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A new species of flightless, jumping, alpine moth of the genus *Thyrocopa* from Hawaii (Lepidoptera: Xyloryctidae: Xyloryctinae)

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Abstract

A new species of brachypterous, flightless, jumping alpine *Thyrocopa* moth, *T. kikaelekea*, is described from Hawaii Island. This new species is similar to *T. apatela* (Walsingham), another flightless species from Maui Island. *Thyrocopa kikaelekea* is hypothesized not to be the sister taxon to *T. apatela*, instead representing an independent loss of flight.

Key words: Gelechioidea, brachyptery, flightlessness

Introduction

Other than in the genus *Thyrocopa* (Gelechioidea: Xyloryctidae), the subject of this paper, no alpine Hawaiian Lepidoptera are known to be flightless, even though some *Agrotis* species occur at very high elevation in Hawaii and female *Agrotis* from New Zealand are sometimes brachypterous (Patrick 1991). In Lepidoptera, brachyptery in both sexes is rare and typically restricted to very windy habitats, usually southern oceanic islands and areas with sparse vegetation where jumping is often utilized as a means of locomotion (Powell 1976; Sattler 1991).

Here, I describe a new flightless, jumping species of moth that inhabits the alpine area of Mauna Kea volcano on Hawaii Island. This moth is similar in outward appearance and behavior to *Thyrocopa apatela* (Walsingham 1907), which is nicknamed the Haleakala "grasshopper moth" because of its jumping behavior, and inhabits alpine areas on Maui Island. *Thyrocopa* is endemic to the Hawaiian Islands; see Zimmerman (1978, pp. 932–936) for a general overview.

R.C.L. Perkins first collected *Thyrocopa apatela* in 1896. This moth historically occurred at elevations above ~1800 m (6000 feet) on Haleakala volcano (Howarth 1979; Zimmerman 1978, from personal communication with J.W. Beardsley). These elevations on Haleakala are characterized by high winds, severe fluctuations in temperature, scattered vegetation, and low moisture content of the soil (Howarth 1987). Currently, this moth is restricted to elevations above ~2750 m (9000 ft.) (pers. obs.), possibly as a result of predation by introduced ants (Cole *et al.* 1992). *Thyrocopa apatela* is quite unusual in that both adult males and females are flightless and brachypterous (Sattler 1991; Sattler & Wojtusiak 2000; Zimmerman 1978). It should be noted that observations by K. & E. Sattler (Zimmerman 1978, p. 940) indicated that "fully-winged males" of this species were found; the taxonomic status of those specimens will be discussed elsewhere.

In 1976, Klaus and Edith Sattler found several *Thyrocopa* on Mauna Kea, near the Hale Pohaku area from between ~2957–2987 m (9700–9800 ft.) (K. Sattler, unpublished field notes; Zimmerman 1978), and several other individuals were collected as well between 1977 and 1991. Both sexes of this moth are also brachypterous, though less so than in *T. apatela*. In 2004, and again in 2005 and 2006, I also collected this species, near the Hale Pohaku area at ~2896m (9500 ft.). This area (fig. 6) is characterized by rocky, dry soil, frequent high

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winds, dramatic fluctuations in temperature both daily and seasonally, and scattered vegetation. Dominant plant species in this area are native mamane shrubs (*Sophora chrysophylla*) and clumps of grasses such as the native *Deschampsia*. The discovery of this species will likely permit comparative studies of the parallel evolution of flightlessness in very similar habitats. A description of this species is here presented in order to make its name available for subsequent papers, which will also discuss the evolution of flightlessness in Lepidoptera at greater length.

Materials and methods

Specimens examined are from the Bernice P. Bishop Museum (BPBM; Honolulu, Hawaii, USA) and the Natural History Museum (BMNH; London, England). When necessary, 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 chlorozol black, soaked in a sequence of 70% EtOH, 100% EtOH, and Euparal essence, then spread on microscope slides and mounted in Euparal (Bioquip, Rancho Dominguez, CA, USA). Photographs of BMNH genitalia slides were taken with a slide scanner, while photographs of BPBM genitalia were taken with a Nikon Coolpix5400 digital camera and an Olympus SZX12 microscope. Photographs of adult moths were taken using a Canon PowerShot A570 digital camera. All measurements were obtained using a Mitutoyo Absolute Digimatic calipers.

Thyrocopa kikaelekea Medeiros, sp. nov.

(Figs. 1–3, 7–12)

Diagnosis. *T. kikaelekea* (Figs. 11–12) is similar to *T. apatela* in outward appearance and behavior but the wings are less strongly reduced and the male sacculus in *T. kikaelekea* (Figs. 2, 7) is longer and narrower (compare with *T. apatela*, Fig. 4). *T. kikaelekea* has very similar male genitalia to *T. epicapna* Meyrick, but *T. kikaelekea* is brachypterous whereas *T. epicapna* is macropterous and its range does not overlap with *T. kikaelekea*. The only other *Thyrocopa* species that has been found in the same area as *T. kikaelekea* is *T. adumbrata* Walsingham. However, the macropterous *T. adumbrata* has significantly different male genitalia (Fig. 5), including a much shorter sacculus and strongly bifurcate uncus.

Description. Adult. — *Head:* Vestiture mostly smooth except scaling erect at hind margin of head; brown to very light brownish-white. Antenna ~ 0.8–0.9x length of forewing; dense, short, cilia surrounding flagellomere in ♂; few extremely short piliform cilia on flagellomere of ♀. Labial palpus mottled white and brown; smooth, long (approx. 2.5x interocular width), recurved; third segment approximately as long as second and very slender. Haustellum present with basal scaling. Ocellus absent. *Thorax:* Brown to very light brownish-white. Wings slightly brachypterous relative to all other *Thyrocopa* (except *T. apatela*) but with all veins found in other *Thyrocopa* (Fig. 3). Forewing length 8–11mm (22 specimens, mean=10mm); mottled white and brown to very light brownish-white; sometimes with black scales forming 1–3 slightly linear spots in some specimens; fringe very short. Hindwing: light brown except apical margin, darker brown in some specimens; fringe light brown to brown with thick brush of hairlike scales at base of wing extended under a narrow costal fold. *Abdomen:* Segments 2-7 with dorsal band of transverse orange spines just anterior to posterior margin; number of spines per segment varies depending on size of segment, most segments with between 80 and 190 spines (Fig. 10); scaling light brown, with row of broad, dense, semi-translucent, silvery-appearing scales at posterior margin.

Male genitalia (Figs. 1–2, 7): Uncus triangular, slightly downcurved, with very small apical notch, with cluster of setae laterally. Gnathos V-shaped, upcurved, slightly flared distally with acute tip (lateral view; Fig.

7). Sacculus terminating in an elongate, pointed spur. Phallus cylindrical, with slightly hollowed-out appearing tip (Fig. 1).

Female genitalia (Figs. 8–9): Anterior apophysis ~ 0.3x length of posterior apophysis. Ductus bursae about as long as anterior apophysis, gradually enlarged to corpus bursae; corpus bursae ovate, about as long as anterior apophysis; signum a sclerotized, elongate ribbon bearing tiny blunt spines.

Immature stages. – No preserved specimens, but see below under "Biology."

Behavior.—*T. kikaelekea*, like *T. apatela*, is active during the day. However, these species may not be strictly diurnal, because they have been reported to be attracted to, and walking or jumping toward, lights at night (F.G. Howarth and S.L. Montgomery, pers. comm.).

Biology.—Larvae of *T. kikaelekea* have been seen under rocks: "…the larva makes a silken tunnel under a rock and at the end of it a blind sack in which it pupates" (K. Sattler, unpublished field notes). Larvae of *T. apatela* also live under rocks and feed on windblown plant debris, such as leaves of na'ene'e (*Dubautia menziesii*) (Howarth 1987). Given that *Thyrocopa* larvae are likely generalists on dead plant material (Zimmerman 1978; Howarth 1979; M.J. Medeiros, pers. obs.), *T. kikaelekea* larvae may be feeding on windblown debris of mamane (*Sophora chrysophylla*) or grass (*Deschampsia* or other species). Adult *T. kikaelekea* are most often found in clumps of grass (M.J. Medeiros, pers. obs.).

Flight period.—At least from May to September, though one unidentifiable specimen with a missing abdomen, possibly of this species, was found in January (see "Additional material examined").

Distribution.—Hawaiian Islands, Hawaii Island, Mauna Kea volcano, from at least ~ 2825 m (9270 ft.) to ~2987 m (9800 ft.). One individual was collected on Mauna Kea at the significantly lower elevation of 2075 m (6807 ft.); this elevation is approximately 275 m above the historical low elevation on Maui for *T. apatela* and is also a windy, dry habitat.

Etymology.—This species is named after the Hawaiian word 'kikaeleke,' meaning "frisky, restless; to jump here and there," alluding to its habit of jumping when disturbed.

Type material.—HOLOTYPE ♂: UNITED STATES: HAWAII: **Hawaii Island**: 9700' (2957m), Hamakua District, Mauna Kea Road, above Hale Pohaku: 7.viii.1976, K. & E. Sattler (slide 21907 BMNH), (BMNH).

Paratypes 11 ♂, 9 ♀: UNITED STATES: HAWAII: **Hawaii Island**: 9700' (2957m), Hamakua District, Mauna Kea Road, above Hale Pohaku: 1 ♂, 2 ♀, 1–14.viii.1976, K. & E. Sattler (BMNH); 9800' (2987m), Hamakua District, Mauna Kea Road, above Hale Pohaku: 1 ♂, 1 ♀, 2.viii.1982, K. & E. Sattler (BMNH); Hale Pohaku, 2825m: 2 ♀, 2.ix.1977, F.G. Howarth (BPBM); Hale Pohaku, 2896m: 1 ♀, 15.vi.1980, F.G. Howarth (BPBM); Mauna Kea Forest Reserve, near Hale Pohaku, approx. 9500' (2896m): 1 ♀ (slide 04A65), 19.vii.2004; 5 ♂ (slides 05A45, 05A50, & 05A45wings), 1 ♀, 27.v.2005; 3 ♂ (slide 06A65), 2 ♀ (slide 06A62), 27.v.2006; M.J. Medeiros; Mauna Kea State Park, 2075m: 1 ♂, 8.vii.1991, S.L. Montgomery (BPBM).

Additional material examined: The two specimens from Mauna Loa mentioned below in the Discussion are both damaged. They have not been included in the type series. UNITED STATES: HAWAII: **Hawaii Island**: Mauna Loa Forest Reserve, near Big Red cave, 7600 ft. (2316m): 1 ♂ (abdomen missing), 23.i.2000, J.G. Giffin (BPBM); approx. 1.6 miles (2.6 km) down from weather station, on S side of road, in patch of vegetation, approx 10,800' (3292m): 1 ♂ (found dead; genitalia broken; specimen severely rubbed) (slide 05A55), 29.v.2005, M.J. Medeiros (BPBM).

Remarks.—One specimen (LA17; BPBM), obtained by me through a loan, has identical genitalia, wing pattern, and mitochondrial DNA as *T. kikaelekea* (M.J. Medeiros, unpublished data). This moth did not have a label affixed to its pin, though it was loaned to me along with a series of also unlabelled *Thyrocopa* found on Diamond Head, Oahu. I believe this specimen was mistakenly placed in this series.

I confirmed that *T. kikaelekea* is incapable of sustained ascending flight using a drop test, whereby moths were dropped into a meter-high cylindrical "drop chamber" identical to that used to study Hawaiian cave *Schrankia* (Noctuidae) (Medeiros *et al.* in press), as well as by allowing them to move freely within an enclosed room at lower elevation (other *Thyrocopa* species, which were observed in flight in the field, flew

frequently and strongly in this same enclosed room). *T. kikaelekea* moved by jumping, and was capable of jumping farther than *T. apatela*, probably aided by its larger wing area (Medeiros, unpublished data). Video of this moth in the field and in the enclosed room revealed that its wings are outstretched while jumping, but the shutter speed of the camera was inadequate to judge whether the wings were flapping (Medeiros, unpublished data).

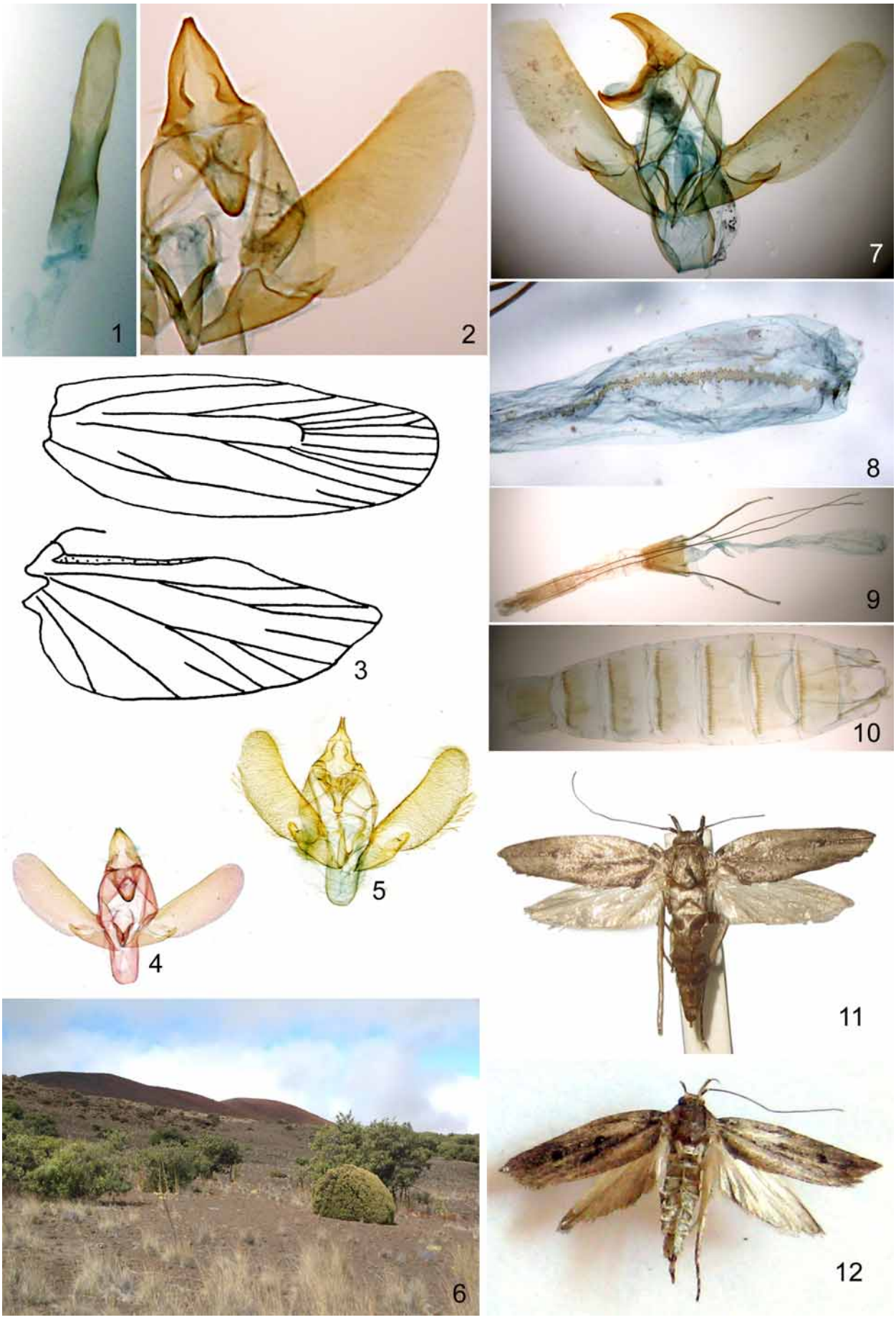
Discussion

Thyrocopa kikaelekea joins *T. apatela* as another example of a flightless jumping moth inhabiting alpine regions of the Hawaiian Islands. This moth is likely not the sister taxon to *T. apatela*, based on male genitalia and a preliminary phylogeny of *Thyrocopa* (M.J. Medeiros, in preparation). If these species are indeed not sister to each other, then *Thyrocopa*, which includes many flying, non-alpine species, will provide a useful group with which to further study environmental correlates of flightlessness because parallel evolution, not diversification after loss of flight, has likely occurred. A molecular phylogeny of *Thyrocopa*, as well as a revision of the genus, is under way.

Thyrocopa kikaelekea, or another flightless *Thyrocopa* species, may also occur in the third Hawaiian alpine area, that of Mauna Loa. Extensive searches of this area have so far resulted in the collection of only two specimens: a dead, badly rubbed adult male, and an adult male missing its abdomen (see "additional material examined"). Whether these moths were flightless is unknown, though the dead individual yielded DNA suitable for sequencing as well as partially intact genitalia, and appears to be conspecific with *T. kikaelekea*. However, it is possible this individual was displaced by wind to where I found it after dying, and that it lived on Mauna Kea. Yet another flightless *Thyrocopa* may occur, or may have occurred, in a windy lowland area on Molokai Island: "One or two" individuals were seen by Perkins before 1913, but it was not collected and has not been seen since then (Perkins 1913). Ants have now invaded this area and this species could be extinct.

Undescribed, reportedly flying (P.T. Oboyski, pers. comm.) *Thyrocopa* from Necker and Nihoa Islands in the Northwest Hawaiian Island chain, as well as the flighted *T. epicapna*, are closely related to *T. kikaelekea* and *T. apatela*. These three species also live in habitats that are very windy, dry, rocky, and have scattered vegetation. The alpine areas of Haleakala and Mauna Kea differ from these low-elevation areas in that they are higher, more strongly seasonal, often colder, larger in area (at least compared with Necker and Nihoa Islands), lack native avian predators (at least since human colonization of Hawaii), and are geologically younger. This suggests that strong winds, insular habitats, abundance and availability of food resources, and persistent habitats (see Roff 1990; Wagner & Liebherr 1992) may not in fact be important correlates of flightlessness in Lepidoptera, at least in some alpine regions. Work in preparation discussing the phylogeny of *Thyrocopa* will further explore these issues.

FIGURES 1–12. *Thyrocopa*, structures and habitat. 1, phallus, *T. kikaelekea* (slide 06A65); 2, male genitalia, *T. kikaelekea* (slide 06A65); 3, wing venation of male *T. kikaelekea* (slide 05A45wings); 4, male genitalia, *T. apatela* (slide Micro19860 BMNH, photo courtesy of BMNH); 5, male genitalia, *T. adumbrata* (slide Micro31574 BMNH, photo courtesy of BMNH); 6, Hale Pohaku area of Mauna Kea (photo by B.J. Ploger); 7, male genitalia, *T. kikaelekea* (slide 05A50); 8, female genitalia featuring corpus bursae and signum, *T. kikaelekea* (slide 06A62); 9, female genitalia, *T. kikaelekea* (slide 06A62); 10, descaled male abdomen, *T. kikaelekea* (slide 06A65); 11, *T. kikaelekea*, male paratype, forewing length = 9mm (BMNH, photo courtesy of BMNH); 12, *T. kikaelekea*, female paratype, forewing length = 10mm (BPBM).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References

Cole, F.R., Medeiros, A.C., Loope, L.L. & Zuehlke, W.W. (1992) Effects of the Argentine ant on Arthropod fauna of Hawaiian high-elevation shrubland. *Ecology*, 73, 1313–1322.

Howarth, F.G. (1979) Notes and exhibitions. *Proceedings of the Hawaiian Entomological Society*, 23, 14.

Howarth, F.G. (1987) Evolutionary ecology of aeolian and subterranean habitats in Hawaii. *Trends in Ecology & Evolution*, 2, 220–223.

Medeiros, M.J., Davis, D., Howarth, F.G., & Gillespie, R. (In press.) Evolution of cave-living in Hawaiian *Schrankia* (Lepidoptera: Noctuidae) with description of a remarkable new cave species. *Zoological Journal of the Linnean Society.*

Patrick, B.H. (1991) Notes on *Agrotis innominata* Hudson (Lepidoptera: Noctuidae). *New Zealand Entomologist*, 14, 32–36.

Perkins, R.C.L. (1913) Introduction. *In:* Sharp, D. (Ed.), *Fauna Hawaiiensis*. Cambridge University Press, 1, pp. xv–ccxxviii.

Powell, J.A. (1976) A remarkable new genus of brachypterous moth from coastal sand dunes in California (Lepidoptera: Gelechioidea, Scythrididae). *Annals of the Entomological Society of America*, 69, 325–339.

Roff, D.A. (1990) The evolution of flightlessness in insects. *Ecological Monographs*, 60, 389–421.

Sattler, K. (1991) A review of wing reduction in Lepidoptera. *Bulletin of the British Museum of Natural History (Entomology)*, 60, 243–288.

Sattler, K. & Wojtusiak, J. (2000) A new brachypterous *Xenomigia* species (Lepidoptera: Notodontidae) from Venezuela. *Entomologica Scandinavica*, 30, 435–442.

Wagner, D.L. & Liebherr, J.K. (1992) Flightlessness in insects. *Trends in Ecology & Evolution*, 7, 216–220.

Walsingham, Lord (Thomas de Grey). (1907) Microlepidoptera. *In:* Sharp, D. (Ed.), *Fauna Hawaiiensis*. Cambridge University Press, 1, 469–759.

Zimmerman, E.C. (1978) Insects of Hawaii, Vol. 9: Microlepidoptera. University of Hawaii Press, Honolulu, 1903 pp.