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Two new endemic cave-living moths from Hawai‘i Island: a new species of *Pseudoschrunkia* (Erebidae), and a new species of *Mestolobes* (Crambidae)

MATTHEW J MEDEIROS¹ & FRANCIS G HOWARTH²

¹The Urban School of San Francisco, 1563 Page St, San Francisco, CA, 94117 USA, and Department of Integrative Biology, 3060 Valley Life Sciences Building, University of California, Berkeley, CA, 94720 USA. E-mail: matt.j.medeiros@gmail.com

²Department of Natural Sciences, Bishop Museum, 1525 Bernice St, Honolulu, HI, 96817

Abstract

Two new endemic Hawaiian Lepidoptera species are herein described; both are associated with caves. The new species, *Pseudoschrunkia nohoana* sp. nov. and *Mestolobes olali* sp. nov., have been found exclusively in caves or cave entrances on the Big Island of Hawai‘i, although neither species appears to possess any specializations for living in caves.

Key words: Crambinae, Hawaii, Hypenodinae, morphology

Introduction

Since the first report of a unique Hawaiian cave biota over forty years ago (Howarth 1972), these lava tube caves continue to yield noteworthy discoveries. Lava tubes in Hawai‘i are common especially on young islands such as the Big Island of Hawai‘i, where many caves are only hundreds or thousands of years old, and form when lava moving downslope quickly cools on the outside and then drains from the inside. Lava tube caves can be divided into several ecological zones (Howarth 1973, 1993): a deep zone, characterized by relatively unchanging abiotic conditions, especially where the atmosphere remains nearly constantly saturated with water vapor; a twilight zone, where ambient light gradually diminishes; a transition zone, a dark area between these two where abiotic factors, especially relative humidity, are affected by weather events on the surface; and an entrance zone, at the mouth of the cave where light is sufficient to support vascular vegetation. Nutrient input beyond the entrance zone in Hawaiian lava tubes is largely via roots of trees that dangle down through the roof of the cave. These are often from the endemic ‘ōhi‘a tree (Myrtaceae: *Metrosideros polymorpha*), but other species are important locally (Howarth 1973, Howarth et al. 2007).

Pseudoschrunkia is an endemic Hawaiian genus described by Zimmerman (1958a) to include three distinctive species originally described by Meyrick and placed in the widespread genus *Hypenodes*. Of these three original species, only four specimens were used in the original descriptions, and very few individuals have been collected since (Medeiros 2015). Subsequently, Medeiros (2015) described a new species of *Pseudoschrunkia*, *Pseudoschrunkia brevipalpis*, with markedly reduced labial palps, yet with nearly identical male genitalia as those found in the original three species.

Mestolobes Butler 1882 is a genus of crambine moths endemic to the Hawaiian Islands. The 31 species in this genus were all described by Meyrick, Butler, and Swezey (Zimmerman 1958b). Little is known of their biology, and the group is in want of study and revision, especially as several species described by Meyrick are known from only female specimens. Unsorted museum specimens at the Bishop Museum (Honolulu, HI) suggest that many additional species await description (Medeiros & Howarth, pers. obs.). The genus is characterized by a “jugal lobe” attached to the hind wing in males, and a pair of “accessory sacs” in the female genitalia (Zimmerman 1958b).

Materials and methods

Pseudoschrankia specimens were collected by hand while perched on tree roots dangling down through the ceilings of lava tube caves or in flight using an insect net. *Mestolobes* individuals were mostly collected the same way, though several were caught with a hand net in the entrance zone of caves after gently shaking tree roots on which they were perched. Culturally sensitive and significant lava tubes are legally protected under Hawai'i or Federal laws, and information on their precise location is considered confidential. However, locality data are archived with the appropriate land owner or agency involved. Accordingly, such data given for lava tubes, including specific elevation above sea level and geographic coordinates, should be regarded as approximate.

Genitalia were prepared and mounted on slides using the following protocol: Abdomens were soaked in simmering 10% KOH solution for one hour, genitalia were removed, stained with lignin pink and chlorazol black, soaked in a sequence of 30% ethyl alcohol, 90% ethyl alcohol, 100% isopropyl alcohol, and Euparal essence, then spread on microscope slides and mounted in Euparal (Bioquip, Rancho Dominguez, CA, USA). Digital photographs of adults were taken with a Canon EOS-1D Mark II camera using a Microoptics Digital Imaging System. Genitalia illustrations were made by starting with a photograph taken using the aforementioned photography system, and then manipulated in Adobe Illustrator to accentuate diagnostic morphological features. Setae were then drawn by hand.

For future studies and to aid in the accumulation of DNA “barcodes,” DNA was extracted from the legs of field-caught specimens using the standard protocol described in Qiagen's (Valencia, CA, USA) DNeasy kits. A “barcoding” segment of the protein coding gene COI (mtDNA) was amplified at the Urban School of San Francisco using the primers LCO1490 (5'-GGTCAACAAATCATAAAGATATTGG-3') and HCO2198 (5'-TAAACTTCAGGGTGACCAAAAATCA-3') and the following thermal profile: 2 min at 94 C; 34 cycles of 94 C for 1 min, 51 C for 1 min, and 72 C for 2 min; 12 min at 72 C. PCR product was purified using ExoSAP-IT (Affymetrix, Santa Clara, CA, USA) and then sequenced on an Applied Biosystems (Grand Island, NY, USA) 3730 DNA Analyzer at UC Berkeley.

Abbreviations:

BPBM B.P. Bishop Museum, Honolulu, U.S.A.
UHIM University of Hawai'i Insect Museum, Manoa, U.S.A.

Pseudoschrankia nohoana Medeiros & Howarth, sp. nov. (Lepidoptera: Erebiidae: Hypenodinae)

(Fig. 1A–C)

Diagnosis. *Pseudoschrankia* can be separated from *Schrankia*, the most externally similar genus in Hawai'i, by their extremely simple male genitalia that lack the prominent setae near the end of the valva, as well as lacking the distinct elongate process and ampulla projecting from the valva. Unlike the original three species of *Pseudoschrankia* Zimmerman, *P. nohoana* has relatively short labial palps and lacks the conspicuous antennal bipectination. These two characters are similar in both *P. nohoana* and *P. brevivalpis* Medeiros. However, the corpus bursae of female *P. nohoana* is shorter than that of *P. brevivalpis*, being half entire length of the abdomen in *P. brevivalpis* and about an eighth of the length of the abdomen in *P. nohoana*. The male genitalia are nearly indistinguishable from all previously described species. Despite being very similar in overall appearance to *P. brevivalpis*, which occurs on O'ahu island, *P. nohoana* is known only from Hawai'i Island caves. The COI DNA barcodes of these two species are distinct: For a 561 base section of COI, *P. nohoana* and *P. brevivalpis* are 7.0% different (1.0% difference at 1st codon position; 0.3% at 2nd; 5.7% at 3rd). In GenBank, the *P. brevivalpis* COI barcode sequence is KX241474, and that of *P. nohoana* is KX241476.

Description (n=7). *Head*: Vertex and frontoclypeus brown to greyish brown. Ocellus present. Antenna ca. 0.5–0.7x forewing length; very short piliform cilia on ventral side of flagellomere in males, cilia absent in females. Labial palpus brown to greyish brown, porrect; second segment heavily scaled, length ca. 1.5x diameter of eye; third segment length ca. 1.0x diameter of eye. Haustellum naked.

Thorax: Tegula and mesonotum brown to greyish brown. Legs brown to dark brown. Forewing length 4.8–5.6

mm (n = 7), ground color pale brown or pale grey; one thick dark brown or dark grey medial band running from costa to anal margin (two additional bands, one antemedial and one postmedial, present in some specimens); irregular dark brown or dark grey spot present near termen; some darker brown or grey scales and small spots scattered throughout; fringe brown or grey. Hindwing pale brown or pale grey, fringe pale brown or pale grey. Female with two acanthae per frenulum; male with one.

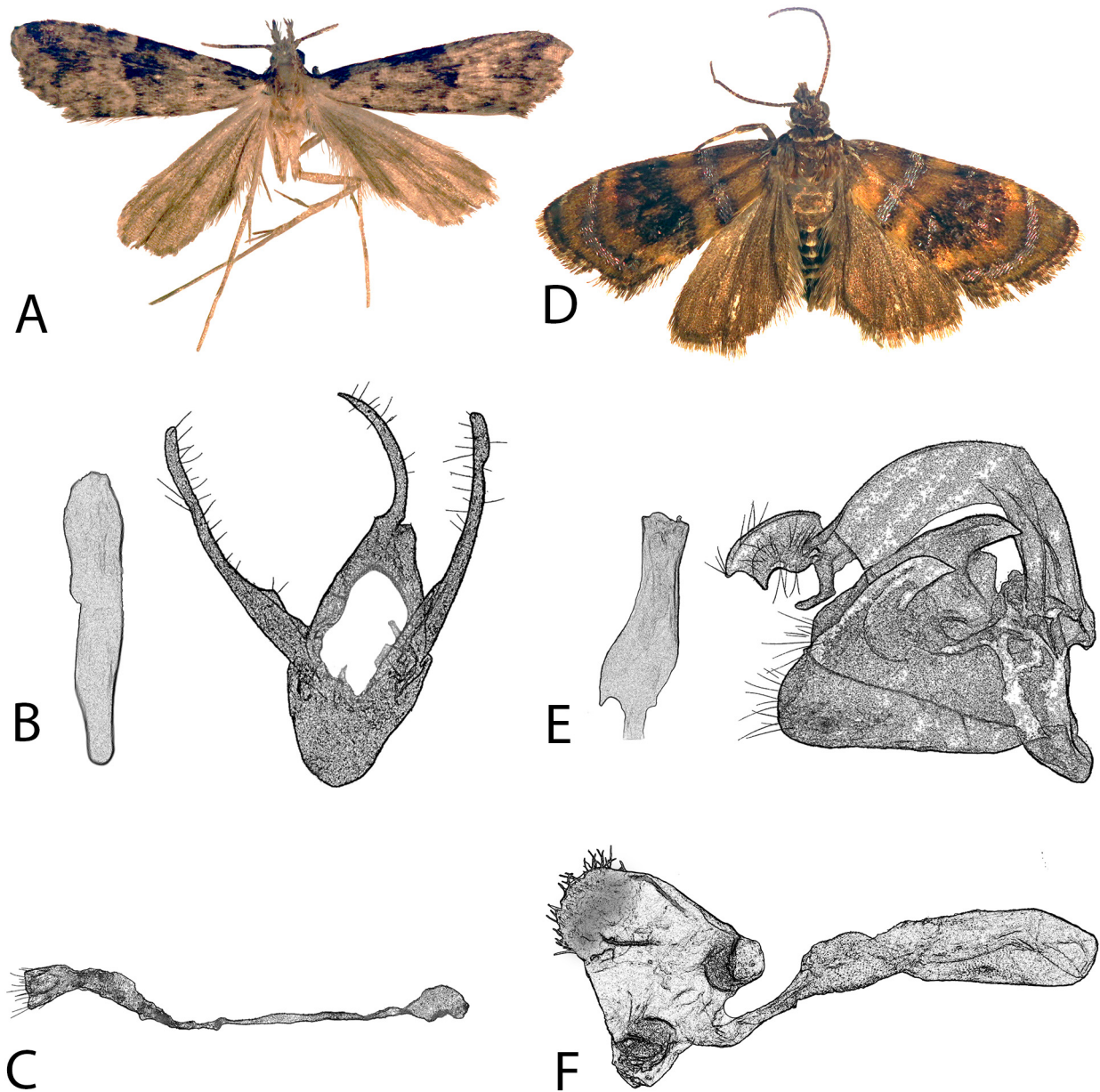


FIGURE 1. A: *Pseudoschrankia nohoana* holotype male. B: *Pseudoschrankia nohoana* male genitalia (slide 16A13; width at widest point = 0.5 mm; aedeagus to scale). C: *Pseudoschrankia nohoana* female genitalia (slide 15A16; width at widest point 2.3 mm). D: *Mestolobes olali* paratype male. E: *Mestolobes olali* male genitalia (holotype slide LA00; width at widest point = 0.8 mm; aedeagus to scale). F: *Mestolobes olali* female genitalia (slide 16A11; width at widest point = 2.1 mm).

Abdomen: Brown to grey.

Male genitalia (Fig 1B): Male genitalia unadorned. Uncus long, slightly downcurved, with setae projecting near apex. Valva ~0.5x length of uncus, thin. Sacculus narrow, extending ~0.3x length of valvae. Vinculum broad, U-shaped. Aedeagus cylindrical, widened along distal half.

Female genitalia (Fig 1C): Papillae anales slightly shorter than posterior apophyses. Anterior and posterior apophyses approximately equal in length, neither extending past segment VII. Ductus bursae gradually enlarged to

corpus bursae; corpus bursae ovate, with ductus bursae + corpus bursae nearly as long as entire abdomen; signum absent.

Holotype ♂: UNITED STATES: HAWAII: **Hawai'i Island:** Hawai'i Volcanoes National Park, Ainahou Cave Entrance <22, 13 Jun 2005, F Howarth & F Stone, slide LB65 (BPBM type #17836).

Paratypes 3 ♂, 3 ♀: UNITED STATES: HAWAII: **Hawai'i Island:** Hawai'i Volcanoes National Park, Ainahou Cave Entrance <22: 1 ♂, 13 June 2005, F Howarth & F Stone (BPBM). Hawai'i Volcanoes National Park, Ainahou Cave upper passage 6: 1 ♀, 4 June 2005, F Howarth & F Stone (BPBM). Hawai'i Volcanoes National Park, Ainahou Cave Entrance 16, Twilight Zone Dry-Wet: 1 ♂, 9 Feb 2006, F Howarth & F Stone (BPBM). Kaumana Cave, twilight zone, 19.687 – 155.131: 1 ♂, 1 ♀, 10 Mar 2015 & 22 Apr 2016, MJ Medeiros, slide 16A13 (UHIM). 290m, Hilo, Kaumana Cave, twilight/deep zones: 1 ♀, 10–11 Jul 2000, FG Howarth (BPBM).

Etymology. Ana is the generic Hawaiian word for cave. “Noho ana” is therefore “cave living.”

Remarks. Remarkably, until 2015, no new species of *Pseudoschrakia* had been described since 1904. Furthermore, no known specimens of the original three species have been collected since 1983. The type series of the new species includes specimens from Howarth's cave survey material housed in the Bishop Museum as well as specimens recently collected by Medeiros. Adults of this species have been collected in all ecological zones of caves, although they are found more commonly in the twilight zone. The type material comes from both the Ainahou and Kaumana cave systems, which are separated by about 35 km; that is, on the south slope of Kīlauea and east slope of Mauna Loa respectively. However, the species is known from several additional cave systems on Kīlauea Volcano (Howarth, unpublished). The moths are evidently rather rare or seasonal, as intensive searching by Medeiros for this particular species, for a total of 15 hours, turned up only two specimens in Kaumana Cave. In comparison, Medeiros located *Schrakia howarthi* Davis & Medeiros (Medeiros *et al.* 2009) specimens at a rate of more than one per hour of searching in the same cave, despite these two species being similar in size and color. In addition, Howarth has spent hundreds of hours conducting biological surveys and ecological studies in suitable cave habitats on Hawai'i Island yet collected specimens only occasionally. For example, in Kaumana Cave, which was surveyed intensively many times over a span of 40 years, this species was present on some visits but absent or not detected on most visits.

Nothing is known of this moth's natural history, whereas its congener, *P. brevipalpis*, is a pollinator for the endemic flower *Schiedea kaalae* (Caryophyllaceae) (Medeiros 2015). Although adults show no special adaptations for living in caves, behaviorally they fly with a slow forward speed characteristic of other volant cave insects, such as flighted *Schrakia howarthi*, crane flies, gnats and midges. The immature stages of *P. nohoana* are unknown, but an unidentified semi-looper found in the same caves is possibly this species. Attempts to rear the larvae have failed, and all adults reared from cocoons attached to roots were *S. howarthi* or very rarely *S. altivolans*. Thus *P. nohoana* possibly pupates elsewhere in more cryptic sites.

***Mestolobes olali* Medeiros & Howarth, sp. nov. (Lepidoptera: Crambidae: Crambinae)**
(Figs. 1D–F)

Diagnosis. *Mestolobes* Butler is endemic to the Hawaiian Islands, and the genus can be identified by presence of the “jugal lobe” of the male hindwing and the “accessory sacs” of the female genitalia (Zimmerman 1958b). *Mestolobes olali* can be separated from the previously described species most easily by examining the male genitalia: the apex of the uncus is very unlike that of any other known species, as instead of being long and narrow, it is adorned with a ridge-like cap, making it much taller. The female genitalia are most similar to *M. amethystias* Meyrick, a Kaua'i & Hawai'i species, which also has the accessory sacs adjacent to the anterior apophyses. *M. amethystias* also has a metallic postmedial band on the forewing, and may be closely related to *M. olali*.

Description (n=9). *Head:* Vertex and frontoclypeus mostly brown, but both surrounded by rows of scales tipped with white. Ocellus present. Antenna ca. 0.4–0.7x forewing length; dense, very short, piliform cilia surrounding flagellomere on male; slightly longer and less dense cilia on ventral side of flagellomere in female. Labial palpus correct, with long brown scales projecting ventrally, three distinct white bands near end of each segment; labial palpus ca. 1.5x length of eye. Maxillary palpus correct; brown with white scales at end of each segment; approximately 0.5x length of eye. Haustellum scaled proximally with pale brown scales, naked for most of its length.

Thorax: Tegula brown with a white band at margin. Mesonotum brown. Legs dark brown with bands of white scales at apex of each segment. Forewing length 4.8–5.7 mm (n = 9), ground color reddish-brown, with four bands running vertically from costal to anal margin, these bands with dark brown scales bordering metallic, faintly bluish, iridescent scales in center of each band; costal margin dark brown; fringe brown. In some specimens three metallic bands present, not four, with center band very wide. Hindwing pale brown near base of wing, becoming brown near termen and anal margin, fringe brown; short modified scales numerous near costal margin (Zimmerman 1958b pg. 296); “jugal lobe” (sensu Zimmerman 1958b pg. 297) present, large, light brown tipped with very dark brown scales. Female with three acanthae per frenulum; male with one.

Abdomen: dark brown with bands of pale scales between each segment.

Male genitalia (Fig 1E): Uncus adorned with wide, ridge-like cap, slightly downcurved, setae present along length of uncus. Gnathos upcurved. Tegumen ~1.5x length of valva, robust, bent at nearly ninety-degree angle halfway along length. Valva wide, sharply recurved distally, ending in sickle-shaped apex, setae present ventrally; sacculus widening along length. Vinculum small, U-shaped. Aedeagus roughly cylindrical with slightly swollen base.

Female genitalia (Fig 1F): Papillae anales short, adorned with thick setae. Anterior apophysis ca. 0.5x length of posterior apophysis. Accessory glands (sensu Zimmerman 1958b) adjacent to anterior apophysis. Ductus bursae short, ca. 2x length of posterior apophysis, gradually enlarged to corpus bursae; corpus bursae elongate, ca. 2.5x length of ductus bursae; small elongate-oval signum present.

Holotype ♂: UNITED STATES: HAWAII: **Hawai‘i Island**: Hawai‘i Volcanoes National Park, Ainahou Cave, 900m, between Entrance 5–6, 4 Jun 2005, F Howarth & F Stone, slide LA00 (BPBM type #17837).

Paratypes 5 ♂, 3 ♀: UNITED STATES: HAWAII: **Hawai‘i Island**: Hawai‘i Volcanoes National Park, Ainahou Cave, 900m, between Entrance 5–6: 2 ♂, 4 Jun 2005, F Howarth & F Stone (BPBM). Kaumana Cave, twilight zone, 19.687–155.131: 2 ♂, 3 ♀, 20 Sep 2006 & 22 Apr 2016, MJ Medeiros, slides 16A10 & 16A11 (UHIM). 290m, Hilo, Kaumana Cave, deep zone, upslope: 1 ♂, 13 Jul 2000, FG Howarth (BPBM).

Etymology. The Hawaiian word for “shiny” is “‘ōlali.” This species has shiny, metallic bands on the forewings.

Remarks. A 650 base sequence of the COI barcode region has been deposited in GenBank as accession KX241475. Very little is known of *M. olali*’s natural history, only that it has been found in all ecological zones of caves. However, it has been observed in great numbers at the entrance to Kaumana Cave, perching on roots in the shade.

Discussion

Neither of these new species is considered “troglobitic” as neither has the significant loss or reduction of eyes, wings, or pigmentation or elongation of appendages compared to their surface relatives and that often characterize truly cave-adapted species (Barr 1968, Howarth 1983). Furthermore, neither species is restricted to deep cave habitat since both have been found in all ecological zones within occupied cave systems including the entrance zone. They may be “troglophilic;” i.e., able to survive and reproduce both in cave and surface environments; or they may be waifs or visitors seeking shelter in caves. Additional sampling and autecological studies of these species are necessary to determine their true association with cave habitats. Identification and curation of Howarth’s extensive voucher collection of Hawaiian cave Lepidoptera will assist this effort especially by providing data on distributions of the cave species as well as indicate geographic gaps needing additional sampling. Likewise additional sampling and systematic studies on related surface species of both *Pseudoschrankia* and *Mestolobes* are urgently needed to better understand the biodiversity of Hawai‘i as well as to elucidate the relationship of these new species within their respective genera. For example, other *Mestolobes* species, notably *M. miniscula* (Butler), have also been found in caves (Howarth unpublished).

The paucity of specimens of these moths in collections may be due in part to sampling effort rather than to rarity. Cave inhabiting moths and many of their surface relatives rarely respond to light and thus are not often captured using a light, which is the conventional method for sampling Lepidoptera.

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