Conservancy Kanepuu Preserve, July 2020. Photograph by C.P.D.T. Gillett.

50 ml of commercial anti-freeze car coolant containing ethylene glycol (Prestone® concentrate antifreeze/coolant). The approximate locations of the four sampling sites are indicated in the map in Figure 5. The sites are detailed below, together with an indication of the sampling effort undertaken at each.

Collected specimens were preserved in 95% ethanol and subsequently identified with reference to a combination of dichotomous keys (Wood 2007), descriptions, photographs (Vega et al. 2015), and authoritatively identified specimens held in two Honolulu-based entomological collections: University of Hawaii Insect Museum (UHIM) and the Hawaii Department of Agriculture (HDOA).

Munro Trail, Lanai Hale (Figure 2). We deployed nine Lindgren funnel traps along a transect running the length of a 1.5 km section of the Munro Trail on the summit of Lanai Hale volcano. We suspended each trap from living native plant branches (e.g., *Cheirodendron trigynum*, *Ilex anomala*, *Freycinetia arborea*), at a height of approximately 2 m, in mesic/"cloud" forest lining the Munro Trail road. The transect began near the second snail enclosure heading up from the south (approximate coordinates 20.812685, –156.873387; 1025 masl), and ended at approximately 1.5 km to the north-west further along the road (approximate coordinates 20.820022, –156.881130; 890 masl). The traps were deployed on 17 July 2020 and their contents were collected twice: on 19 July (after 2 days), and on 31 July (after a further 12 days), when the traps were removed, for a total of 126 trap-days (one trap-day equals one trap deployed for 24 hours).

The Nature Conservancy Kanepuu Preserve (Figure 3). We deployed five Lindgren funnel traps in dryland forest within the TNC Kanepuu Preserve, within a narrow elevation range of 515–525 masl. Each trap was suspended from a living native tree branch (e.g., *Diospyros sandwicensis*, *Nestegis sandwicensis*) at a height of approximately 2 m, (approximate trap coordinates: 20.8744222, –156.9788833; 20.8747306, –156.9791361; 20.874964, –156.978989; 20.8791917, –156.9769611; 20.8785, –156.991667). The traps were deployed on 17 July 2020 and their contents were collected twice: on 19 July (after 2 days), and on 31 July (after a further 12 days), when the traps were removed, for a total of 45 trap-days.

Kapano Gulch (Figure 4). Several dozen coffee berries (<100) from multiple trees were manually checked for evidence of CBB infection in an area containing feral *Coffea arabica* L. (Rubiaceae) growing in Kapano Gulch (approximately 20.81730, –156.91253; 540 masl) on 6 August 2020 by KKB. More than half the berries showed clear signs of CBB infestation, and a sample of six potentially

Figure 4. View of a section of Kapano Gulch, with feral coffee, *Coffea arabica* L., visible (center and left), September 2020. Photograph by Kari K. Bogner.

infested berries were split open to reveal beetles and larvae, which were preserved in ethanol together with the berries and sent to CG and JM for confirmation of identification.

Agricultural lots near Lanai airport. Similarly, hundreds of coffee berries were manually inspected for CBB in an agricultural area near Lanai airport during August 2020. This is the main area for coffee cultivation on the island (approximately N20.79670° W156.95030° (407 masl). Three coffee berries displaying typical CBB damage were found, and these were split open to reveal larvae and adults of CBB within (KKB, personal observation).

Results

Coffee berry borer was recorded and collected from all four sampled sites in Lanai. A total of seven female specimens of CBB were collected in Lindgren funnel traps (six from Munro Trail and one from TNC Kanepuu) and a number of adults and larvae were directly collected from within coffee berries gathered at Kapano Gulch and near Lanai airport. These specimens constitute a **new island record for Lanai** and vouchers are deposited at UHIM, HDOA, and the Bernice Pauahi Bishop Museum (BPBM) as follows:

4 ♀♀ (UHIM); 2 ♀♀ (HDOA): Lanai, Munro Trail (20.821139, -156.880297; 928

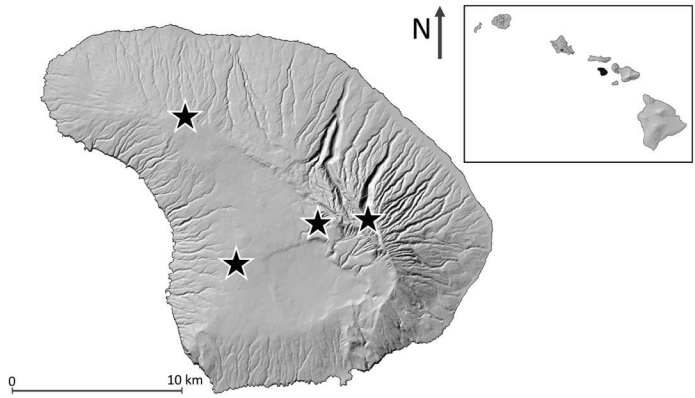

Figure 5. Map indicating the approximate locations (black stars) of the four CBB sampling sites on the island of Lanai. Inset: Position of Lanai (in black) within the Hawaiian Islands archipelago.

m), 31.vii.2020, Lindgren funnel trap set on *Freycinetia arborea*, leg. C.P.D.T. Gillett and D. Honsberger, det. J. Matsunaga and C.P.D.T. Gillett.

1 ♀ (UHIM): Lanai, TNC Kanepuu Preserve (20.8747306, -156.9791361; 525 m), 31.vii.2020, Lindgren funnel trap set on *Diospyros sandwicensis*, leg. C.P.D.T. Gillett and D. Honsberger, det. J. Matsunaga and C.P.D.T. Gillett

4 ♀♀ (UHIM); 6 ♀♀ (HDOA); 4 ♀♀ (BPBM): Lanai, Kapano Gulch (20.81730, -156.91253; 540 masl), 06.viii.2020, inside *Coffea arabica* berries, leg. K.K. Bogner, det. J. Matsunaga and C.P.D.T. Gillett.

Discussion

The present new records reveal Lanai as the fourth Hawaiian island to be invaded by CBB, which is the 14th species of Scolytinae to be recorded from the island. It is evident that CBB is widespread on Lanai, having been found at a range of elevations and in both xeric and mesic forest habitats (Figures 2–5). There is a possibility that the species has been present there, undetected, for some time, but it is difficult to estimate an accurate date for its arrival. Feral coffee is widespread across the Hawaiian Islands and is thought to harbor reservoir populations of CBB despite comparatively low infestation rates (Johnson and Manoukis 2020). These feral populations are probably responsible for the presence of the beetle away from areas of coffee cultivation, such as the summit of Lanai Hale and Kanepuu.

Although coffee is not a common commercial crop on Lanai, it is important to document, and now to monitor, populations of CBB there because these might potentially act as a reservoir for the re-infection of commercially important coffee plantations on other islands, especially Maui, which has close transport links with Lanai. Consequently, it will be vital to ensure that Lanai is not neglected when devising control strategies and management practices against CBB.

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