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SCIENTIFIC NOTE

REDISCOVERY OF AN ENIGMATIC BARK BEETLE (COLEOPTERA: CURCULIONIDAE: SCOLYTINAE) ENDEMIC TO THE HAWAIIAN ISLANDS

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The Hawaiian archipelago is one of the most isolated land masses on the planet. It harbors a fauna containing over 10,000 endemic insect species that is largely the result of the disharmonious and fortuitous arrival of a small number of colonizing ancestral species via long-distance dispersal, followed by subsequent *in situ* diversification (Zimmerman 1948, 1970; Howarth and Mull 1992; Paulay 1994). Extensive environmental deterioration resulting from modification and urbanization of the landscape and the widespread introduction of non-native adventive and invasive species by human settlers have resulted in high extinction rates across most indigenous taxa. Consequently, Hawai'i is often considered the extinction and endangerment capital of the world (Cabin 2013). The islands contain more endangered species per square kilometer than anywhere else on the planet, being home to a quarter of all endangered species in the USA (Messing and Wright 2006). Because insects make up 70% of all endemic animals in Hawai'i (Medeiros *et al.* 2013), their continued survival is a real concern, yet they remain comparatively understudied. Up-to-date records are a useful contribution to knowledge of the distribution and persistence of rarely recorded taxa and are of value to conservation efforts on the islands.

One relatively small radiation of Hawaiian insects is represented by xyleborine ambrosia beetles

(Curculionidae: Scolytinae: Xyleborini), consisting of 21 described endemic species of *Xyleborus* Eichhoff, which are the only native Scolytinae in the Hawaiian Islands (Samuelson 1981). Members of *Xyleborus* typically bore tunnels into dying or dead wood, in which they 'farm' symbiotic fungi as a source of food for their larvae (Kirkendall *et al.* 2015). Xyleborini have an apparent haplo-diploid sex determination system, wherein unfertilized eggs give rise to haploid males, which then mate with their diploid sisters (Kirkendall *et al.* 2015). *Xyleborus* contains hundreds of species (Wood 1986; Wood and Bright 1992). The group was historically somewhat of a 'taxonomic dumping ground', containing many unrelated species (Hulcr and Smith 2010), but it has now been shown to be paraphyletic (*e.g.*, Hulcr *et al.* 2007; Hulcr and Cognato 2013) and is undergoing critical systematic review.

The endemic Hawaiian *Xyleborus* radiation is monophyletic and descended from potentially a single ancestor that arrived in the archipelago 7.5 million years ago (Cognato *et al.* 2018). Eleven of the 21 species are known as single-island endemics, with the remaining species occurring on between two and five islands each (Samuelson 1981). Each of the six main Hawaiian islands (Kaua'i, O'ahu, Moloka'i, Lāna'i, Maui, and Hawai'i) is host to between four and 11 species, and all except Lāna'i contain at least one single-island endemic. The

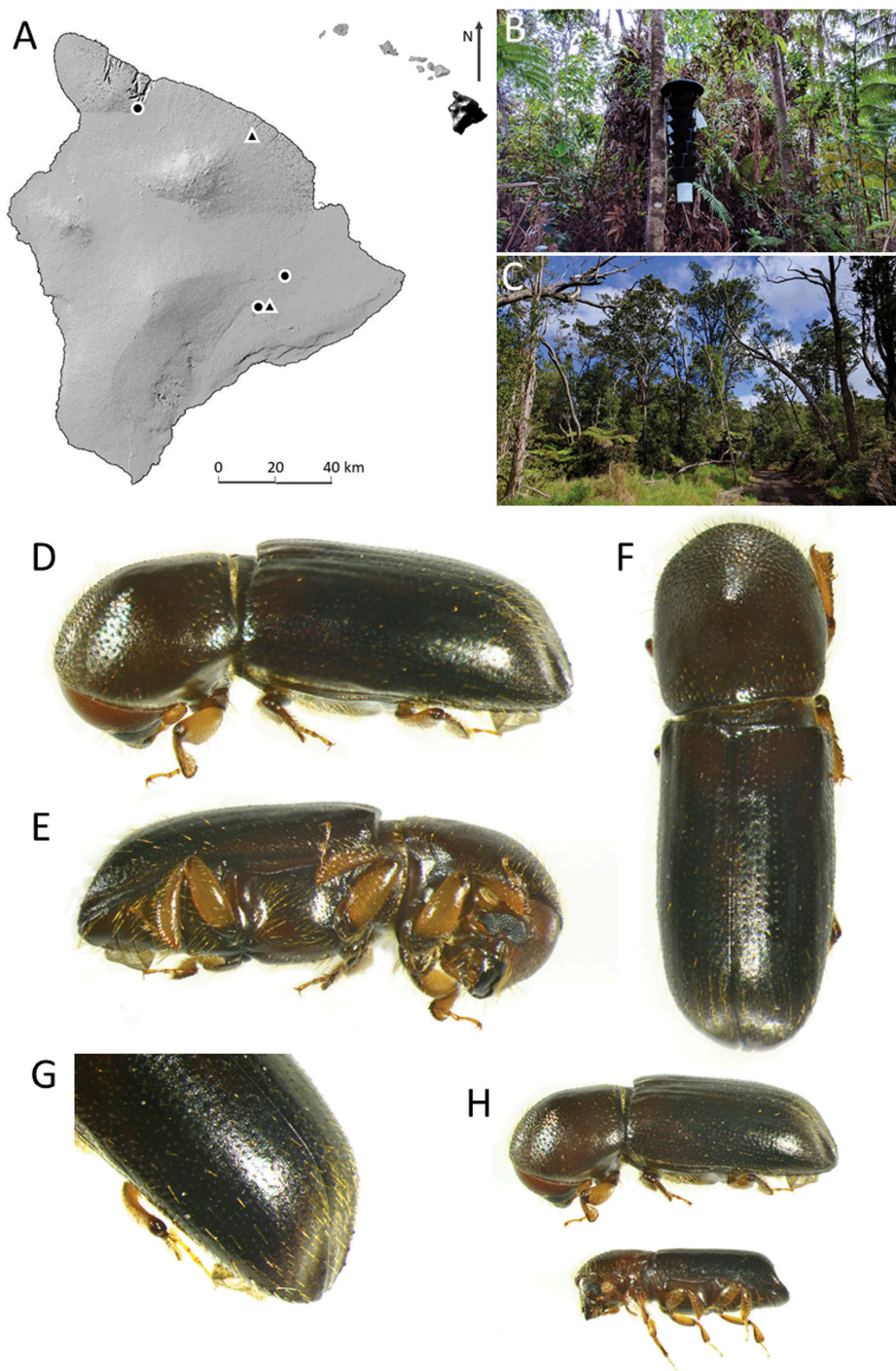


Fig. 1. *Xyleborus pele*. A) Distribution map of collecting localities on Hawai'i Island (circles = historical localities from 1907–1929; triangles = recent localities from 2018), B) Lindgren funnel trap deployed in mixed mesic forest at Kilauea Iki Trail, Hawai'i Volcanoes National Park, February 2018, C) Mixed mesic forest at Laupāhoehoe Experimental Forest Unit (Hilo Forest Reserve), February 2018. Female collected at Kilauea Iki Trail, 23 January 2018, length = 5.0 mm: D) Left lateral view, E) Right lateral view, F) Dorsal view, G) Oblique view of left side of elytral declivity, H) Size comparison of *X. pele* (above) to female *Xyleborus nubilus* Samuelson, 1981 (below), another endemic scolytine from Hawai'i Island. Photographs by Conrad P. D. T. Gillett.

island of Hawai'i contains the largest number of species (11), including five single-island endemics. Published records indicate that 22 plant genera (the vast majority of which are native to Hawai'i) are recorded as hosts for the beetles. Six Hawaiian *Xyleborus* species are each recorded from two or more host plants, and a further 10 species are known from a single host plant each. The remaining five species have unknown host plants (Samuelson 1981). Native Hawaiian plants of the genus *Cheirodendron* Nutt. ex Seem. (Araliaceae), known locally as 'ōlapa' or 'lapalapa', which naturally occur in mesic forest habitats (now largely restricted to elevations above 1,000 m), are recorded as hosts for six species of *Xyleborus*, including four species that have hitherto uniquely been recorded from plants of that genus (Samuelson 1981).

One of Hawai'i Island's endemic and uniquely *Cheirodendron*-associated species is *Xyleborus pele* Samuelson, 1981, described from three female specimens collected at three different localities: Kilauea (1912); 'Ola'a (1920); and the upper Hamakua Ditch Trail (1929) (Fig. 1A) (Samuelson 1981). It is a very distinctive species (Fig. 1D-G) and rather enigmatic for being both the largest native Hawaiian scolytine (4.7–5.0 mm) (Fig. 1H) and named after Pele, the goddess of fire, lightning, wind, and volcanoes, one of the most well-known deities of Hawaiian mythology. As popular legends recount, Pele, being of tempestuous temperament and longing for far-away lands, was driven from her birthplace of Tahiti by her father. She traveled far across the sea by canoe to the Hawaiian Islands, where she, in turn, created the landmark volcanoes on each island she visited, eventually making the summit of Kilauea (one of the world's most active volcanoes) her home (Westervelt 1916). Since its description, no further records of *X. pele* have been published, and it appears that no additional specimens have been collected since 1929. As a result of recent targeted fieldwork surveying for native Hawaiian scolytines, we are able to present recent records for *X. pele* from two sites on Hawai'i Island, including a new locality for the species, indicating that the species remains present in native forest ecosystems.

To survey native Hawaiian scolytines, we trapped at several localities containing native forest on Hawai'i Island during 2017–2018. Lindgren funnel traps baited with an ethanol/methanol solvent lure (Klean-Strip® denatured alcohol) containing 40–50% ethanol and 50–55% methanol, and anti-freeze coolant containing ethylene glycol, were suspended from living native tree branches in mesic tropical forest areas. Trapped specimens were collected approximately every two weeks, when the traps were checked and rebaited with fresh lures. Five traps, separated from each other by approximately 50–100 m, were deployed at each of two

sites, Kilauea Iki trail in Hawai'i Volcanoes National Park and Laupāhoehoe Hawai'i Experimental Tropical Forest unit, between 18 December 2017 and 19 February 2018 (63 days) and between 4 January and 15 February 2018 (42 days), respectively.

Collected specimens were preserved in 95% ethanol and identified using the keys in Samuelson (1981) and by comparison to specimens held in the three Honolulu-based entomological collections listed below. Specimen length was measured from the elytral apices to the pronotal apex, and photographs of specimens were taken with a Nikon D-7100 DSLR camera mounted on an Olympus stereomicroscope. The images were subsequently focus-stacked using Helicon Focus (Helicon Soft) running on an iMac computer.

In addition to newly collected material, the following three institutional entomological collections in Hawai'i were studied:

BPBM	Bernice Pauahi Bishop Museum, Honolulu
HDOA	State of Hawai'i Department of Agriculture, Honolulu
UHIM	University of Hawai'i Insect Museum, Honolulu

Additionally, enquiries were made to the curators of the following collections known to contain important holdings of entomological specimens from the Hawaiian Islands:

AMNH	American Museum of Natural History, New York, NY
BMNH	Natural History Museum, London, UK
CAS	California Academy of Sciences, San Francisco, CA
HALE	Haleakalā National Park, Maui, HI
HAVO	Hawai'i Volcanoes National Park, HI
NMNH	US National Museum of Natural History, Smithsonian Institution, Washington DC
UHH	University of Hawai'i at Hilo, HI

The following are the data from the newly collected specimens: One female, length 5.0 mm (Fig. 1D–H), Hawai'i Island: Kau District, Kilauea Iki Trail, Hawai'i Volcanoes National Park, 23.i.2018, Lindgren funnel trap set on *Cheirodendron trigynum* (Gaudich.), 19.4133°N, 155.2391°W, 1,180 m elevation, mixed mesic forest, leg. C.P.D.T. Gillett (UHIM). One female, length 5.0 mm, Hawai'i Island: Hilo District, Laupāhoehoe Hawai'i Experimental Tropical Forest unit, Hilo Forest Reserve, 23.i.2018, Lindgren funnel trap set on *Cheirodendron trigynum*, 19.946°N, 155.2844°W, 980 m elevation, mixed mesic forest, leg. C.P.D.T. Gillett (UHIM). One female, length 4.9 mm, same data as preceding specimen except 01.ii.2018, leg. C.P.D.T. Gillett (UHIM).

Beyond the type series held at BPBM (data in Samuelson 1981), the only preserved specimens that we are aware of are four females held at NMNH collected in 1907 by W. Ashmead and identified by Donald Bright (L. Chamorro, personal communication), with the following data: One female, Hawai'i Island: Olaa, 2,000 ft [610 m], 19.vii.1907, W.H. Ashmead, det. D. Bright (NMNH). Three females, Hawai'i Island: Kilauea, 4,000 ft [1,220 m], 21.vii.1907, W.H. Ashmead, det. D. Bright (NMNH).

We interpret the locality name 'Olaa' on old labels as the environs of the present 'Ola'a Forest Reserve in Puna District, currently spanning elevations between approximately 400 and 1,200 m. The current town of Kea'au was formerly known as 'Ola'a, but because it lies at approximately 100 m elevation, it is inconsistent with the label data and is probably not the collecting locality in those cases. Collecting localities are shown in Fig. 1A–C.

The two localities where *X. pele* was found during January–February 2018 share similarities, including the dominance of native Hawaiian trees and shrubs, a comparable elevation, and a windward aspect or exposure. However, tree communities at the two sites differ in that the forest at Kilauea is dominated by 'ōhi'a lehua, *Metrosideros polymorpha* Gaudich. (Myrtaceae), whereas that of Laupāhoehoe is dominated by *Acacia koa* A. Gray (Fabaceae), although both sites contain a rich understory of other indigenous trees, including *Cheirodendron* species, the previously known host plant of *X. pele*.

Xyleborus pele is recorded from elevations ranging between 610 and 1,220 m, although it is unlikely that the species now persists at the lower elevation boundary, where exotic and invasive plants, in addition to invasive predatory ants, can be expected to dominate. All known collecting sites lie on the wet 'windward' side of the island of Hawai'i (from Hamakua District in the north, to Kau District in the south), where mixed mesic forests are most common.

A total of 525 trap-days was necessary to collect the three specimens reported here, indicating that the beetles were either difficult to sample using Lindgren funnel traps with ethanol-methanol lures, present in small numbers, or not very flight-active. Five other species of native Hawaiian *Xyleborus* were also collected at the two sites during the sampling period. However, two species of adventive scolytines, *Xylosandrus crassiusculus* (Motschulsky) and *Xyleborinus saxeseni* (Ratzeburg), dominated the catch, with the abundance of each being an order of magnitude greater than that of all six native species combined (unpublished data). It should be highlighted here that the three newly recorded female specimens each are slightly longer than

previously examined specimens, extending the maximum length to 5.0 mm (from 4.95 mm). The male of *X. pele* remains unknown.

The rediscovery of *X. pele* 89 years since it was last collected is a small and rare piece of welcome positive news for Hawaiian invertebrate conservation. It serves as a reminder of both how understudied Hawai'i's unique insect fauna remains to this day, and that despite the degradation and fragmentation of indigenous forests, native insects persist wherever their habitat remains largely intact. It is fitting that the rediscovery of *X. pele*, a beetle whose ancestor made a long and fortuitous oceanic crossing to the Hawaiian Islands long ago, took place on the very volcano where its mythological namesake made her home following a similarly long overseas journey.

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