

Taxonomic review of the leek moth genus *Acrolepiopsis* (Lepidoptera: Acrolepiidae) in North America

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Abstract—The North American species of *Acrolepiopsis* are reviewed and include six described species: *A. assectella* (Zeller), *A. californica* Gaedike, *A. heppneri* Gaedike, *A. incertella* (Chambers), *A. leucoscia* (Meyrick), and *A. reticulosa* (Braun). *Acrolepiopsis liliivora* Gaedike is considered a junior synonym of *A. californica* (new synonymy). *Acrolepiopsis assectella*, commonly known as the leek moth, is a recently invasive alien species in North America and a pest of the plant genus *Allium*, including leek, onion, garlic, and related cultivated plants. A key to species based on adults is provided, diagnostic characters including male and female genitalia are illustrated, and geographical distribution, host plants, and larval feeding pattern and damage (where known) are given. Diagnostics and illustrations are presented also for *A. sapporensis* (Matsumura); known as the Asiatic onion leafminer, it is very similar to *A. assectella* and is an invasive alien species present in Hawaii, though not in North America. Adult diagnostic characters of the genus *Acrolepiopsis*, the family Acrolepiidae, and the superfamily Yponomeutoidea are also provided and illustrated. DNA barcoding data (short sequences of the mitochondrial cytochrome *c* oxidase I gene) obtained for five of the six species revealed interspecific differences averaging 8.1%, whereas intraspecific variation was $\leq 0.16\%$, and provided unequivocal species separation matching morphology-based identifications.

Résumé—L'auteur passe en revue les espèces d'*Acrolepiopsis* d'Amérique du Nord. Il reconnaît six espèces : *A. assectella* (Zeller), *A. californica* Gaedike, *A. heppneri* Gaedike, *A. incertella* (Chambers), *A. leucoscia* (Meyrick) et *A. reticulosa* (Braun). Il considère *A. liliivora* Gaedike comme un synonyme récent de *A. californica* (synonymie nouvelle). *Acrolepiopsis assectella*, appelée communément teigne du poireau, est une introduction récente et invasive sur le continent nord-américain, et un ravageur des ail (*Allium* spp.), y compris les poireaux, les oignons, l'ail et autres espèces cultivées. Il fournit un tableau d'identification des adultes, présente et illustre les caractères diagnostiques des génitalia mâles et femelles, donne la répartition géographique, les plantes nourricières et le mode d'alimentation des larves (lorsque connu). Il présente aussi les caractères diagnostiques de la mineuse asiatique de l'oignon, *A. sapporensis* (Matsumura), un espèce invasive à Hawaii qui n'est pas connue du continent nord-américain mais qui ressemble beaucoup à *A. assectella*. Il donne et illustre des caractères diagnostiques permettant de reconnaître le genre *Acrolepiopsis*, la famille des Acrolepiidae et la superfamille des Yponomeutoidea. Les codes-barres génétiques (de courtes séquences du gène mitochondrial de la sous-unité I de la cytochrome oxydase *c*), obtenus pour cinq des six espèces, présentent des différences interspécifiques de 8.1 % en moyenne, alors que la variation intraspécifique est $\leq 0.16\%$, et permettent la séparation sans équivoque des espèces qui correspond à l'identification basée sur les traits morphologiques.

Introduction

The leek moth, *Acrolepiopsis assectella* (Zeller), was first detected in Canada in 1993 in the city of Ottawa infesting onion and garlic in a garden. Larvae were found again in 1994 on leek in a different part of Ottawa, and in 1997 adults

were taken at light in Gatineau, Quebec (Handfield *et al.* 1997). In 2000, larvae were found in growers' fields about 40 km east of Ottawa (Landry and Parker 2000), indicating that the species was established and adventive. Surveys conducted by the Canadian Food Inspection Agency from 2001 to 2003 using pheromone traps revealed the expanding range of *A. assectella* over southeastern Ontario and southwestern Quebec (Canadian Food Inspection

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Agency 2001–2003; Garland 2002; Callow *et al.* 2003).

The leek moth is native to Europe, where it has been known as a pest of *Allium* species (Liliaceae) for centuries. Related species of *Acrolepiopsis* doing similar damage to *Allium* species also occur in Asia and Hawaii (the species introduced in Hawaii is *A. sapporensis* (Matsumura)). Besides *A. assectella*, two native species of *Acrolepiopsis* also occur in Canada, *A. incertella* (Chambers) and *A. californica* Gaedike (Handfield *et al.* 1997; Pohl *et al.* 2005 as *liliivora*).

Surveys using pheromone traps heighten the need for good diagnostics and separation of the leek moth from closely related native species. At present it is unknown whether *A. assectella* pheromones are attractive to native species of *Acrolepiopsis*.

A taxonomic revision of the New World Acrolepiidae exists (Gaedike 1984). However, it was published in German in a little accessible European journal, contains no illustrations of

adults or key to species, and predates the occurrence of *A. assectella* in North America. Moreover, an additional species was later described from California and Oregon (Gaedike 1994a). The introduction of the invasive alien pest *A. assectella* into North America necessitates an updated taxonomic review of the North American fauna of the genus *Acrolepiopsis* with emphasis on diagnostics. *Acrolepiopsis sapporensis* is included in the treatment even though it has never been reported from North America. However, it is present in Hawaii, where it was previously misidentified as *A. assectella* (Zimmerman 1978), and could possibly be introduced into North America from Hawaii or eastern Asia.

The objectives of the present paper are to describe and illustrate diagnostic features of the adults of known species of *Acrolepiopsis* of North America, to present and illustrate diagnostic features of the larva and pupa of the leek moth, and to distinguish acrolepiid moths from other superficially similar microlepidoptera.

Materials and methods

Specimens were examined from the following collections:

- ANSP The Academy of Natural Sciences, 1900 Benjamin Franklin Parkway, Philadelphia, PA 19103-1195, USA (J.D. Weintraub)
- CNC Canadian National Collection of Insects, Arachnids and Nematodes, Agriculture and Agri-Food Canada, K.W. Neatby Building, 960 Carling Avenue, Ottawa, ON K1A 0C6, Canada (J.-F. Landry)
- ECK E.C. Knudson Collection, 8517 Burkhardt Road, Houston, TX 77055, USA
- FLMNH McGuire Center for Lepidoptera and Biodiversity, Florida Museum of Natural History, University of Florida, P.O. Box 112710, Gainesville, FL 32611-2710, USA (P. Goldstein and G.T. Austin)
- INHS Collection of the Illinois Natural History Survey, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820, USA (T.L. Harrison)
- MEM Mississippi Entomological Museum, Mississippi State University, Box 9775, Mississippi State, MS 39762-9775, USA (R.L. Brown)
- NFC Northern Forestry Centre, Canadian Forest Service, 5320 122nd Street, Edmonton, AB T6H 3S5, Canada (G.R. Pohl)
- OSU Ohio State University Insect Collection, Museum of Biological Diversity, Ohio State University, 1315 Kinnear Road, Columbus, OH 43212, USA (T. Gilligan)
- UCB Essig Museum of Entomology, 201 Wellman Hall, University of California, Berkeley, CA 94720-3112, USA (J.A. Powell)
- USNM National Museum of Natural History, Smithsonian Institution, Washington, DC 20560-0165, USA (J.W. Brown and J. Lewis)

I studied the type material of *A. californica*, *A. heppneri* Gaedike, *A. liliivora* Gaedike, and *A. reticulosa* (Braun), as well as specimens of European origin of *A. assectella* and specimens of Asian origin of *A. sapporensis*. The type specimens of *A. leucoscia* (Meyrick), which are in the Natural History Museum in London, were not borrowed, but photographs of the lectotype from Clarke (1965, p. 260) were examined in addition to the genitalia figures in Gaedike (1984).

All specimens were given a unique voucher alphanumeric code, in the format "Database # CNCLEP*n*", which is shortened to "CNCLEP*n*" in the text. These numbers are used in the database of Lepidoptera that I maintain. Label data for primary types examined are given verbatim with slashes (/) indicating line breaks. Square brackets are used to indicate inferred information or data not present on the specimen labels. Geographic coordinates of collecting localities not present on labels were obtained extraneously by using Google Earth.

Specimen preparation

Some adult specimens were collected at mercury light or at black light. The main source of *A. assectella* was larvae found on cultivated *Allium* plants and reared to adult stage. Many specimens were reared from larvae infesting garlic and leek from eastern Ontario; these were supplemented by specimens from a laboratory colony maintained on leek at Agriculture and Agri-Food Canada in Ottawa. Freshly collected adults were killed, spread, and mounted following the method described by Landry and Landry (1994).

Sticky-trap specimens

Some specimens collected from pheromone sticky traps in eastern Ontario were examined. For this purpose, a small area of the trap wall was cut out around glued specimens and soaked in Histo-Clear™ (DiaMed Lab Supplies, Mississauga, Ontario) for a few hours. Specimens usually floated off the sticky card within a few minutes but were left to soak in Histo-Clear overnight to ensure that the adhesive was fully dissolved from the body. Specimens were rinsed in 95% ethanol for a few minutes and then transferred into 70% ethanol (where they can be stored). For genitalia dissection, the abdomen was removed and processed as described below.

Genitalia preparation

The entire abdomen was removed from dry specimens by applying gentle upward pressure from beneath and was then wetted in 70% ethanol, placed in a shell vial in a 20% KOH aqueous solution, and macerated in a hot water bath (kept just below simmering point) on a hot plate for 5 min. The abdomen was transferred with a plastic pipette into a dissecting dish containing distilled water with a drop of diluted dish detergent (to break surface tension). Scales and

macerated tissues were removed by gentle brushing with two fine-tipped (No. 000) nylon artist's brushes, taking care to flatten the abdomen dorsoventrally. The male genitalia were separated by teasing the connecting membrane between them and the 8th abdominal segment with fine forceps, taking care to leave the pleural lobes and their coremata attached to the abdomen. Remaining macerated tissues were removed from inside the abdomen with a hooked minuten pin. Female genitalia were separated by cutting and teasing the membrane between the 7th and 8th segments, after the ovipositor had been extended with brush strokes. Tracheae and macerated soft tissues were carefully cleaned with fine forceps and brushes from around the corpus bursae and ductus bursae and from inside the ovipositor. Spermatophores and other particles inside the corpus bursae were brushed out through a small slit cut in the anterior extremity of the bursa.

The aedeagus was separated by pulling it off anteriorly. The valvae were spread out by inserting the closed tip of dissecting forceps between the valvae from the anterior side, holding the genitalia down against the bottom of the dissecting dish, and then applying gentle pressure on the entire genitalia with a fine brush to flatten structures slightly. Once the valvae were spread at the desired angle, a small glass chip was gently applied over the genitalia and left for several minutes so that the structures began to get fixed in position. For some male specimens, one valve was removed from the genitalia and mounted flat with the inner side up.

All dissected parts were lightly stained with Orange G (to enhance sclerites) dissolved in lactic acid and diluted in 30% ethanol. This step ensured both staining and complete neutralizing of the KOH. Some female genitalia were also stained lightly with Chlorazol Black (to enhance membranes) dissolved in water and diluted in 30% ethanol after Orange G staining.

Clean, stained parts were then transferred into 100% propanol in covered glass dishes, with glass chips applied over the parts to maintain proper folding and spreading, and were left overnight for dehydration and hardening. Parts were transferred briefly into Euparal essence before being mounted in Euparal on microscope slides.

Genitalia storage

Dissected genitalia should be preserved whenever possible as vouchers along with the

remainder of the specimen from whence they came. While slide mounts ensure the best preservation and the easiest method for subsequent examination of the dissections, they require significant practice to achieve quality and are not always necessary. Unmounted dissections, such as those from sticky-trap samples, were preserved inexpensively and conveniently in pure lactic acid in 0.5 mL plastic microcentrifuge tubes appropriately cross-numbered with the specimens. Lactic acid is superior to glycerine for non-fixing preservation of dissections because it has a higher refractive index, does not chemically bind to the cuticle, and maintains cuticular integrity should subsequent resin mounting on a slide be required.

Illustrations

Slide-mounted structures were photographed at 100× or 200× magnification with a Nikon DMX 1200F digital camera mounted on a Nikon Eclipse 800 microscope. CombineZ5 software (<http://www.hadleyweb.pwp.blueyonder.co.uk>) was used to assemble multiple images from successive focal planes into single deep-focus images. Pinned specimens were photographed with a Leica DC 500 digital camera mounted on a Leica Z16 APO stereoscope. They were illuminated with a fiber-optic ring light that was diffused with a white styrofoam cup placed around the specimen. All photos and illustrations were processed, adjusted, and assembled into plates with Adobe Photoshop CS2. Valva outlines were traced from digital photos using Adobe Illustrator CS2.

Genetic analysis

The same pinned and dried specimens examined for morphological characters were used for DNA analysis. DNA barcoding (Hebert *et al.* 2003) was effected mostly using specimens <15 years old. Because of the rarity of specimens for most species, a few older specimens (1981–1990) of *A. californica* and *A. leucopsis* were also analyzed. Additional specimens representing two species of *Plutella* L. (Plutellidae) that were sequenced as part of the Barcode of Life Network project (Hebert *et al.* 2003; Dooh and Hebert 2005) were included in the analysis to provide a comparative measure of divergence between *Plutella* and *Acrolepiopsis*. *Plutella* was selected for two reasons: it is an yponomeutoid group that has been considered closely related to acrolepiids (Kyrki 1990), and from an identification standpoint, the

immature stages of the diamondback moth (*P. xylostella* (L.)) could be found in the same habitat and confused with those of the leek moth.

A single dry leg was removed from each specimen with cleaned forceps, transferred into 95% ethanol in a coded tube in a Matrix box (TrakMates® microplate system, Matrix Technologies, Hudson, New Hampshire), and sent to the Biodiversity Institute of Ontario, University of Guelph, for DNA extraction and sequencing. Each leg tube was labelled with the same voucher alphanumeric code as the corresponding specimen. Each delegged specimen was affixed with a blue label saying “Barcodes of Life Project/ DNA extracted” to enable rapid and easy visual location within collection drawers.

The standard protocol used for DNA extraction and amplification, sequencing of the barcoding region of the cytochrome *c* oxidase I (COI) gene (*cox1*), sequence editing, and sequence alignment is given in detail in Hajibabaei *et al.* (2005, 2006a). Sequence information was entered in the Barcode of Life Database (BOLD) (Ratnasingham and Hebert 2007) along with a photograph and collateral information (collecting data) for each specimen. Kimura’s two-parameter model of base substitution was used to calculate genetic distances and neighbour-joining (NJ) trees were produced using BOLD. Sequences have been submitted to GenBank (accession Nos. EF380034–EF380093). Sequences and voucher specimen data are available in the “Lepidoptera: Acrolepiidae and Plutellidae” file in the Published Projects section of the Barcode of Life Web site (www.barcodinglife.org).

Yponomeutoidea and the family Acrolepiidae

Acrolepiidae are a small family of microlepidoptera in the superfamily Yponomeutoidea (Dugdale *et al.* 1998). The family comprises three genera, *Acrolepia* Curtis, *Acrolepiopsis* Gaedike, and *Digitivalva* Gaedike, with 95 species worldwide (Gaedike 1997). Seven species of *Acrolepiopsis*, one species of *Digitivalva*, and no species of *Acrolepia* are known from the Nearctic region. Larvae of *Acrolepiopsis* feed on Liliaceae and Dioscoreaceae, those of *Acrolepia* feed on Asteraceae, and those of *Digitivalva* feed on Solanaceae (Gaedike 1997).

The Yponomeutoidea comprise several well-known pests, most notably the diamondback moth

(*P. xylostella*) and ermine moths (*Yponomeuta* spp., Yponomeutidae). From a systematics standpoint, the superfamily Yponomeutoidea is defined by features of the male abdomen; specifically, the membranous pleural lobes of the 8th abdominal segment are markedly enlarged and envelop the genitalia. A pair of ventrolateral coremata occurs between the pleural lobes and the genitalia in most taxa (Figs. 10–12). However, there are no external adult characters enabling unequivocal recognition of Yponomeutoidea. The basal part of the haustellum is devoid of scales, which distinguishes yponomeutoids from the very diverse and often similarly shaped and sized Gelechioidea. Many Gelechioidea have upcurved labial palpi and maxillary palpi that fold over the base of the haustellum, but a similar feature occurs in some, though not all, Yponomeutoidea, notably in Acrolepiidae.

In the only phylogenetic treatments of the Yponomeutoidea, Kyrki (1984, 1990) included the *Acrolepia* group of genera (i.e., *Acrolepia*, *Acrolepiopsis*, and *Digitivalva*) in the family Plutellidae as the subfamily Acrolepiinae based on the shared putative apomorphies of a large-meshed cocoon and female post-vaginal lamella (sternum 8) consisting of two separate setose lobes. However, both traits are not unique to these taxa and occur in some other Yponomeutoidea. The lack of reliable synapomorphies is why both groups, the Acrolepiidae and the Plutellidae, have been treated as separate families (Dugdale *et al.* 1998).

Externally, acrolepid moths have the following characters: head scales appressed on frons, erect (“rough”) scales on vertex; ocelli present behind antennal scape; chaetosemata absent; labial palpi upcurved, extended to top of vertex, with 3rd article longer than 2nd, not ventrally tufted; maxillary palpi 3-articled, folded over base of haustellum; haustellum developed and coiled, with base devoid of scales (“naked”) (Figs. 5–6); wing venation complete (Figs. 7–9); forewing without scale tufts or raised scale patches, with all five radial veins separate, and with a chorda (stem of R4 + R5) present and delineating an “areole” in discal cell; hind wing as wide as forewing, fringe as long as greatest width of hind wing, three medial veins present, M3 stalked with CuA1.

Few, if any, other Nearctic microlepidoptera with similar habitus can be confused with the above combination of external characters. In

habitus, adults somewhat resemble chunky plutellid moths.

In male genitalia (Fig. 49), acrolepiids have the tegumen–uncus–gnathos region reduced to a membranous tube surrounding the anal tube, markedly elongate saccus, valvae with dilated bases bearing a patch of long setae, and an aedeagus (Figs. 56–62) with an enlarged, swollen base and distal half attenuated to a narrow, gently curved tube with a small vesica and no cornuti (there are very fine spicules covering the often protruding apical part of the vesica membrane but no cornuti proper). Males also have modifications of the 8th abdominal segment (Figs. 10–12) that characterize the Yponomeutoidea: enlarged pleural lobes, usually containing a pair of coremata, a trapezoid T8, and a small, crescentic, weakly sclerotized S8. The coremata contain two types of scales: elongate, hairlike scales and short, suboval, leaflike scales (Figs. 37–48). The structure and function of coremata in *A. assectella* were described in some detail by Thibout (1972).

Acrolepid female genitalia (Figs. 75–80), though without unique features, present the following combination of diagnostic characters: S8 is bilobate; the distal portion of the ductus bursae is variously sclerotized; the corpus bursae is thin and weakly sclerotized; and a pair of elongate, band-like signa is present. Kyrki (1990) mentioned the bilobate S8 as an apomorphic character of the Plutellidae (Plutellinae + Acrolepiinae), but this feature is not unique to this group.

The larvae of Acrolepiidae can be recognized by a combination of characters: seta L2 antero-ventrad of seta L1 on abdominal segments 1–8; seta SD1 anterodorsad of spiracle on A1–A8; abdominal segment 9 with six setae, setae L1 and L2 proximate; proleg crochets in uniordinal circles, with 3–4 extra setae inside the circle. Plutellid larvae have 8–9 setae on A9 (Heppner 1987).

The acrolepid pupa (Figs. 127–128, 133–134) is enclosed in a lacelike, large-meshed cocoon similar to that of *Plutella xylostella* (Figs. 129–130), some other Plutellidae, and some Yponomeutidae (e.g., *Prays* spp.) and is not protruded from the cocoon at adult emergence. A similar-looking meshed cocoon is present in some Urodidae (e.g., *Urodus parvula* (Hy. Edwards, 1881) and *Wockia asperipunctella* (Bruand, 1851)), a ditrysian family of

uncertain affinities with a pupa that protrudes before adult emergence.

In general, acrolepiid moths are little attracted to light and are rarely encountered (Agassiz 1996). Terry Harrison (personal communication 2003) offered the following comment about collecting *A. incertella* in Illinois: "I believe that the key reason for the paucity of specimens of *A. incertella* in most collections is that adults of that species (and probably other *Acrolepiopsis* spp.) are not at all attracted to light (as we both know, the microlepidoptera components of many collections are made up mainly or entirely of light-collected adults). Many times, I have black-lighted right near the foodplant of *A. incertella* (and sometimes even in the midst of populations of *Smilax* on which I know *A. incertella* larvae to have occurred in abundance earlier in the year); but out of all of that, I have seen only one or two adults, ever, at light, and even those probably came in only because I set up right on top of them. I don't believe that parasitism is an important contributing factor to the rarity of adults at light because I have recorded only a very low incidence of parasitism in the *A. incertella* that I have reared." Thus, adult acrolepiid habits are poorly known. All species are undercollected; few specimens are in collections and most North American species are known from only a few scattered records.

Constituent genera of Acrolepiidae

Traditionally, all known members of the Acrolepiidae were included in the genus *Acrolepia*. Gaedike (1970), in a revision of the Palearctic fauna, split *Acrolepia* into three genera and transferred all but one species into two new genera, *Acrolepiopsis* and *Digitivalva*. Separation of these genera was based on features of the male genitalia and on larval host plants and was not phylogenetic. *Acrolepiopsis* was defined as having long, narrow, lancet-shaped valvae without costal processes, a long saccus, a long aedeagus, and larvae that feed on Liliaceae and Dioscoreaceae. *Digitivalva*, with a single species in North America but many elsewhere, was defined on the basis of valvae with one or more fingerlike costal processes and larvae feeding on Asteraceae (with a notable exception in the European species *D. perlepidella* (Stainton, 1849), which feeds on Asteraceae and Solanaceae). *Acrolepia* was not really defined but was isolated within the

family based on unspecified genital characters and external features; larvae feed primarily on Solanaceae. No species of *Acrolepia* is known to occur in North America.

Adults of *Acrolepiopsis* are distinguished from those of the other two genera only by genital characters. *Acrolepiopsis* males have simple blade-like or spatulate valvae, as well as prominent pencil-like coremata on the pleural lobes of the 8th abdominal segment. *Digitivalva* males have valvae with prominent, strongly incurved, digitate dorsal lobes and smaller, knobby ventral lobes. *Acrolepia* males also have simple blade-like valvae rather similar in shape to those of *Acrolepiopsis*, but the setae in the apical half are strongly spiniform and the vesica is covered with strong spines apically.

Females apparently lack group-defining features, although trends are discernable. For example, many *Acrolepiopsis* females have paired, band-like signa (some have none); *Digitivalva* females tend to lack clearly defined signa or have several rows of very fine denticles in lieu of signa; and the female of the type species of *Acrolepia*, *A. autumnitella* Curtis, 1838, has three bands of signa. The females of several species of *Acrolepia* and *Digitivalva* are unknown, which hinders a full assessment.

It is unresolved whether all three genera are monophyletic and defined by autapomorphies. Zimmerman (1978) did not follow Gaedike's (1970) system of generic separation on grounds that "it is untenable for non-Eurasian species", and he retained all five species occurring in Hawaii, including the introduced *sapporensis*, in *Acrolepia*. Curiously, in his catalogue of world Acrolepiidae, Gaedike (1997) retained Zimmerman's placement of the Hawaiian species, yet examination of the *Acrolepia* genitalia illustrations in Zimmerman (1978) suggests that the species are more similar to *Acrolepiopsis* than to *Acrolepia*. A phylogenetic analysis of the world fauna of Acrolepiidae is needed to assess the value of current generic divisions.

The genus *Acrolepiopsis* Gaedike, 1970

Acrolepiopsis Gaedike, 1970: 32.

Type species: *Roeslerstammia assectella* Zeller, 1839, by original designation.

Argiope Chambers, 1873: 13.

Type species: *Heribeia incertella* Chambers, 1872, by monotypy. Preoccupied by *Argiope* Audouin, 1827 (Araneae).

Among the six North American species, the white posteromedian fasciae of the forewings join to form a single larger mark when the wings are folded (Figs. 1–4, 13–30). This triangular white mark is diagnostic for members of the genus, although it is subdued in *A. leucoscia* (Fig. 22).

Superficially, worn *Acrolepiopsis* specimens could be confused with specimens of the only known North American species of *Digitivalva*, *D. clarkei* Gaedike, 1984 (now known from South Carolina, Alabama, and Mississippi), which lacks the clear white fasciae. However, the genitalia of *D. clarkei* have an overall appearance very different from those of *Acrolepiopsis* species.

The genus *Acrolepiopsis* includes 37 species distributed in most regions except Australia and Oceania (Gaedike 1997). Most species (18) occur in the Palearctic region. All species feed on two related families of plants in the order Liliales (suborder Liliinae): Liliaceae (recorded hosts include *Allium* spp., *Disporum* spp., *Hosta* spp., *Smilax* spp., and *Lilium* spp.) and Dioscoreaceae (recorded hosts include *Dioscorea* spp. and *Tamus* spp.).

Generally, adult moths of most North American species of *Acrolepiopsis* are superficially similar to each other, with modest or no differences in colouration. Individual colour variation is present in most species and often blurs interspecific differences. Additionally, colours fade with age and older specimens usually have a

lighter tone. Besides DNA barcode analysis (see later section in this paper), genital differences provide the best means of recognizing the species, and for wild-collected specimens dissections must be performed to identify most species.

I noted some interspecific variation in the relative size and shape of the abdominal coremata and of the leaflike scales within (Figs. 37–48). However, the differences in leaflike scales are minor and easily altered by the process of dissection and slide mounting, rendering them difficult to interpret. Where noted or illustrated, they should not be construed as diagnostic. Likewise, the aedeagus varies significantly in absolute size, amount of curvature, and proportions among the species (Figs. 56–62) but is difficult to use in trying to identify specimens unless representatives of different species are available for comparison. Signum size also varies markedly both intra- and interspecifically (Figs. 93–113). Gaedike (1994a) used absolute signum size as a specific character to recognize *A. liliivora* as a separate species from *A. californica* (see comments on synonymy under that species). However, the amount of intraspecific variation in *A. californica* and in other species is so pronounced, even in the limited amount of material available, as to make the specific value of this character doubtful.

Species are presented after the key in alphabetical order.

Identification key to adults of North American *Acrolepiopsis*

1. Moth predominantly pale grey; forewing pale grey peppered with scattered dark brown scales and with diffuse or indistinct white posteromedian fascia adjoining hind margin (Fig. 22) *leucoscia*
- 1'. Moth predominantly brown; forewing medium brown to dark brown with mottled appearance in some specimens and with sharply delineated white triangular or square posteromedian fascia on hind margin (Figs. 13–21, 23–30) 2
2. Forewing with white posteromedian fascia subquadrate or subrectangular; distal third of forewing predominantly pale and contrasting with dark proximal two-thirds (Figs. 27–28) *reticulosa*
- 2'. Forewing with white posteromedian fascia triangular or subtriangular; forewing more or less uniformly patterned (some contrast may be present in distal portion in some *assectella* specimens, but they have a clearly triangular posteromedian fascia). 3
3. Males (to sex undissected specimen: apex of abdomen somewhat tufted, often with tips of valvae visible; frenulum of hind wing with one acanthus) 4
- 3'. Females (to sex undissected specimen: apex of ovipositor or papillae anales usually visible at apex of abdomen; frenulum of hind wing with two acanthi) 8
4. Valva proportionally short and stout, with dorsal edge straight or slightly concave (Figs. 72, 74) 5
- 4'. Valva proportionally slender, with dorsal edge convex or arched (Figs. 63–71, 73) 6
5. Distal half of valva club-shaped, ventrally rounded; base of valva deeply emarginate with thin apophysis; valvae spreading laterally when flattened in preparation (Fig. 53) *incertella*
- 5'. Distal half of valva wedge-shaped, ventrally angulate; base of valva shallowly emarginate with thick apophysis; valvae remaining semi-closed when flattened in preparation (Fig. 52) *heppneri*
6. Distal part of dorsal edge of valva distinctly, albeit slightly, concave or sinuate (Fig. 64) *sapporensis*
- 6'. Distal part of dorsal edge of valva evenly rounded or convex (Figs. 63, 65–71, 73) 7

7. Saccus abruptly narrowed, parallel-sided, and without lateral flanges; length of vinculum-saccus 2 times length of valva (Fig. 50) *assectella*
- 7'. Saccus gradually tapered and with lateral flanges; length of vinculum-saccus 1.75 times or less length of valva (Fig. 51) *californica*
8. Sclerotized part of ductus bursae short, anteriorly not extended beyond intersegmental membrane between S7 and S8 (Figs. 78, 80) 9
- 8'. Sclerotized part of ductus bursae long, anteriorly extended at least to middle of S7 (Figs. 75–77, 79) 10
9. Terminal part of ductus bursae conical, curved, or bent leftward, projected outwardly beyond plane of intersegmental membrane between S7 and S8 (Figs. 78, 88–89) *incertella*
- 9'. Terminal part of ductus bursae cylindrical, short, not projected, surrounded by oval plate in plane of intersegmental membrane between S7 and S8 (Figs. 80, 91) *sapporensis*
10. Sclerotized part of ductus bursae narrow, of even width, gently curved; ostium bursae small, less than one-fifth of greatest width of surrounding plate of sterigma; plate of sterigma subquadrate or subtrapezoid (Figs. 76, 82–86) *californica*
- 10'. Sclerotized part of ductus bursae wide, tubular or funnel-shaped, gradually widened posteriorly, straight; ostium bursae more than half of greatest width of plate of sterigma; plate of sterigma with bilobate or shouldered appearance (Figs. 75, 77, 81, 87) 11
11. Sclerotized part of ductus bursae about three-quarters of length of S7 with proportionally small apical shoulders around ostium (Fig. 75); inception of ductus bursae lateral on corpus bursae and distant from inception of ductus seminalis (Fig. 75); signum finely denticulate (Figs. 93–94) *assectella*
- 11'. Sclerotized part of ductus bursae about half of length of S7 with proportionally large apical shoulders around ostium (Fig. 77); inception of ductus bursae apical and adjacent to ductus seminalis on corpus bursae (Fig. 77); signum smooth (Figs. 95–96) *heppneri*

1. *Acrolepiopsis assectella* (Zeller)

(Figs. 1–14, 31, 37, 43, 50, 60, 63, 75, 81, 93–94, 114–121, 127–128, 131)

Roeslerstammia assectella Zeller, 1839: 203.

Acrolepia assectella; Heinemann 1870: 96; Staudinger and Wocke 1871: 276.

Acrolepiopsis assectella; Gaedike 1970: 36; Gaedike 1997: 6.

Lita vigeliella Duponchel, 1842: 275. Synonymized by Staudinger and Wocke 1871: 276.

Lita vigiliella; Gaedike 1970: 36; Gaedike 1997: 6. Incorrect subsequent spelling of *vigeliella*.

Diagnosis

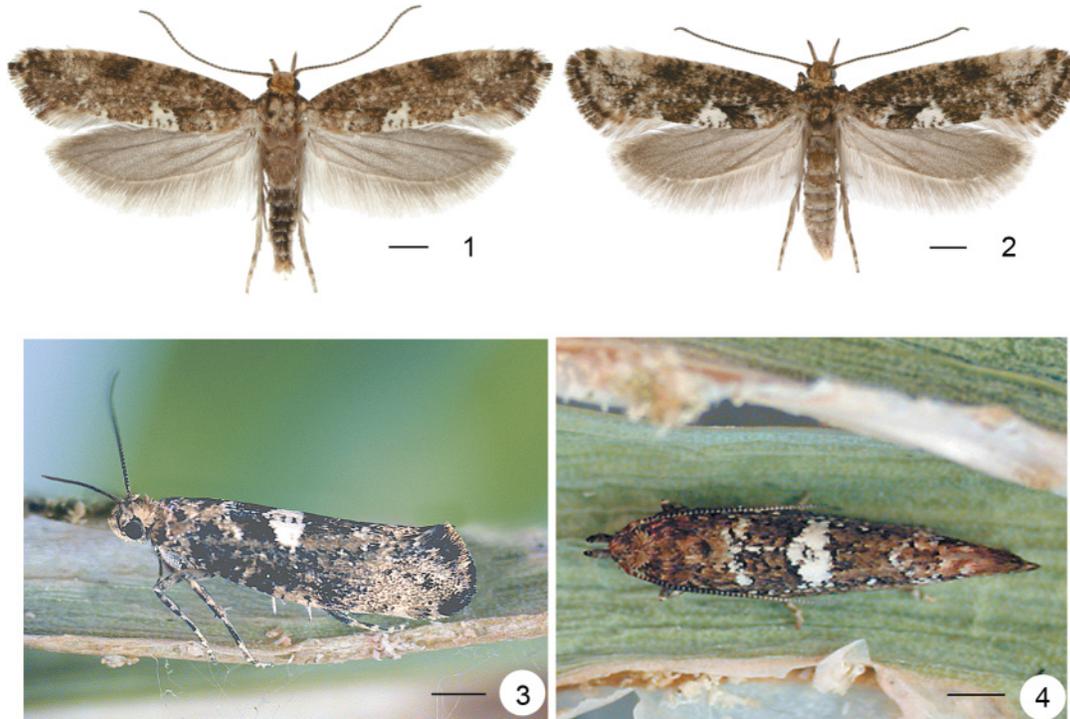
Adult

The forewings of *A. assectella* (Figs. 1–2, 13–14) have a somewhat more mottled appearance than those of other *Acrolepiopsis* species except *A. sapporensis* (Fig. 30), owing to the greater amount of white or dirty white scales interspersed over the dark areas. The white posteromedian fascia is triangular and proportionally broader than in other species with a triangular fascia, except *A. sapporensis*. Specimens of *A. reticulosa* have a large amount of white in the distal third of the forewing but have a rectangular posteromedian fascia (Figs. 27–28) and are larger (>16 mm wingspan vs. <14 mm for *A. assectella*). The pale mottling of the

forewing is more distinct and spotty in *A. sapporensis*, whereas it is rather diffuse in *A. assectella*. There is a significant amount of individual variation, so wing appearance alone is not diagnostic. The white posteromedian fascia can be immaculate or can have various amounts of dark scaling, as with the other species. Worn specimens of species of similar size are easily confused. Forewing length 4.9–6.6 mm (mean 5.9 mm, $n = 85$).

In genitalia (Figs. 50, 60, 63), *A. assectella* is readily separated from all other North American species. Males have a long (2 times length of valva), narrow saccus with an abruptly narrowed stem (Fig. 50), and the valva is smoothly arched and medially narrow (Fig. 63). They are most similar to males of *A. californica*, which are distinguished by the proportionally shorter saccus (≤ 1.75 times length of valva), which is gradually narrowed with lateral flanges (Fig. 51); male genitalia of *A. leucoscia* are intermediate in overall shape between those of *A. assectella* and *A. californica*, but *A. leucoscia* is easily distinguished by its pale grey colouration. The abdominal coremata are the longest of any North American species and extend beyond the level of the spiracle on S7 (Fig. 31). Females of *A. assectella* are unlike other species treated here in having a long, wide, sclerotized section of the ductus bursae extending nearly the length of S7 (Fig. 75) and abruptly widened and shoulder-like near the

Figs. 1–4. Adults of *A. assectella*: 1, male, specimen CNCLEP00002724; 2, female, specimen CNCLEP00016753; 3, live moth in lateral aspect on leek leaf; 4, live moth in dorsal aspect. Scale bars = 1 mm.



ostium (Fig. 81), a densely denticulate signa (Figs. 93–94), and the inception of the ductus bursae laterally on the bursa distant from the inception of the ductus seminalis (Fig. 75).

The immature stages of *A. assectella* may be confused with those of *Plutella xylostella*. The two species occur together if weeds from the mustard family that serve as hosts for *P. xylostella* happen to grow in the vicinity of cultivated *Allium* plants. Below is a superficial comparison of the larvae and pupae of the two unrelated species, which will adequately provide for their identification.

Larva

The larva of *A. assectella* (Fig. 121) is very pale greenish yellow with thin, pale golden setae, grey papillae on greenish-grey pinacula, rufous-yellow head with faintly darker pigmented patches on lateral areas, and rufous-brown anteclypeus, labrum, and adfrontal suture contrasting with the ground colour of the head capsule; it has 6 setae on A9. Mature larvae are 13–14 mm long. The 5th-instar larva leaves its feeding site to pupate. The larva of *P. xylostella* is leaf green with stout, black setae, black papillae on pale green or whitish-

green pinacula, greenish-yellow head with several irregularly shaped, contrastingly greenish-grey pigmented patches on the lateral areas, and anteclypeus, labrum, and adfrontal suture coloured about the same as the rest of the head capsule; it has 8–9 setae on A9.

Pupa

The pupa of *A. assectella* is reddish brown and enclosed in a white netlike cocoon, which may turn buff with aging (Figs. 127–128). This type of cocoon occurs in some other Yponomeutoidea and is not diagnostic. Most cocoons are found on the leaves of the host plant, but they can also be found on the ground and occasionally on neighbouring plants. *Plutella xylostella* has a similarly constructed cocoon, which could be confused with that of *A. assectella* (Figs. 129–130). Meshes of *A. assectella* cocoons are made of thicker strands than those of *P. xylostella* cocoons (Figs. 131–132). The leek moth pupa has prominent spiracles protruded or raised from the cuticular surface of abdominal segment 8; the diamondback moth pupa has small, inconspicuous spiracles flat on the cuticular surface of A8. Differences in the larva and pupa of *A. heppneri* and *A. incertella*

are given under *A. heppneri*, but the immature stages of these species of *Acrolepiopsis* are unlikely to be found near those of *A. assectella*.

Distribution

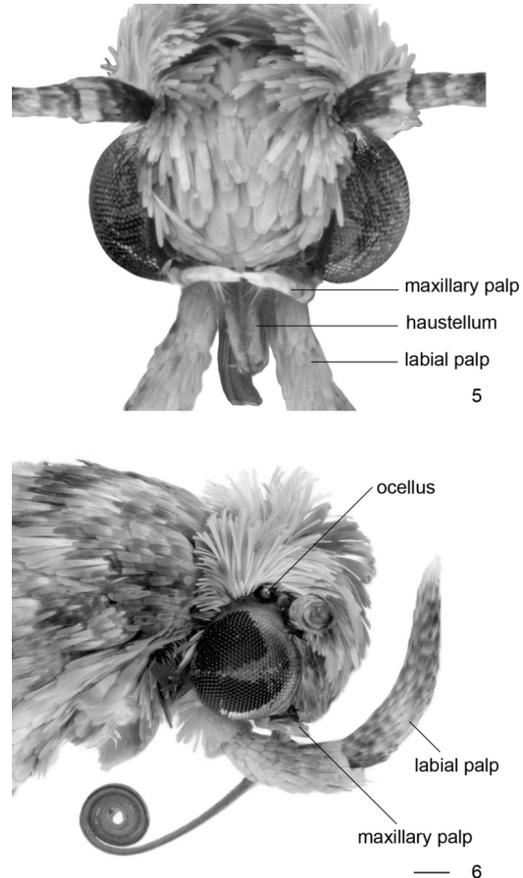
The leek moth is native to Europe, where it is widespread from Scandinavia and western Russia in the north, south to northern Africa (Algeria) (Gaedike 1996, 1997). It was first detected in Canada in 1993 when larvae were found in the city of Ottawa infesting onion and garlic in a private garden (voucher specimens in CNC). Larvae were found again in 1994 on leek in another part of Ottawa. In 1996 adults were taken at light in Gatineau, Quebec (Handfield *et al.* 1997). In 2000, larvae were found in growers' fields about 40 km east of Ottawa (Landry and Parker 2000). Surveys conducted by the Canadian Food Inspection Agency from 2001 to 2003 using pheromone traps showed the expanding range of *A. assectella* in southeastern Ontario and southwestern Quebec (Canadian Food Inspection Agency 2001–2003; Callow *et al.* 2003).

Life history

Larvae feed on several species of the genus *Allium*. They prefer leek (*A. porrum* L.) and onion (*A. cepa* L.) but will develop readily on several other *Allium* species and varieties, such as garlic (*A. sativum* L.), elephant garlic (*A. ampeloprasum* L.), shallot (*A. cepa* L. var. *aggregatum*), and chive (*A. schoenoprasum* L.) (Carter 1984; Gaedike 1997; Garland 2002). They attack the aerial part of the plant, mining and boring through the leaves, the stem, the base of the developing bulb, and to a lesser extent the flower buds (Figs. 114–120). They are usually concealed inside the leaves of the plant (Fig. 117) but do come out to change feeding site and to pupate (Fig. 121). During the summer of 2000 I bred two full generations and a partial third on potted chives placed in a cage kept indoors: the third generation failed to complete development because the larvae eventually killed the plants. I repeatedly observed several larvae lined up head to tail inside single hollow chive leaves.

In Ontario, there are at least 2–3 generations per summer (Mason *et al.* 2006). In warm regions, the leek moth has several generations per year: 3–5 in France (Ghalia and Thibout 1983b), 5–6 in southern Italy (Scaltriti and Rezadore 1982), and up to 8 in Algeria (Lecomte

Figs. 5–6. Heads of *A. assectella*: 5, frontal aspect (labials palps have been pulled down to better expose maxillary palps and base of haustellum); 6, lateral aspect. Scale bar = 0.1 mm.



1976); it may develop continuously, leading to large populations if left uncontrolled.

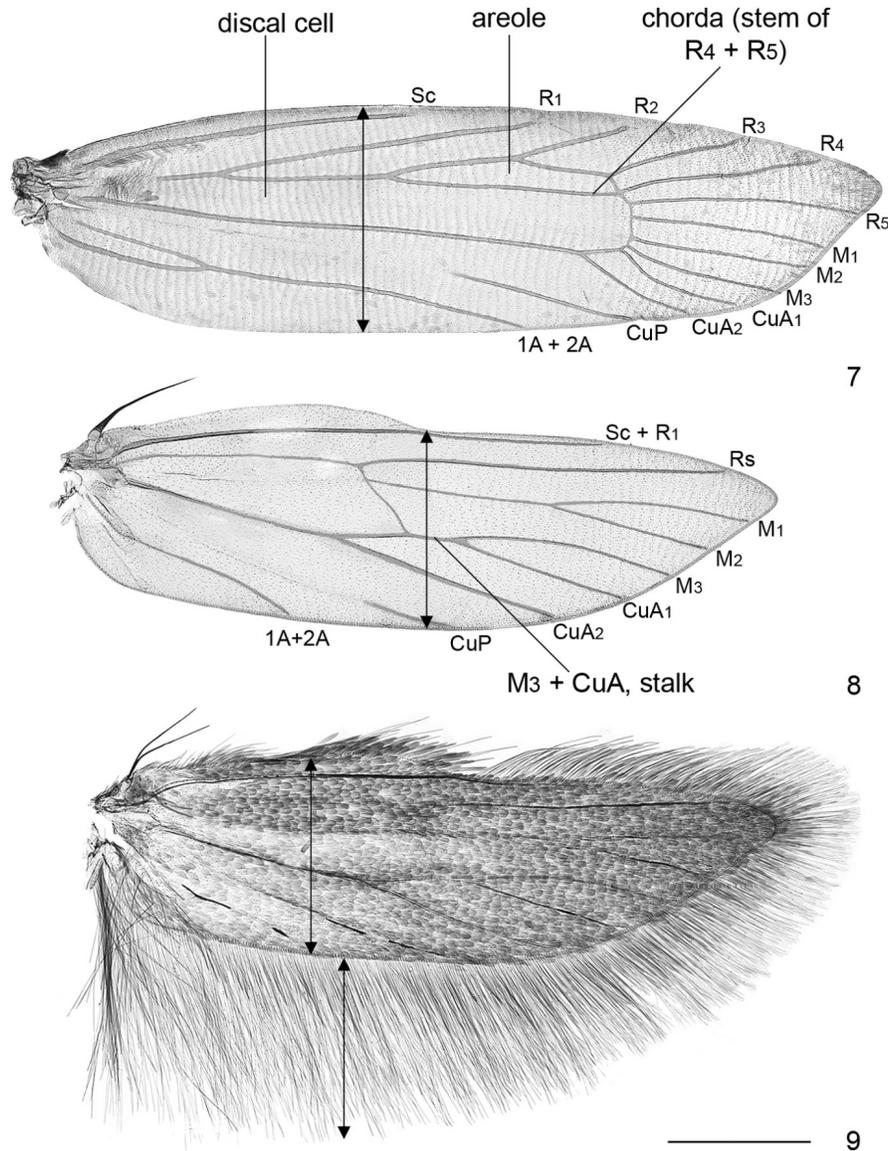
In temperate regions first-generation moths of *A. assectella* emerge in the spring and lay eggs on young plants. Winter is spent as an adult or a pupa. The adult has a facultative diapause during which females do not reproduce (Ghalia and Thibout 1983a).

Although most *Acrolepiopsis* species are not attracted to lights, *A. assectella* is attracted to some extent as evidenced by a number of records obtained at mercury lights in Gatineau, Quebec (see Material examined).

Comments

The species is commonly known as the leek moth (Carter 1984) or onion leafminer (Zimmerman 1978); in French, *teigne du poireau* (Labeyrie 1966). There is a voluminous

Figs. 7–9. Wings of *A. assectella*: 7, denuded forewing showing venation (veins were chemically stained and digitally enhanced), slide MIC 5208, specimen CNCLEP00006907; 8, hind wing, ditto, slide MIC 5209, specimen CNCLEP00016729; 9, hind wing with scales and fringe to show width of fringe relative to wing, slide MIC 5210, specimen CNCLEP00016769. Scale bar = 1 mm.



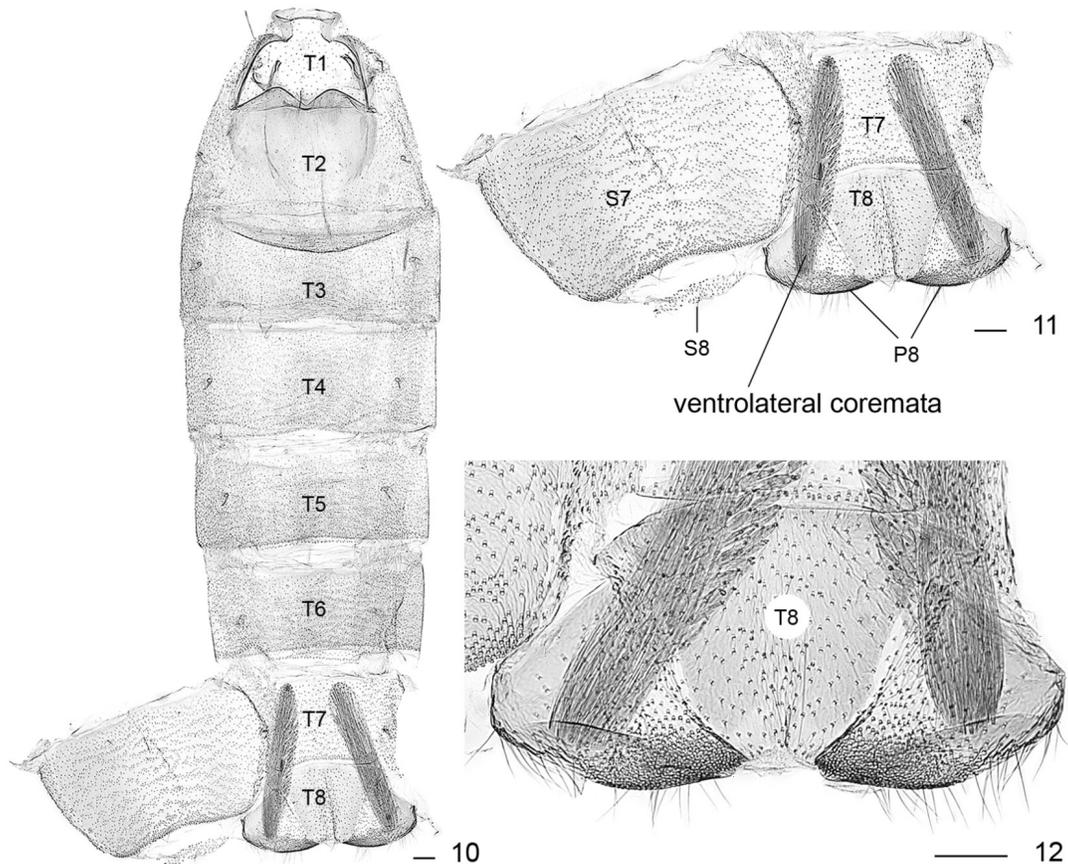
literature on this economically important species, treating all aspects of its morphology, physiology, biology, natural enemies, control, *etc.* (see Garland 2002 for partial bibliography). Currently there is an active research project of Agriculture and Agri-Food Canada in Ottawa (Mason *et al.* 2006) that seeks to develop integrated pest management methods adapted to Ontario and Quebec.

Material examined

41 ♂, 47 ♀.

Canada, Ontario, Ottawa, Nepean, 45.3488°, -75.7173°, larva 2.vi.1993 on cultivated garlic (*Allium sativum* L.), B. Forrest, 1 ♀, em. 22.vi.1993, CNCLEP00002717; 1 ♂, 1 ♀, em. 29.vii.1993, CNCLEP00002715–2716, genitalia slides MIC 4690 and MIC 4691 (CNC); Canada, Ontario, Ottawa, Central Experimental Farm,

Figs. 10–12. Male abdomen of *A. assectella*, cleared and descaled: 10, whole abdomen in dorsal aspect with sternum 7 (S7) cut and flipped to the left, slide MIC 5177, specimen CNCLEP00002726; 11, segments 7 and 8 showing the pleural lobes of the 8th segment (P8) with the pair of ventrolateral coremata and reduced sternum 8 (S8), slide MIC 5177, specimen CNCLEP00002726; 12, enlarged view of tergum 8 (T8) and pleural lobes with coremata, slide MIC 5176, specimen CNCLEP00002720. Scale bars = 0.1 mm.



45.3938°, -75.7135°, larva on leek (*Allium porrum* L.), J.-F. Landry, 1 ♀, em. 19.vii.2001, CNCLEP00007611; 1 ♀, em. 1.viii.2001, CNCLEP00007612; 2 ♂, 4 ♀, em. 9–10.ix.2001, CNCLEP00007613–7618 (CNC); Canada, Ontario, Prescott-Russell Co., Clarence Creek, 45.537°, -75.21°, reared from elephant garlic (*Allium ampeloprasum* L.), J.-F. Landry, 1 ♀, em. 1–2.vii.2000, CNCLEP00002734 (CNC); Canada, Ontario, Prescott-Russell Co., Sarsfield, 2789 Sarsfield Rd, 45.4664°, -75.3575°, ex cultivated garlic (*Allium sativum* L.), D. Bedard, 5 ♂, 5 ♀, em. 27–28.vi.2000, CNCLEP00002724–2733, male genitalia slide MIC 5177 (CNC); Canada, Ontario, Ottawa-Carleton Co., Almonte-Osgoode area, 45.1143°, -76.2932°, lab-reared from leek (*Allium porrum* L.) from wild-collected stock, P.G. Mason, 3 ♂, 6 ♀, em. 18.viii.2004, CNCLEP00006901–6909, male genitalia slides

MIC 5208 and MIC 5172; 7 ♂, 3 ♀, em. 18–20.xii.2004, CNCLEP00016724–16733, male genitalia slides MIC 5174 and MIC 5209, female genitalia slide MIC 5271; 3 ♂, 10 ♀, em. 18.iii.2005, CNCLEP00016734–16746 (CNC); Canada, Quebec, Gatineau, Aylmer, 48 rue du Couvent, 45.3967°, -75.849°, at mercury-vapour light, J.-F. Landry, 1 ♂, 3.v.1999, CNCLEP-00002723, genitalia slide MIC 4692; 1 ♀, 8.v.1998, CNCLEP00002721; 1 ♀, 12.ix.1996, CNCLEP00002719, genitalia slide MIC 4693; 1 ♀, 20.vi.1998, CNCLEP00002722, genitalia slide MIC 5270 (CNC); Canada, Quebec, Gatineau, Aylmer, 18 rue Washington, 45.3974°, -75.8421°, at mercury-vapour light, B. Landry, 1 ♂, 29.iv.1997, CNCLEP00002735; 2 ♂, 5.v.1997, CNCLEP00002720, genitalia slide MIC 5176, CNCLEP00002736; 1 ♂, 3.vi.1997, CNCLEP-00002737; 1 ♂, 27.iv.1998, CNCLEP00002738;

1 ♂, 30.v.1999, CNCLEP00002739 (CNC); Canada, Quebec, Saint-Damase, ferme Desnoyers, 45.51°, -72.99°, on leek (*Allium porrum* L.), S. Dagenais, 1 ♂, 14.viii.2003, CNCLEP-00018935, genitalia slide MIC 4796 (CNC); France, Tours, Ville-aux-Dames, 47.39667°, 0.765278°, lab culture on leek (*Allium porrum* L.), W. Jenner, 2 ♂, em. 16.iii.2005, CNCLEP00016747-16748; 3 ♂, 5 ♀, em. 18.iii.2005, CNCLEP00016749-16756; 6 ♂, 4 ♀, em. 4-5.iv.2005, CNCLEP00016757-16766, male genitalia slide MIC 3990; 1 ♀, em. 6.iv.2005, CNCLEP00016767; 1 ♂, 1 ♀, em. 7.iv.2005, CNCLEP00016768-16769, female genitalia slide MIC 5210 (CNC).

2. *Acrolepiopsis californica* Gaedike

(Figs. 15–21, 32, 38, 44, 51, 56, 65–70, 76, 82–86, 107–113)

Acrolepiopsis californica Gaedike, 1984: 183.
Acrolepiopsis liliivora Gaedike, 1994a: 46.
Poole 1996: 803; Gaedike 1997: 7; Pohl *et al.* 2005: 67. **New synonymy.**

Diagnosis

Superficially specimens of *A. californica* tend to be more uniformly brown than other species of *Acrolepiopsis* but there is a significant amount of individual variation that blurs this minor distinction (Figs. 15–21). The posteromedian fascia tends to be smaller and narrower than in other species. The male genitalia (Figs. 51, 65–70) resemble those of *A. leucoscia* in overall appearance but have the dorsal edge of the valva less arched and the apex slightly more dilated. The saccus is proportionally shorter relative to the valva than in *A. assectella*, with a broader base, more gradual tapering, and lateral flanges. The coremata (Fig. 32) extend slightly beyond the level of the spiracles on abdominal segment 7 but are not as slender as those of *A. assectella*. The female genitalia are distinctive, with an evenly narrow sclerotized section of the ductus bursae and an ostium situated on a trapezoidal plate (Figs. 76, 82–86). The signa vary greatly in size (Figs. 107–113), and I consider the large size represented in the type series of *liliivora* to be an extreme variant. Forewing length 4.4–6.7 mm (mean 5.7 mm, $n = 15$).

Distribution

Known from western California (northern half, from Monterey County northwards), western Oregon, and Alberta. The Alberta records were reported by Pohl *et al.* (2005) as *A. liliivora* and represented a major range extension.

Life history

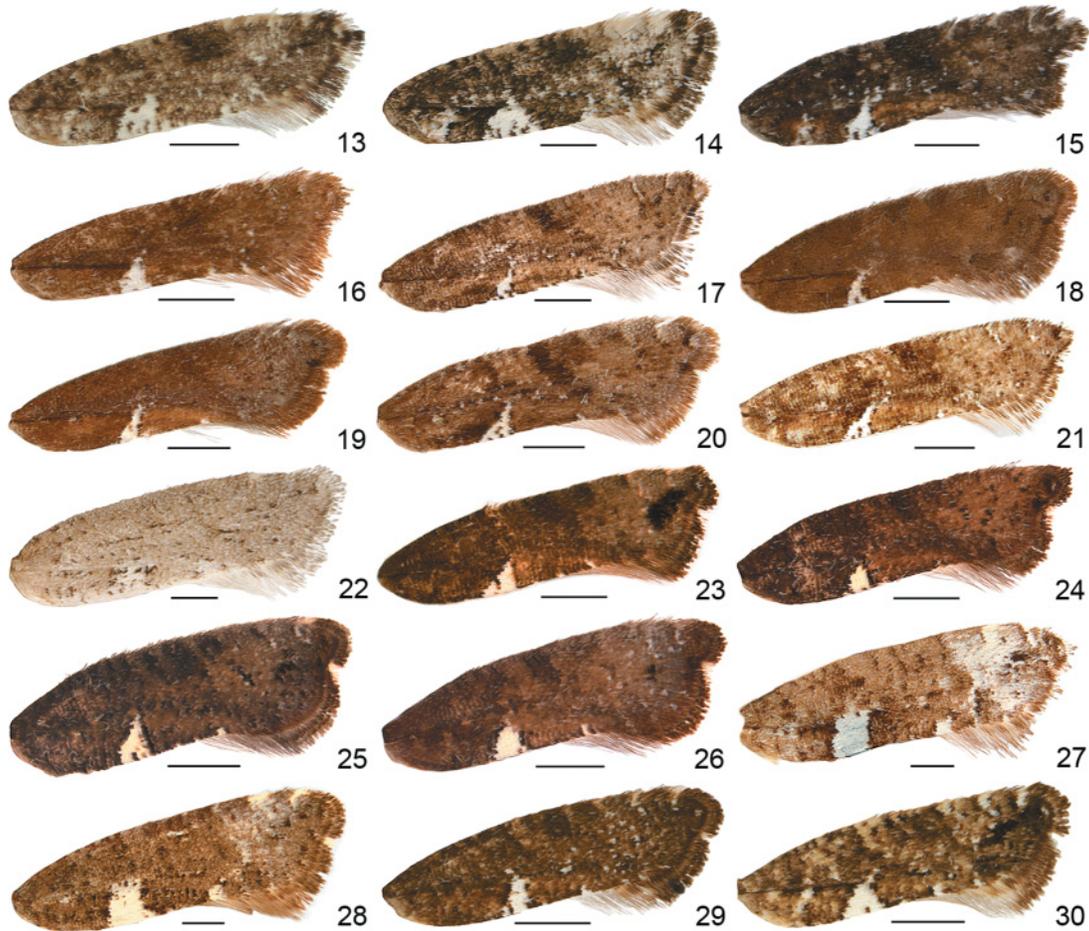
In California, adults have been reared from larvae feeding on *Lilium pardalinum* Kellogg and *Disporum hookeri* (Torr.) Nichols (Liliaceae) in the same area in Big Creek Reserve, Monterey County (J.A. Powell, personal communication 2003). The type series of *liliivora* was reared from bulbs of *Lilium washingtonianum* Kellogg from an unknown site in California and from Oregon. In late July 2003 Greg Pohl and I found acrolepiid larvae mining the unripened fruit of *Disporum trachycarpum* (S. Wats.) Benth. & Hook. from the site near Edmonton where adults had previously been collected. No lilies were present in that aspen grove, but *D. trachycarpum* grew abundantly and was likely the host.

Jerry Powell (personal communication, 2006) kindly provided the following observations from his rearings of *A. californica*: “The larva [found in May 1987 on *Disporum hookeri*] had webbed and eaten the inflorescence bud when young and had expanded its web onto a subtending leaf when found. In the lab it continued to feed by skeletonizing the underside of one of the two terminal leaves. In April 1990 I reared three specimens from larvae found on the undersides of leaves of two *Disporum* plants. None of these had webbed up the inflorescences. In the lab one or more also fed on the leaf upperside. The larvae moved around a lot as the leaves dried and fed on later added leaves. I found the larvae on *Lilium pardalinum* Kellogg in June 1994 at the same site on plants that were in bud and identified several weeks later when they had bloomed. These larvae had eaten the terminal buds of numerous plants, and still occupied the eaten, webbed buds in some instances. In this group, larvae ate extensive holes in the leaves that were adjacent to the inflorescence buds, in the lab. At that locality (coastal Monterey Co.) apparently there are two (or more?) generations, and later ones take advantage of the later growth of *Lilium*.”

Comments about synonymy

Gaedike (1994a) indicated in his remarks under *liliivora* that “it is closely related to

Figs. 13–30. Forewings of *Acrolepiopsis* species (right wing shown unless otherwise indicated): 13, *A. assectella*, Ontario, specimen CNCLEP00002754; 14, *A. assectella*, Ontario, specimen CNCLEP00016753; 15, *A. californica*, Alberta, specimen CNCLEP00002740; 16, *A. californica*, California, specimen CNCLEP00020300; 17, *A. californica*, California, specimen CNCLEP00020304; 18, *A. californica*, California, *ex Disporum hookeri*, specimen CNCLEP00020305; 19, *A. californica*, California, *ex Lilium pardalinum*, specimen CNCLEP00020308; 20, *A. californica*, holotype, California; 21, *A. californica*, paratype, California; 22, *A. leucoscia*, Texas, specimen CNCLEP00002747; 23, *A. heppneri*, New Hampshire, specimen CNCLEP00024650; 24, *A. heppneri*, Tennessee, specimen CNCLEP00014105; 25, *A. incertella*, Illinois, *ex Smilax tamnoides*, specimen CNCLEP00020498; 26, *A. incertella*, Michigan, *ex Smilax* sp., specimen CNCLEP00025055; 27, *A. reticulosa*, holotype, Wyoming; 28, *A. reticulosa*, left wing reversed, paratype, New Mexico; 29, *A. sapporensis*, Japan, specimen CNCLEP00018264; 30, *A. sapporensis*, Japan, specimen CNCLEP00018265. Scale bars = 1 mm.



A. californica. It differs in the coloration of the cilia below the apex, in having somewhat broader valvae and longer signa than *californica*.”

Regarding the colouration, Gaedike’s description preceding the remarks reads “cilia beneath apex [emphasis mine] pale distally”. Although Gaedike used different and ambiguous terms to describe that part of the cilia

(“beneath” vs. “below”), I presume that his description refers to the posterior portion of the cilia on a spread wing. The holotype and four paratypes of *liliivora* that I examined are so badly damaged that there is hardly any cilia left at all. In fact, two of the paratypes have no forewings at all, and the other two have only parts of the forewings with no cilia. The holotype has the left forewing broken off and

stored in a gelatine capsule under the labels; that wing is complete, though not fully expanded, and has some of its cilia, but I could not observe the pale area or part mentioned by Gaedike. As a result, I could not interpret this allegedly diagnostic feature of *liliivora* from the type material.

Regarding genitalia, the difference in the absolute size of the male valvae and female signa between *liliivora* and *californica* is observable, but the specific value of these characters is dubious because they may result from an allometric effect (specimens of the type series of *liliivora* appear slightly larger). In shape or outline, the valvae of the single known male *liliivora* are indistinguishable from those of *californica*, and *californica* specimens also exhibit individual variation in size and shape of the valva (Figs. 66–70).

Signum size is the most notable difference between *liliivora* and *californica*, those of *liliivora* being about twice as large (Figs. 111–113). The original description of *californica* was based on males only (Gaedike 1984). The female genitalia of *californica* were described subsequently, in the same paper in which *liliivora* was described (Gaedike 1994a): the signa of *californica* are illustrated without the bursa and without indication of size, whereas those of *liliivora* are shown within the corresponding outline of the bursa; thus, it is difficult to assess the size of the *californica* signa relative to the bursa from that publication. A further difficulty in interpretation arises from the fact that the signa on the two *liliivora* specimens illustrated by Gaedike (1994a) are oriented differently, one being shown on edge, the other shown flat, giving them a markedly different appearance. The specific value of the observable difference in signum size is doubtful when one considers the pronounced intraspecific variation in signum size in other *Acrolepiopsis* species. For example, a twofold size difference was observed within the same introduced population of *A. assectella* (Figs. 93–94), and significant variation of nearly the same magnitude was observed in *A. incertella* from various locations (Figs. 97–102). Note that all signa illustrated here (Figs. 93–113) are shown at the same scale and mounted flat.

Therefore, I synonymize *liliivora* with *californica* because of the lack of consistent morphological differences between them and because of the pronounced intraspecific

variation exhibited by other *Acrolepiopsis* species in characters originally used to define *liliivora*.

The initial identification of the Alberta records of *A. californica* as *liliivora* (Pohl *et al.* 2005) illustrates the difficulty in identifying this nominal species. The barcoding data helped to confirm the conspecificity of the Alberta specimens with *californica* specimens from California (see below). Unfortunately it was not possible to sequence and barcode the type material of *liliivora* owing to its old age.

Material examined

13 ♂, 10 ♀.

Types

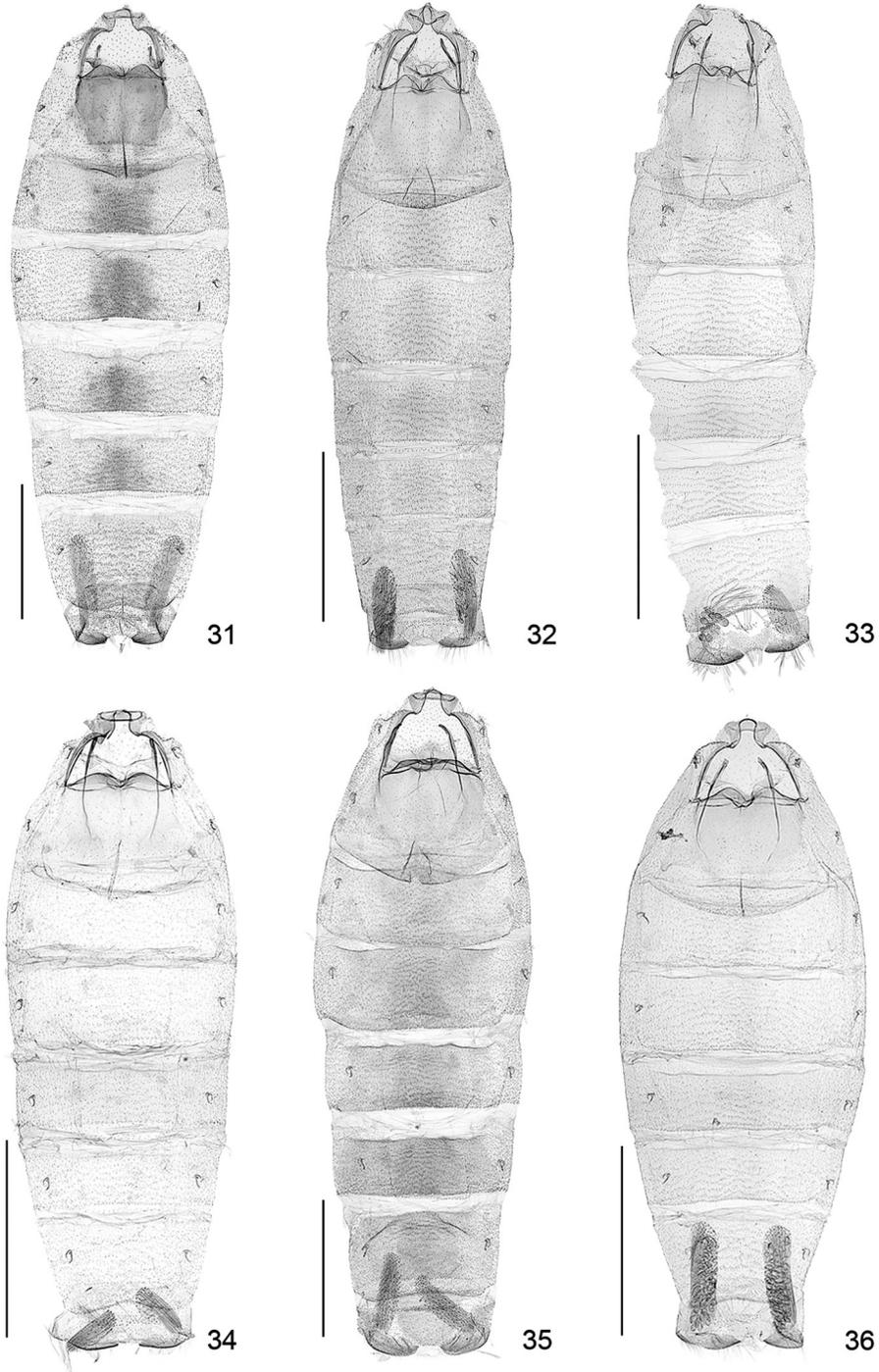
Acrolepiopsis californica. Holotype ♂: “Holotypus” [red, printed]; “Sept.[ember]/ 1–7” [printed]; “Shasta Retreat/ Siskiyou Co./ Calif.” [printed]; “Gen[italia]. Präp[aration].Gaed.[ike]/ Nr. 2419” [white, printed with number handwritten]; “Acrolepiopsis ♂/ californica sp. n./ Holotypus/ det. R. Gaedike [19]82” [handwritten, with red border]; “Genitalia Slide/ By R. Gaedike/ USNM 91,616” [green], CNCLEP-00020321 (USNM). Paratype: locality and date same as those of holotype, 1 ♂, CNCLEP-00020322, genitalia slide USNM 91617 (USNM).

Acrolepiopsis liliivora. Holotype ♂: “Holotypus” [brown, printed]; “Auto Rest/ Cal[ifornia] 8[August]-18-[19]18” [handwritten]; “David Griffiths/ Coll.[ector]” [handwritten]; “on Lilium/ washingtonianum” [handwritten]; “Gen[italia]. Präp[aration].Gaed.[ike]/ Nr. 2421” [white, printed with number handwritten]; “Acrolepiopsis ♂/ liliivora sp. n./ Holotypus/ det. R. Gaedike [19]89” [handwritten, with red border]; “Genitalia Slide/ By R. Gaedike/ USNM 91,630” [green], CNCLEP00020316 (USNM). Paratypes: locality and dates same as those of holotype, 3 ♀, CNCLEP00020318–20320, genitalia slides USNM 15939, USNM 91628, USNM 91629 (USNM); Oregon, Santiam National Forest [nowadays included in Willamette National Forest], reared from bulb of *Lilium washingtonianum*, [no collector], 1 ♀, em. 9.x.1931, CNCLEP00020317, genitalia slide USNM 91627 (USNM).

Other material examined

Canada, Alberta, Edmonton, 8 km SE Sherwood Park, 53.47792°, –113.229°, aspen

Figs. 31–36. Male abdomens of *Acrolepiopsis* species, cleared and descaled, ventral aspect: 31, *A. assectella*, slide MIC 5264, specimen CNCLEP00007614; 32, *A. californica*, slide MIC 5169, specimen CNCLEP00002740; 33, *A. heppneri*, slide USNM 15936, specimen CNCLEP00002746; 34, *A. incertella*, slide MIC 4694, specimen CNCLEP00002712; 35, *A. leucoscia*, slide USNM 15934, specimen CNCLEP00002747; 36, *A. sapporensis*, slide USNM 15930, specimen CNCLEP00018263. Scale bars = 1 mm.



forest, G.R. Pohl, 1 ♀, 14.iv.2003, CNCLEP-00002741, genitalia slide MIC 5173 (CNC); 1 ♀, 20.vi.2001, CNCLEP00002318, genitalia slide JFL 1601 (NFC); 1 ♂, 21.iv.2001, CNCLEP00002740, genitalia slide MIC 5169 (CNC); 1 ♂, 22.vi.2002, CNCLEP00002317, genitalia slide JFL 1600 (NFC); United States of America, California, Monterey Co., Big Creek Reserve (UCNRS), Big Creek [36.1°, -121.6°], reared from *Lilium pardalinum* L:3–5.vi.1994, J.A. Powell, 1 ♂, 1 ♀, em. 8.vii.1994, CNCLEP00020308, genitalia slide JFL 1647, CNCLEP00020309, genitalia slide JFL 1648; 1 ♂, em. 21.vi.1994, CNCLEP-00020307, genitalia slide JFL 1646 (UCB); United States of America, California, Monterey Co., Big Creek Reserve (UCNRS), Brunette Creek trail [36.1°, -121.6°], redwoods, reared from *Disporum hookeri* L:27–29.iv.1990, J.A. Powell, 1 ♀, em. 16.v.1990, CNCLEP-00020305, genitalia slide Essig 3822; 1 ♂, em. 19.v.1990, CNCLEP00020306, genitalia slide Essig 3827 (UCB); United States of America, California, Alameda Co., Strawberry Creek [37.873°, -122.244°], P.A. Opler, 1 ♀, 15.viii.1968, CNCLEP00020301, genitalia slide JFL 1616 (UCB); United States of America, California, Humboldt Co., Myers Flat [40.266°, -123.869°], J.A. Powell, 1 ♀, 14.viii.1963, CNCLEP00020300, genitalia slide Essig 2706 (UCB); United States of America, California, Plumas Co., Meadow Valley, 1 mi [1.6 km] S [39.918°, -121.062°], black light, J.A. Powell, 1 ♂, 1–3.vi.1984, CNCLEP00020304, genitalia slide Essig 3821; 1 ♂, 20–21.v.1982, CNCLEP00020303, genitalia slide JFL 1645 (UCB); United States of America, California, Siskiyou Co., McCloud River, Ash Creek Ranger Station [41.2617°, -121.9494°], black light trap, J.A. Powell, 1 ♂, 9.vi.1974, CNCLEP00020302, genitalia slide Essig 2704 (UCB); United States of America, California, Siskiyou Co., Shasta Retreat [41.236°, -122.271°], 2 ♂, 1–7.ix.[no year], CNCLEP00020321, genitalia slide USNM 91616, CNCLEP00020322, genitalia slide USNM 91617 (USNM).

3. *Acrolepiopsis heppneri* Gaedike

(Figs. 23–24, 33, 40, 46, 52, 57, 72, 77, 87, 95–96, 122–124, 134)

Acrolepiopsis heppneri Gaedike, 1984: 183; Gaedike 1997: 6.

Diagnosis

Superficially *A. heppneri* is indistinguishable from *A. incertella*, with which it overlaps in forewing pattern variation (Figs. 23–26).

In genitalia, *A. heppneri* is readily recognized: the male genitalia have a heavy appearance with an elongate, flanged saccus that is nearly twice the length of the valvae, a large anellus that appears to extend laterally almost beyond the valvae, and chunky valvae with thick bases that do not spread out in conventional genital preparations (hence the “unopened” aspect shown in Fig. 52) and that have a straight dorsal edge and a wedge-shaped, ventrally angulate apical portion (Fig. 72). *Acrolepiopsis incertella* males also have short valvae but they spread in conventional fashion in flattened preparations and are club-shaped with a ventrally rounded apical portion (Fig. 74); the saccus is proportionally shorter relative to the valvae and the anellus is narrower (Fig. 53). The female genitalia of *A. heppneri* (Figs. 77, 87) are distinctive in having a funnel-like sclerotized section of the ductus bursae ending in a wide ostium that is more than half the greatest width of the sterigma and that protrudes a little from the plane of the sterigma, and a bilobate sterigma with a markedly concave surface that looks like large shoulders bracing the ostium. The signa are smooth like those of *A. incertella* and variable in size (Figs. 95–96). Forewing length 5.0–5.6 mm (mean 5.4 mm, $n = 9$).

Within the variation in forewing pattern, some specimens of *A. heppneri* have a subterminal black spot (Fig. 23) that is larger than any observed in *A. incertella*. Also, in some *A. heppneri* specimens the brown area immediately adjacent to the white triangle is a tawny colour slightly paler than the rest of the ground colour. However, neither of these two differences is consistent across all specimens examined, so they cannot be construed as diagnostic for the species, considering the small number of specimens available for study.

The larva of *A. heppneri* (Fig. 122) is pale green with a pale brownish-yellow head and does not have distinctively coloured pinacula, in contrast to the larva of *A. assectella* (Fig. 121). It is quite similar to the larva of *A. incertella* (Fig. 125).

The cocoon of *A. heppneri* (Fig. 134) is distinctly conical with thick, oblique mesh strands and regularly spaced longitudinal meshes of thinner strands, and the anterior third has a

Figs. 37–48. Male ventrolateral coremata on pleurum 8 of *Acrolepiopsis* species: 37–42, whole corema; 43–48, higher magnification view of a corema showing both spatulate and hairlike scales. 37, *A. assectella*, slide MIC 4690, specimen CNCLEP00002715; 38, *A. californica*, slide JFL 1600, specimen CNCLEP00002317; 39, *A. incertella*, slide MIC 4694, specimen CNCLEP00002712; 40, *A. heppneri*, slide USNM 15936, specimen CNCLEP00002746; 41, *A. leucoscia*, slide USNM 15934, specimen CNCLEP00002747; 42, *A. sapporensis*, slide USNM 15930, specimen CNCLEP00018263; 43, *A. assectella*, slide MIC 4692, specimen CNCLEP00002723; 44, *A. californica*, slide JFL 1600, specimen CNCLEP00002317; 45, *A. incertella*, slide MIC 5171, specimen CNCLEP00002708; 46, *A. heppneri*, slide USNM 15936, specimen CNCLEP00002746; 47, *A. leucoscia*, slide USNM 15934, specimen CNCLEP00002747; 48, *A. sapporensis*, slide USNM 15930, specimen CNCLEP00018263. Scale bars: 37–42 = 0.1 mm; 43–48 = 0.05 mm.

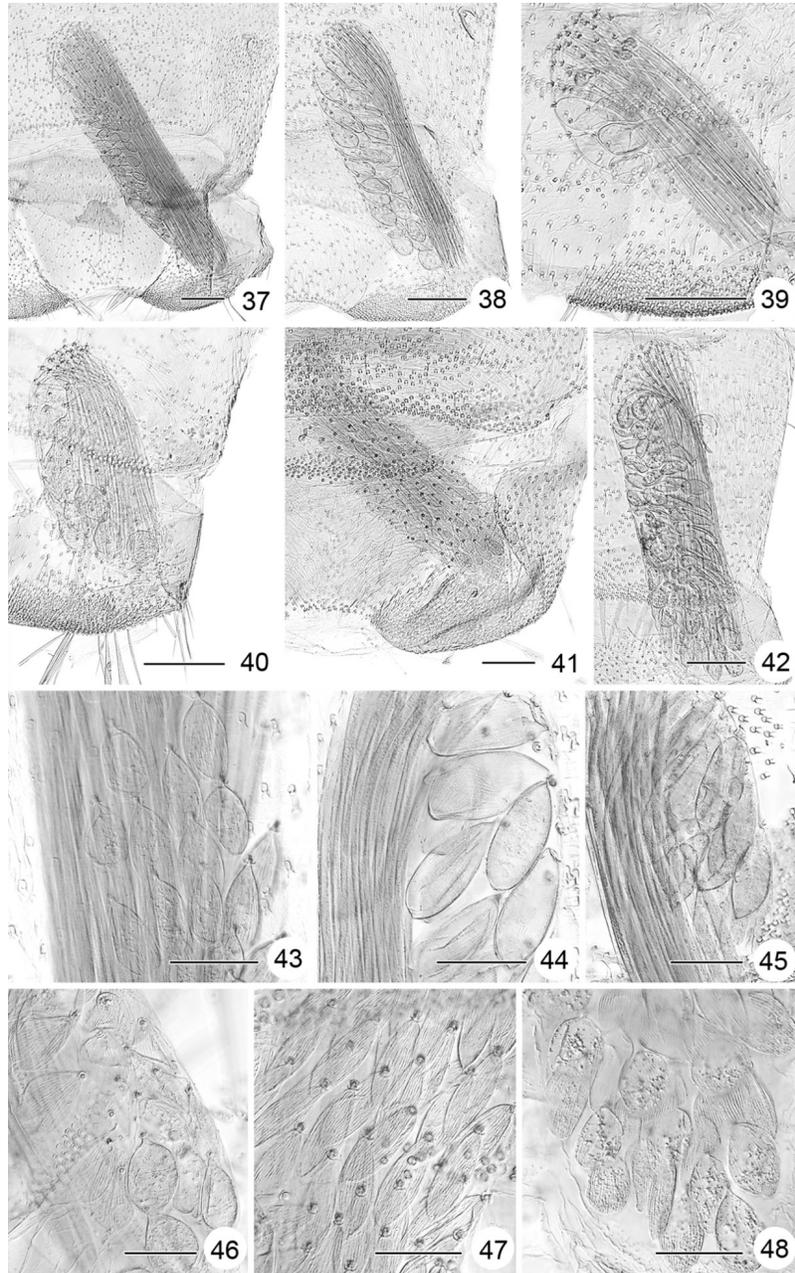
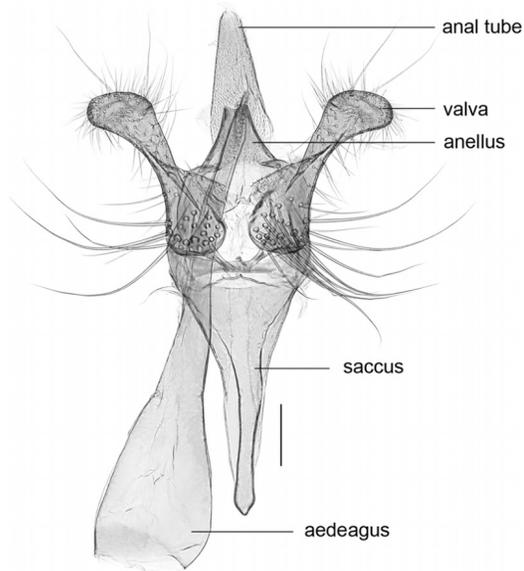


Fig. 49. Male genitalia of *A. incertella*, ventral aspect, aedeagus *in situ* with base slightly shifted leftwards, valvae partly spread outwards, slide MIC 5263, specimen CNCLEP00020495. Scale bar = 0.1 mm.



thick, transverse mesh strand that gives the appearance of a cap. It is similar to the cocoon of *A. incertella*. In contrast, the cocoon of *A. assectella* is spindle-shaped and has an irregular network of smaller meshes made of evenly sized strands.

Distribution

Widely distributed from Connecticut and New Hampshire in the east, south to Tennessee, Alabama, and Mississippi, and west to Illinois, but known from relatively few scattered records.

Life history

Larvae were reared on *Smilax tamnoides* L. (Smilacaceae) in Illinois (see Material examined below) and on unspecified *Smilax* spp. Terry Harrison (personal communication, 2006) kindly provided the following observations from his recent rearing of *A. heppneri*: “This past Sunday (25 Sep.), near Charleston here in central Illinois, I collected five of these larvae, each of them skeletonizing the underside of a leaf of *Smilax* [later identified as *S. tamnoides*] from within a black, frass-covered silken tube placed alongside a leaf vein” (Figs. 123–124). “I saw more damage when I visited plants near

the edge of the river, than I saw on the trail where I originally collected larvae (the trail is about 50–100 feet away from the river). Also, the patches of damage occur most frequently on large *Smilax* plants of complex architecture, rather than on the many small, single-dimensional plants.” Adults emerged shortly thereafter between 13 and 27 October. Dissection of emerged adults confirmed the identity of the species. It is likely that the adults overwinter in reproductive diapause, as suggested by the late emergence dates. Adults have also been taken in spring (May in Tennessee).

Comments

Acrolepiopsis heppneri and *A. incertella* probably represent a pair of closely related species based on similarities in the barcoding region of the mitochondrial COI gene and the following similarities in genitalia and host plant: males with chubby valvae with a straight to concave dorsal edge and short coremata; females with the apex of the ductus bursae and ostium bursae protruded beyond the plane of the sterigma, and smooth signa situated at the posterior end of the corpus bursae proximate to the inception of the ductus bursae; larvae are skeletonizers on *Smilax* leaves.

Material examined

8 ♂, 9 ♀.

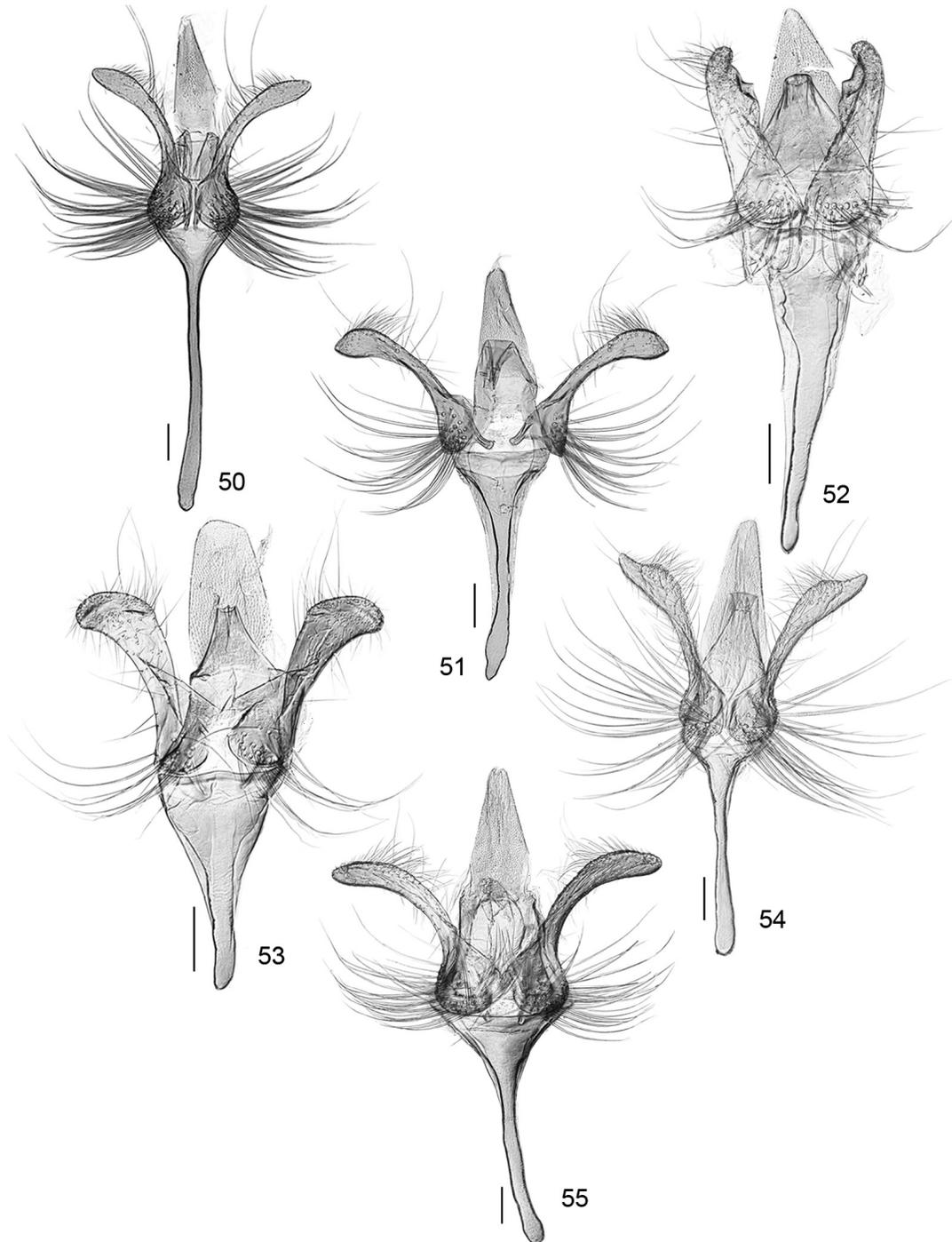
Types

Holotype ♂: “Holotypus” [red, printed]; “III.-28-1908” [handwritten]; “Hampton./ N.H./ S.A. Shaw” [printed]; “Gen[italia]. Präp[aration]. Gaed.[ike]/ Nr. 2433” [white, printed with number handwritten]; “*Acrolepiopsis* ♂/ *heppneri* sp. n./ Holotypus/ det. R. Gaedike [19]82” [handwritten, with red border]; “Genitalia Slide/ By R. Gaedike/ USNM 91,624” [green] (USNM). Paratypes 2 ♂, 3 ♀: United States of America, Connecticut, East River [41.285°, -72.639°], [no day].ix.1916, bred from *Smilax*, C.R. Ely, CNCLEP00002742–2746, genitalia slides USNM 15932, 15933, 15935, 15936, and 15938 (USNM).

Other material examined

United States of America, New Hampshire, Hampton [42.937°, -70.839°], S.A. Shaw, 1 ♂, 12.xi.1905, CNCLEP00024651; 1 ♂, 16.x.1904, CNCLEP00024650; 1 ♀, 27.x.1908, CNCLEP00024652, genitalia slide MIC 5265 (USNM);

Figs. 50–55. Male genitalia of *Acrolepiopsis* species, ventral aspect, aedeagus removed, valvae spread outwards: 50, *A. assectella*, slide MIC 5177, specimen CNCLEP00002726; 51, *A. californica*, slide JFL 1648, specimen CNCLEP00020309; 52, *A. heppneri*, slide USNM 15932, specimen CNCLEP00002745; 53, *A. incertella*, slide MIC 4694, specimen CNCLEP00002712; 54, *A. sapporensis*, slide USNM 15930, specimen CNCLEP00018263; 55, *A. leucoscia*, slide USNM 15934, specimen CNCLEP00002747. Scale bars = 0.1 mm.



Figs. 56–62. Aedeagi of *Acrolepiopsis* species, apex directed upwards, all at same scale: 56, *A. californica*, slide MIC 5169, specimen CNCLEP00002740; 57, *A. heppneri*, slide USNM 15932, specimen CNCLEP00002745; 58, *A. incertella*, slide MIC 4694, specimen CNCLEP00002712; 59, *A. sapporensis*, slide USNM 15930, specimen CNCLEP00018263; 60, *A. assectella*, slide MIC 4690, specimen CNCLEP00002715; 61, *A. leucoscia*, slide USNM 15934, specimen CNCLEP00002747; 62, *A. reticulosa*, holotype, slide Gaedike 2556. Scale bar = 0.1 mm.



United States of America, Illinois, Coles Co., 8 mi [12.8 km] S Charleston, leaf-tying larva on *Smilax tannoides* L., 24.ix.2006, T. Harrison, 2 ♂, 2 ♀, em. 24–27.x.2006, CNCLEP-00028483–28486, genitalia slide MIC 5300 (CNC); United States of America, Tennessee, Sevier Co., 0.8 km S Greenbrier, Ranger Station, 35.727°, –83.402°, blacklight trap, B. Scholtens, 1 ♂, 20.v.2005, CNCLEP00014105, genitalia slide MIC 5170 (CNC); Mississippi, Warren Co., Vicksburg [32.353°, –90.878°], R. Patterson, 1 ♀, 30.i.2002, CNCLEP00024725, genitalia slide JFL 1661 (MEM); Alabama, DeKalb Co., Desoto State Park, 1240 ft [380 m], [34.548°, –85.590°], R.L. Brown and D. Pollock, 1 ♀, 20–24.v.1990,

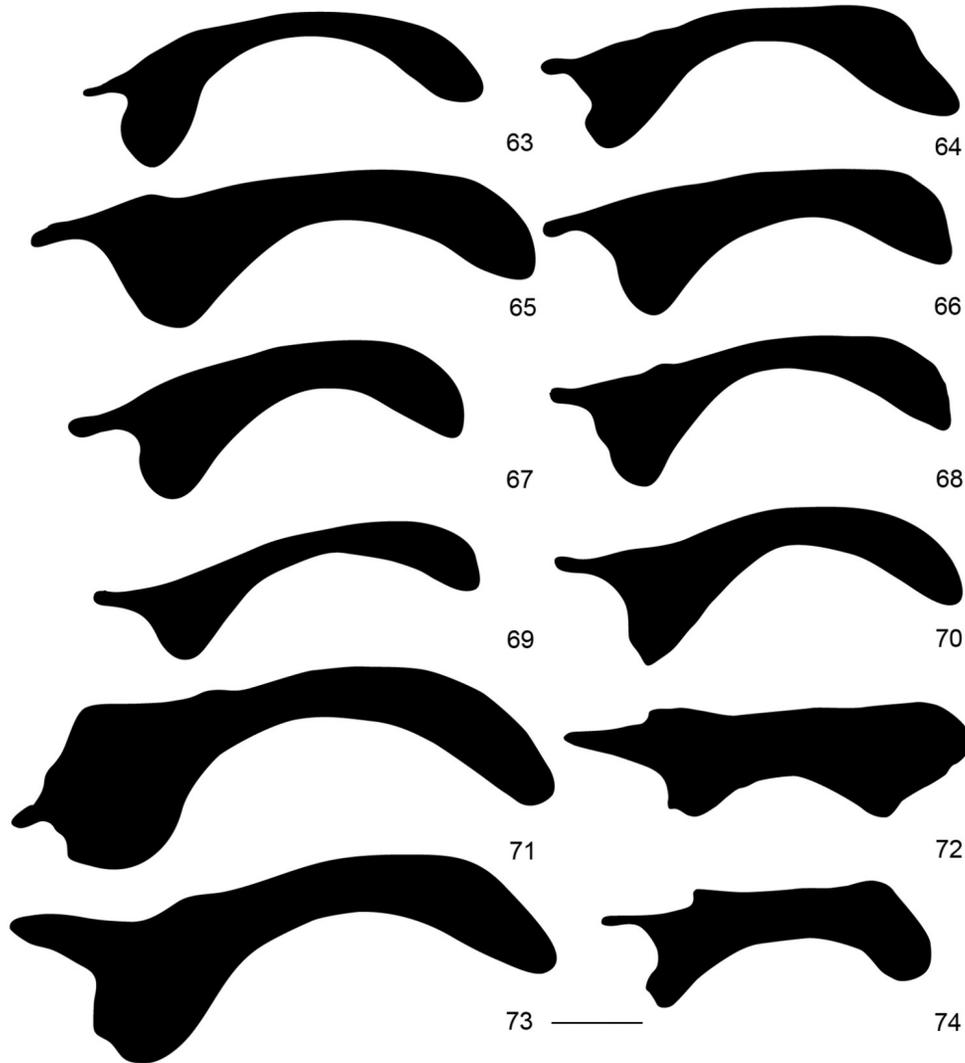
CNCLEP00024726, genitalia slide JFL 1662 (MEM); United States of America, Tennessee, Sevier Co., Great Smoky Mountains National Park, Elkmont, 2300 ft [700 m], [35.654°, –83.581°], D. Adamski, 1 ♀, 27.viii–3.ix.1986, CNCLEP00024724, genitalia slide JFL 1658 (MEM).

4. *Acrolepiopsis incertella* (Chambers)

(Figs. 25–26, 34, 39, 45, 49, 53, 58, 74, 78, 88–89, 97–102, 125–126, 133)

Heribeia incertella Chambers, 1872: 44.

Figs. 63–74. Outlines of male valvae of *Acrolepiopsis* species, apex directed rightwards, all at same scale: 63, *A. assectella*, slide MIC 5172, specimen CNCLEP00006906; 64, *A. sapporensis*, slide USNM 15937, specimen CNCLEP00018264; 65, *A. californica* (holotype of *A. liliivora*), slide USNM 91630; 66, *A. californica*, paratype, slide USNM 91617; 67, *A. californica*, holotype, slide USNM 91616; 68, *A. californica*, ex *Lilium pardalinum*, slide JFL 1646, specimen CNCLEP00020307; 69, *A. californica*, slide JFL 1645, specimen CNCLEP00020303; 70, *A. californica*, slide JFL 1600, specimen CNCLEP00002317; 71, *A. leucoscia*, slide USNM 15934, specimen CNCLEP00002747; 72, *A. heppneri*, slide MIC 5170, specimen CNCLEP00014105; 73, *A. reticulosa*, holotype, slide Gaedike 2556; 74, *A. incertella*, slide MIC 5171, specimen CNCLEP00002708. Scale bar = 0.1 mm.



Argiope incertella; Chambers 1873: 13.

Acrolepia incertella; Dyar 1903: 568.

Acrolepiopsis incertella; Heppner and Duckworth 1983: 27; Gaedike 1984: 182; Gaedike 1997: 6.

Argiope dorsimaculella Chambers, 1873: 13.
Synonymized by Dyar 1903: 568.

Acrolepia dorsimaculella; Walsingham 1882: 172.

Diagnosis

Although *A. incertella* is superficially indistinguishable from *A. heppneri*, it is readily separable by its genitalia. The male genitalia

(Fig. 53) have an elongate-triangular, flanged saccus that is barely longer than the length of the valvae; stubby valvae with a straight or slightly concave dorsal edge and a club-shaped, ventrally rounded apical portion (Fig. 74); and an aedeagus with a distal portion proportionally shorter and less curved than in *A. heppneri*. The female genitalia are distinctive in having a conical sterigma and an ostium that protrudes from the plane of the sterigma, and the sclerotized apical section of the ductus bursae has a short leftward bend (Figs. 78, 88–89). The signa are smooth and situated in the posterior, narrowed part of the corpus bursae proximate to the inception of the ductus bursae, like those of *A. heppneri*, and are variable in size, the largest being about two times larger than the smallest (Figs. 97–102). Forewing length 4.3–6.0 mm (mean 5.2 mm, $n = 30$).

The larva (Fig. 125) and cocoon (Fig. 133) are similar to those of *A. heppneri* (see under that species).

Distribution

Widely distributed over the eastern half of North America from southern Ontario to Florida and Mississippi in the south and to Illinois and Michigan in the west. Despite its wide distribution, the species is known from relatively few scattered records.

Life history

Larvae feed on young leaves of *Smilax* spp. and have been reared from both *S. tannoides* L. (INHS) and *S. herbacea* L. (CNC). The following account again was generously provided by Terry Harrison (personal communication, 2003), who reared the species repeatedly in Illinois on *S. tannoides*: “Larvae of *A. incertella* appear once per year, early in the season, just as the *Smilax* is starting to put out leaves (which, in a phenologically ‘normal’ year here in central Illinois, would be during the first week of May). The larval damage is very distinctive and easy to spot. Each larva ties together the margins of one of the waxy-looking, yellowish-green terminal leaves, to make a shelter that looks something like a tiny jalapeno pepper (averaging perhaps three-quarters of an inch [<2 cm] in length) (Fig. 126). The larva lives and feeds as a skeletonizer inside this shelter (Fig. 125), and in the advanced stages, translucent ‘window-like’ patches can sometimes be seen on the external surface of the shelter, in

areas where the larva within has eaten away all but the outer epidermis. A further telltale sign of *Acrolepiopsis* activity is that the apex of the shelter turns black. As far as I know, the larvae complete development, pupate, and then emerge in late May/early June as adults that remain reproductively inactive until finally mating and laying eggs sometime around mid-April of the following year.”

Forbes (1923) reported that, in addition to feeding on *Smilax* spp., larvae of *A. incertella* also fed on *Lilium* spp. by boring into the bulbs. However, this observation is unsubstantiated by any reared voucher specimens and probably refers to misidentified *A. californica* because Forbes also mentioned that *A. incertella* occurred “west to California”, which it does not.

Comments

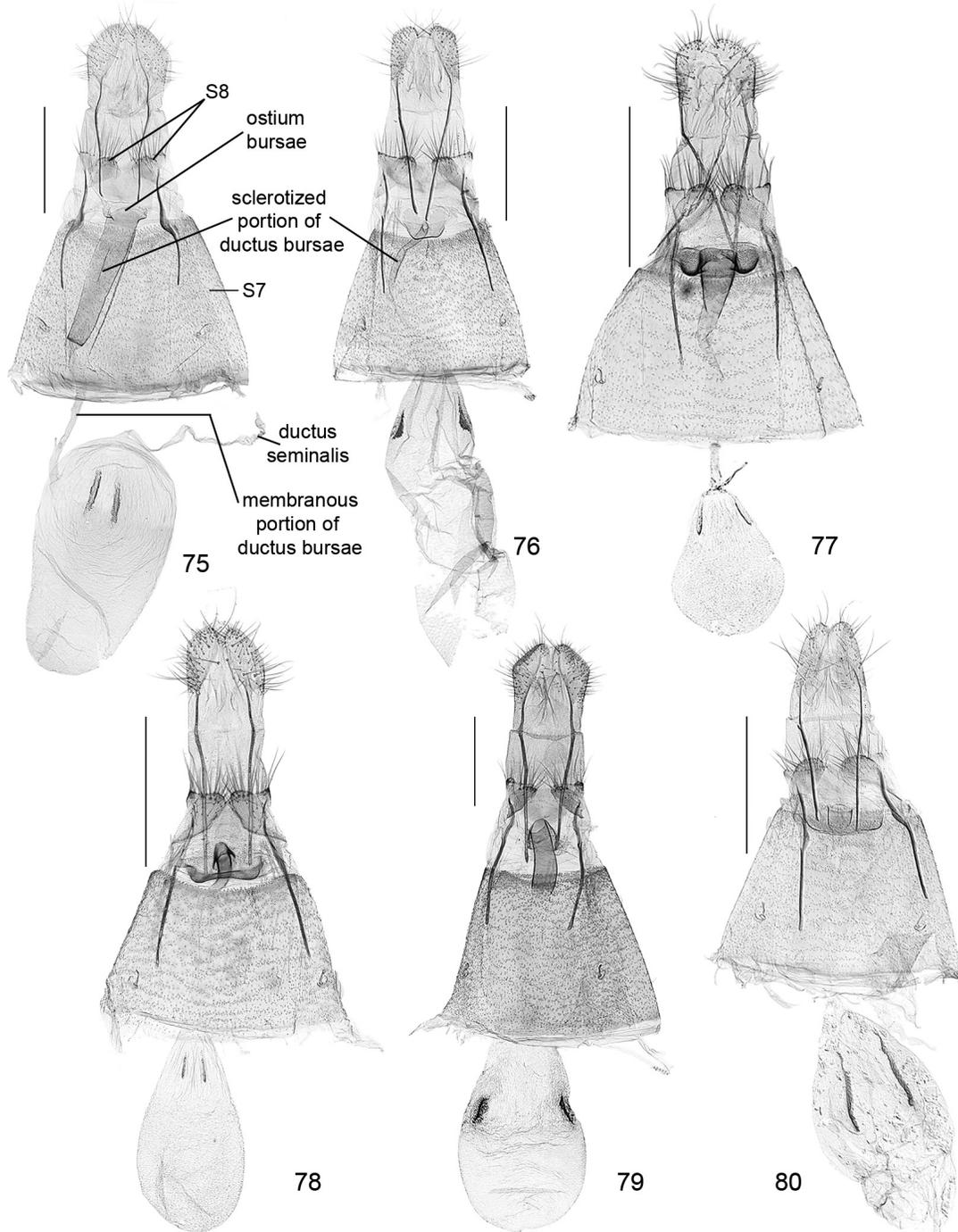
See under *A. heppneri*.

Material examined

18 ♂, 14 ♀.

Canada, Ontario, Vineland, Vineland Station [43.15°, -79.39°], host *Smilax herbacea*, W.L. Putnam, 5 ♂, 2 ♀, 14.iv.1938, CNCLEP-00002708–2714, genitalia slides MIC 5171, MIC 4694, MIC 4695, MIC 5218 (CNC); United States of America, Florida, Alachua Co., University of Florida Hort. Unit, 9 mi [14.5 km] NW Gainesville [29.648°, -82.349°], malaise trap, G.B. Fairchild, 1 ♂, 24–25.iii.1975, CNCLEP00020485, genitalia slide JFL 1652 (FLMNH); United States of America, Illinois, Coles Co., 8 mi [12.8 km] S Charleston, leaf-tying larva on *Smilax tannoides* L., 30.iv.2006, T. Harrison, 1 ♂, em. 27.v.2006, CNCLEP00020495, genitalia slide MIC 5263; 1 ♀, em. 28.v.2006, CNCLEP00020496; 1 ♂, em. 30.v.2006, CNCLEP00020498; 1 ♀, em. 31.v.2006, CNCLEP00020499 (CNC); United States of America, Illinois, Coles Co., 1 mi [1.6 km] W Charleston [39.498°, -88.229°], leaf-tying larva on *Smilax tannoides* L., 30.iv.2006, T. Harrison, 1 ♀, em. 29.v.2006, CNCLEP00020497 (CNC); United States of America, Illinois, Coles Co., Fox Ridge State Park, T11A R9E NE 1/4, sec. 14 [39.41°, -88.15°], larva 14.v.1990 on terminal leaves of *Smilax tannoides* L., T. Harrison, 1 ♂, em. 6.vi.1990, CNCLEP00020250, genitalia slide MIC 5207 (CNC); United States of America, Massachusetts, Martha’s Vineyard [41.394°, -70.625°], F.M. Jones, 1 ♀, 9.viii.1941,

Figs. 75–80. Female genitalia of *Acrolepiopsis* species, ventral aspect, apex directed upwards: 75, *A. assectella*, slide MIC 4693, specimen CNCLEP00002719; 76, *A. californica*, slide JFL 1601, specimen CNCLEP00002318; 77, *A. heppneri*, slide USNM 15935, specimen CNCLEP00024652; 78, *A. incertella*, slide MIC 5272, specimen CNCLEP00020496; 79, *A. leucoscia*, slide JFL 1668, specimen CNCLEP00024770; 80, *A. sapporensis*, slide MIC 4698, specimen CNCLEP00002748. Scale bars = 0.5 mm.



CNCLEP00020313, genitalia slide JFL 1649 (ANSP); United States of America, Michigan, Cass Co., Westmate Farm [41.95°, -85.8667°], larva in leaf shelter of *Smilax*, 24.v.2006, G. Balogh, 1 ♂, em. 16.vi.2006, CNCLEP00025052; 1 ♀, em. 17.vi.2006, CNCLEP00025053; 2 ♂, 2 ♀, em. 18.vi.2006, CNCLEP00025054–25057, male genitalia slide MIC 5262; 1 ♂, em. 19.vi.2006, CNCLEP00025058; 1 ♂, 2 ♀, em. 20.vi.2006, CNCLEP00025059–25061 (CNC); United States of America, Ohio, Cincinnati [39.16°, -84.46°], A.F. Braun, 1 ♀, 19.iv.1906, CNCLEP00020315, genitalia slide JFL 1651 (ANSP); United States of America, Ohio, Reynoldsburg [39.95°, -82.81°], at lights, S. Passoa, 1 ♂, 1.vii.1990, CNCLEP00020251, genitalia slide JFL 1642 (CNC); United States of America, Pennsylvania, Philadelphia, inside Academy of Natural Sciences [39.959°, -75.17°], E.G. Vanetta, 1 ♀, 12.i.1912, CNCLEP00020314, genitalia slide JFL 1650 (ANSP); United States of America, North Carolina, Haywood Co., Lake Junaluska [35.518°, -82.96°], J.B. Heppner, 1 ♂, 25–27.iv.1988, CNCLEP00020486, genitalia slide JFL 1653 (FLMNH); United States of America, South Carolina, Greenville Co., Caesar's Head State Park [35.104°, -82.618°], J.B. Heppner, 1 ♂, 20–22.iv.1988, CNCLEP00020487, genitalia slide JFL 1654 (FLMNH). Mississippi, Oktibbeha Co., 6 mi [9.6 km] SW Starkville [33.407°, -88.892°], R.L. and B.B. Brown, 1 ♀, 31.iii.1986, CNCLEP00024723, genitalia slide JFL 1660 (MEM); Ohio, Scioto Co., Shawnee State Forest, Picnic Point [38.721°, -83.214°], D.J. Wright, 1 ♂, 30.iv.1990, CNCLEP-00024722, genitalia slide JFL 1657 (MEM).

5. *Acrolepiopsis leucoscia* (Meyrick)

(Figs. 22, 35, 41, 47, 55, 61, 71, 79, 90,
104–106)

Acrolepia leucoscia Meyrick, 1927: 359. Clarke 1965: 260.

Acrolepiopsis leucoscia; Heppner and Duckworth 1983: 27; Gaedike 1984: 181; Gaedike 1997: 7; Knudson and Bordelon 2003: pl. 1, fig. 29.

Diagnosis

Externally this is the most distinctive North American species because of its predominantly pale grey colouration (Fig. 22). The forewings

have fine, faintly dark peppering and an indistinct posteromedial white fascia. It is larger than other species except *A. reticulosa*. The male genitalia (Fig. 55) resemble a larger version of those of *A. assectella* with a proportionally shorter saccus; the valvae are similarly shaped but larger (Fig. 71). The female genitalia are distinctive in having the sclerotized distal section of the ductus bursae medially dilated and about half the length of sternum 7 (Figs. 79, 90). The signa vary markedly in size and proportions, the largest being about two times larger than the smallest, and have a rough, scabrous texture (Figs. 104–106). Forewing length 6.7–7.7 mm (mean 7.2 mm, $n = 8$).

Distribution

Known from the central United States from Texas north to Illinois, Missouri, and Ohio. Reportedly common in central and northeastern Texas (Knudson and Bordelon 2003).

Life history

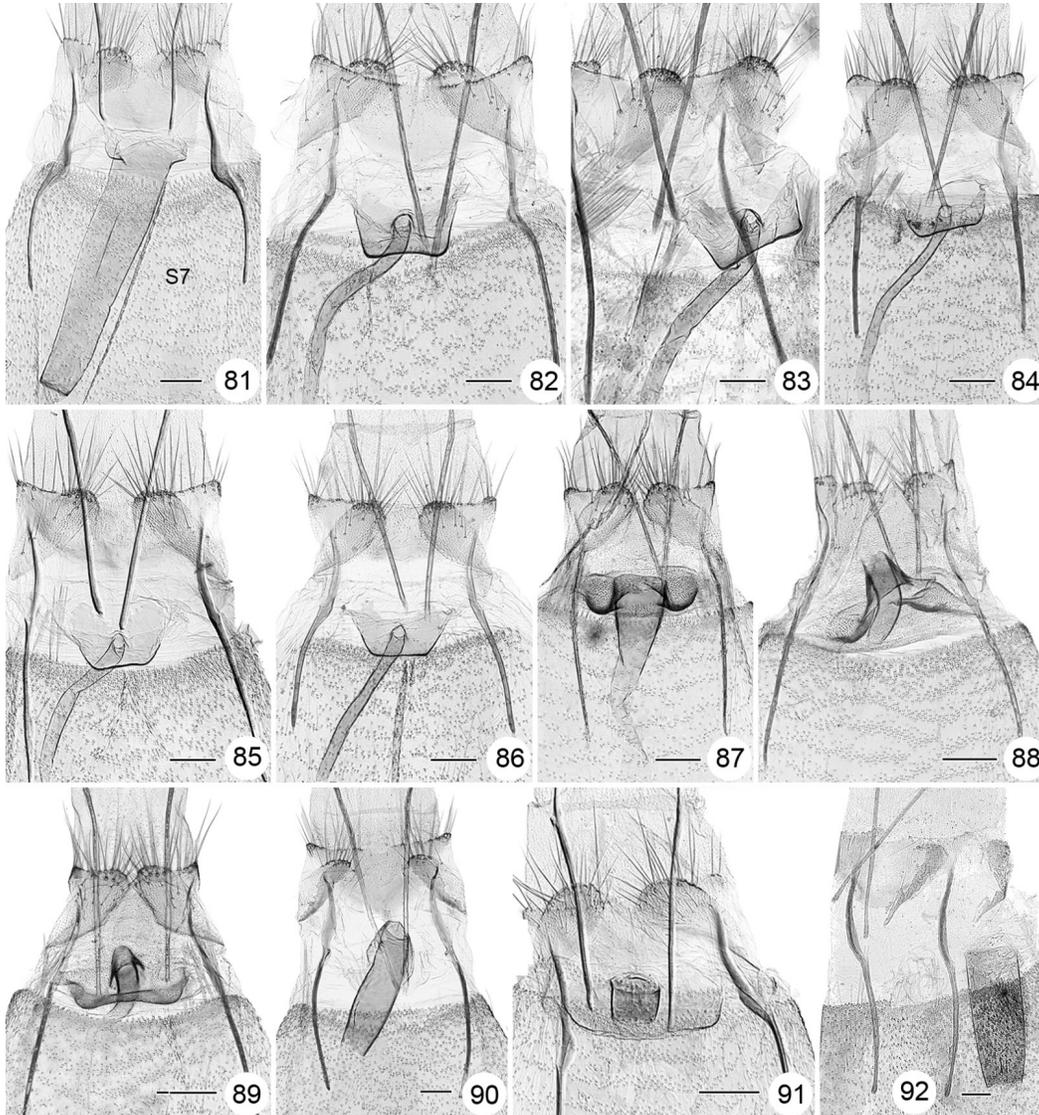
Unknown. All specimens examined were collected at light in March in Texas and in late April and early May in Illinois, Missouri, and Ohio.

Material examined

9 ♂, 5 ♀.

United States of America, Illinois, Coles Co., Lake View Park, 39.55°, -88.233°, T. Harrison, 1 ♂, 28.iv.1994, CNCLEP00024601 (CNC); 1 ♂, 6.v.1995, CNCLEP00024603, genitalia slide NS 018 (INHS); 1 ♀, 15.v.1995, CNCLEP-00024602, genitalia slide NS 019 (INHS); United States of America, Missouri, Columbia [38.952°, -92.334°], W.S. Craig, 1 ♂, 1.v.1969, CNCLEP00020484, genitalia slide Gaedike 2506 (AMNH); United States of America, Ohio, Greene Co., Wright-Patterson Air Force Base, Huffman Prairie, 39.8067°, -84.0583°, E.H. Metzler, 1 ♂, 6.v.1994, CNCLEP-00020252, genitalia slide JFL 1641 (OSU); United States of America, Texas, Tyler Co., Town Bluff, Dam B [30.798°, -94.173°], A. and M.E. Blanchard, 1 ♂, 11.iii.1966, CNCLEP00002747, genitalia slide USNM 15934 (USNM); United States of America, Texas, Anderson Co., Engling Wildlife Refuge [31.768°, -95.554°], E.C. Knudson, 1 ♂, 22.iii.1981, CNCLEP00020489; 1 ♂, 15.iii.1983, CNCLEP00020488 (FLMNH).

Figs. 81–92. Female sternum 8, ostium bursae, and distal portion of ductus bursae of *Acrolepiopsis* species, ventral aspect, apex directed upwards: 81, *A. assectella*, slide MIC 4693, specimen CNCLEP00002719; 82, *A. californica*, slide USNM 15939, specimen CNCLEP00020320; 83, *A. californica*, slide USNM 91628, specimen CNCLEP00020319; 84, *A. californica*, slide JFL 1616, specimen CNCLEP00020301; 85, *A. californica*, slide JFL 1601, specimen CNCLEP00002318; 86, *A. californica*, slide JFL 1647, specimen CNCLEP00020308; 87, *A. heppneri*, slide MIC 5265, specimen CNCLEP00024652; 88, *A. incertella*, slide JFL 1649, specimen CNCLEP00020313; 89, *A. incertella*, slide MIC 5272, specimen CNCLEP00020496; 90, *A. leucoscia*, slide JFL 1667, specimen CNCLEP00024769; 91, *A. sapporensis*, slide MIC 4698, specimen CNCLEP00002748; 92, *A. reticulosa*, slide Gaedike 2504, paratype. Scale bars = 0.1 mm.



Additional distribution data (provided by E.C. Knudson for specimens not seen): Texas, Anderson Co., Engeling Wildlife Management Area [31.9083°, -95.9054°], 14.iii.1983, 1 ♂, CNCLEP00024771, 15.iii.1983, 1 ♀, CNCLEP-00020488, 22.iii.1981, 1 ♀, CNCLEP00020489,

E.C. Knudson; Travis Co., Brackenridge Field Lab. Univ. of Texas [30.2850°, -97.7783°], 1–2.iii.1997, 1 ex., 25.ii.1998, 1 ex., J. Gillaspay [not seen]; Bastrop Co., Bastrop State Park [30.112°, -97.261°], 3.iii.1987, E.C. Knudson, 1 ex. [not seen]; Jasper Co., Martin Dies State

Park [30.9697°, -94.1952°], 5.iii.1986, E.C. Knudson, 1 ♂, CNCLEP0002472; Burnet Co., Inks Lake State Park [30.7278°, -98.3725°], 3.iii.1987, E.C. Knudson, 1 ex. [not seen]; Palo Pinto Co., Possum Kingdom State Park [32.867°, -98.564°], 9.iii.1986, E.C. Knudson, 1 ♀, CNCLEP00024769, genitalia slide JFL 1667; Bexar Co., San Antonio, Mount McKinley Drive [29.4874°, -98.6954°], 11.iii.1984, E.C. Knudson, 1 ♀, CNCLEP00024770, genitalia slide JFL 1668, 1 ex. [not seen]; Jefferson Co., Beaumont [30.09°, -94.10°], 10.i.1998, C. Bordelon, 1 ex. [not seen] (ECK).

6. *Acrolepiopsis reticulosa* (Braun)

(Figs. 27–28, 62, 73, 92)

Acrolepia reticulosa Braun, 1927: 193.

Acrolepiopsis reticulosa; Heppner and Duckworth 1983: 27; Gaedike 1984: 180; Gaedike 1997: 7.

Diagnosis

Acrolepiopsis reticulosa is recognized by the white posteromedian patch that is rectangular or square and, to a lesser extent, by the distal third of the forewing that is predominantly white or pale with dark mottling and a small black patch. The latter character, however, is not diagnostic because it differs between the specimens examined. In other brown *Acrolepiopsis* species, the white posteromedian patch is clearly triangular, and the distal portion of the forewing is predominantly brown with some pale mottling and does not contrast as starkly with the rest of the wing. *Acrolepiopsis reticulosa* is the largest North American species in the genus, although it is known from only four specimens. Forewing length 7.3–8.6 mm (mean 8.0 mm, $n = 2$).

The genitalia could not be illustrated and compared well with those of other species because the only two preparations available (one male and one female) are mounted differently from the aspect used and illustrated in the present work, and both are damaged. In the male genitalia of the holotype, the valva (Fig. 73) resembles in outline that of *A. californica* and the aedeagal shaft (Fig. 62) is thicker in relation to the base than in other species. The female genitalia have the distal portion of the ductus bursae tubular, nearly straight-sided (Fig. 92). According to Gaedike (1984), the corpus bursae lacks signa. However, the only female genital

preparation of *reticulosa* available for study (Fig. 92) was damaged, overcleared, and somewhat laterally flattened, and the bursa was missing altogether, so the validity of that character state could not be verified. The shape of the sterigma could not be well assessed from that preparation either. Several Palearctic species lack signa (Moriuti 1961a, 1961b, 1964, 1972, 1974; Gaedike 1970).

Distribution

Known only from two widely separated locations in Wyoming and New Mexico. Conspecificity of the single female from New Mexico and the Wyoming specimens was based on comparison of the former with the paratype female from the type locality in Wyoming (Gaedike 1984), which I could not examine. However, superficially the New Mexico female resembles the male holotype in both colouration and size and conspecificity appears reasonable.

Life history

Unknown.

Material examined

1 ♂ and 1 ♀.

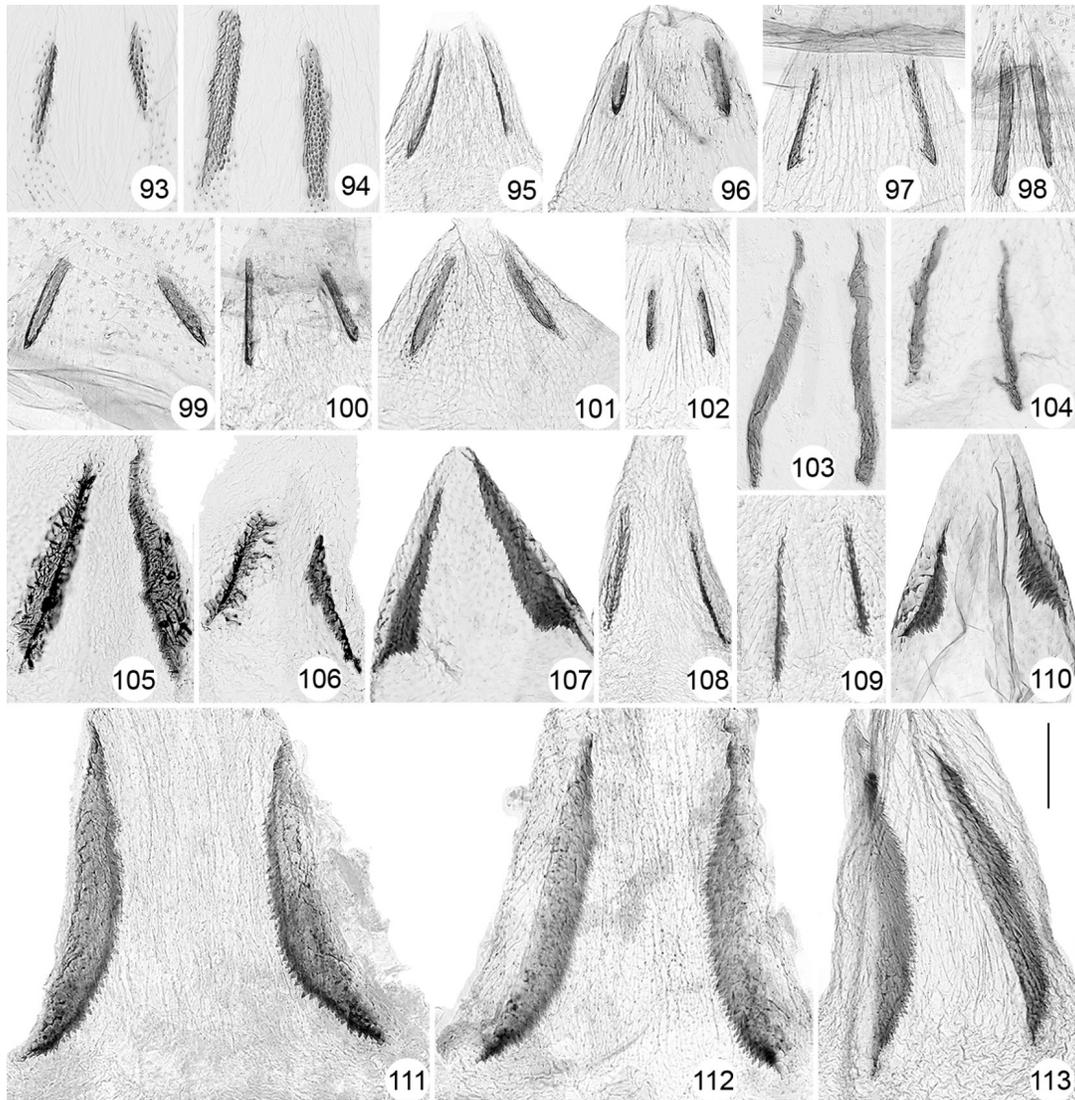
Types

Holotype ♂: “Holotypus” [red, printed]; “TYPE/ Collection of/ Annette F. Braun” [red, printed]; “Old Faithful” [printed]; “Yellowstone/ National Park/ Wyo.[ming] VII.4.[19]24/ A.F. Braun” [printed, date handwritten]; “Acrolepia/ reticulosa/ Type Braun” [white with top and bottom black border, handwritten]; “Gen[italia]. Präp[aration].Gaed.[ike]/ Nr. 2556” [white, printed with number handwritten]; “Acrolepiopsis/ reticulosa/ Braun [male symbol]/ Holotypus/ det. R. Gaedike [19]82” [handwritten, with red border] (CNCLEP00020500, ANSP). One paratype female with the same collecting locality and date as the holotype, allegedly deposited in ANSP, could not be located in that collection.

Other material examined

United States of America, New Mexico, vicinity of Santa Fe, Little Tesuque Canyon, 9200 ft., 1 ♀, 27.vii–10.viii.1932, CNCLEP00020483, genitalia slide Gaedike 2540 (AMNH).

Figs. 93–113. Female signa of *Acrolepiopsis* species, apex directed upwards, all at same scale, spacing between the two signa on a specimen varies with the amount of stretching or shrinking of the bursa membrane during preparation and is not diagnostic: 93, *A. assectella*, slide MIC 4691, specimen CNCLEP00002716; 94, *A. assectella*, slide MIC 4693, specimen CNCLEP00002719; 95, *A. heppneri*, slide USNM 15935, specimen CNCLEP00002743; 96, *A. heppneri*, slide USNM 15938, specimen CNCLEP00002742; 97, *A. incertella*, slide JFL 1650, specimen CNCLEP00020314; 98, *A. incertella*, slide MIC 4695, specimen CNCLEP00002713; 99, *A. incertella*, slide JFL 1651, specimen CNCLEP00020315; 100, *A. incertella*, slide MIC 5218, specimen CNCLEP00002714; 101, *A. incertella*, slide JFL 1649, specimen CNCLEP00020313; 102, *A. incertella*, slide MIC 5272, specimen CNCLEP00020496; 103, *A. sapporensis*, slide MIC 4698, specimen CNCLEP00002748; 104, *A. leucoscia*, slide NS 019, specimen CNCLEP00024602; 105, *A. leucoscia*, slide JFL 1667, specimen CNCLEP00024769; 106, *A. leucoscia*, slide JFL 1668, specimen CNCLEP00024770; 107, *A. californica*, slide JFL 1616, specimen CNCLEP00020301; 108, *A. californica*, slide JFL 1647, specimen CNCLEP00020308; 109, *A. californica*, slide MIC 5173, specimen CNCLEP00002741; 110, *A. californica*, slide JFL 1601, specimen CNCLEP00002318; 111, *A. californica*, slide USNM 91929, paratype of *liliivora*; 112, *A. californica*, slide USNM 91928, paratype of *liliivora*; 113, *A. californica*, slide USNM 91929, paratype of *liliivora*. Scale bar = 0.1 mm.



7. *Acrolepiopsis sapporensis* (Matsumura)

(Figs. 30, 36, 42, 48, 54, 59, 64, 80, 91, 103)

Diplodoma marginepunctella f. *sapporensis*
Matsumura, 1931: 1107.

Narycia marginepunctella sapporensis; Inoue
1954: 18.

Acrolepia sapporensis; Moriuti 1975: 250.

Acrolepiopsis sapporensis; Moriuti 1982: 205;
Gaedike 1994b: 321; Gaedike 1997: 7.

Acrolepia alliella Semenov and Kuznetsov,
1956: 1676; Moriuti 1961: 23. Synonymized
by Moriuti 1975: 250.

Acrolepiopsis assectella; Zimmerman 1978:
774 (misidentification).

Diagnosis

In wing pattern (Fig. 30), *A. sapporensis* is quite variably mottled, as evidenced by the amount of individual variation that I have seen among the few specimens examined, with variants that are reminiscent of some *A. californica* and *A. assectella* specimens. In male genitalia, it resembles *A. assectella*, from which it is distinguished mainly by the apical part of the valva, which has the dorsal edge slightly concave or sinuate (Fig. 64), and the saccus that is only about 1.25 times the length of the rest of the genitalia (Fig. 54); in *A. assectella*, the apical part of the valva has its dorsal edge evenly rounded or convex (Fig. 63), and the saccus is about 2 times the length of the rest of the genitalia (Fig. 50). In female genitalia, *A. sapporensis* is easily recognized by the cylindrical and short terminal part of the ductus bursae, which is not projected beyond the intersegmental membrane and is surrounded by an oval plate (Figs. 80, 91). The signa have faintly developed denticles that give them a rough appearance (Fig. 103). Forewing length 4.7–5.0 mm (mean 4.8 mm, $n = 5$).

Distribution

Known in Asia from Mongolia to Japan (Gaedike 1997). Introduced in the Hawaiian Islands, where it was initially misidentified as *A. assectella* (Zimmerman 1978). Currently not known from North America.

Life history

Host plants include *Allium fistulosum* L. (cibol or bunching onion), *A. cepa* (onion), *A. porrum* (leek), *A. odorum* L. (scallion),

A. nipponicum Franchet & Savatier (wild ramboule), and *A. schoenoprasum* (chive). Larvae feed in a manner similar to those of *A. assectella*, attacking the leaves but sometimes also the scape, bulb, or seed capsule (Semenov and Kuznetsov 1956; Moriuti 1961a).

Comments

This species is known under the common names of Asiatic onion leafminer, stone leek miner, or allium leafminer. In Asia, it is a pest of the onion group of plants, like *A. assectella*. In Hawaii there are reports of its occurrence as early as 1939 (Zimmerman 1978). It was long considered to be *A. assectella*, and the identification error was discovered and rectified quite recently (Gaedike 1997). Zimmerman's illustrations are all based on European specimens of *A. assectella* or drawn from European publications. The Hawaiian specimen that I examined is unquestionably *A. sapporensis*, as evidenced by its genitalia compared with Japanese specimens.

With the increase in fresh garlic imports from Asia, it is conceivable that this species might be intercepted or accidentally introduced on the North American continent.

Material examined

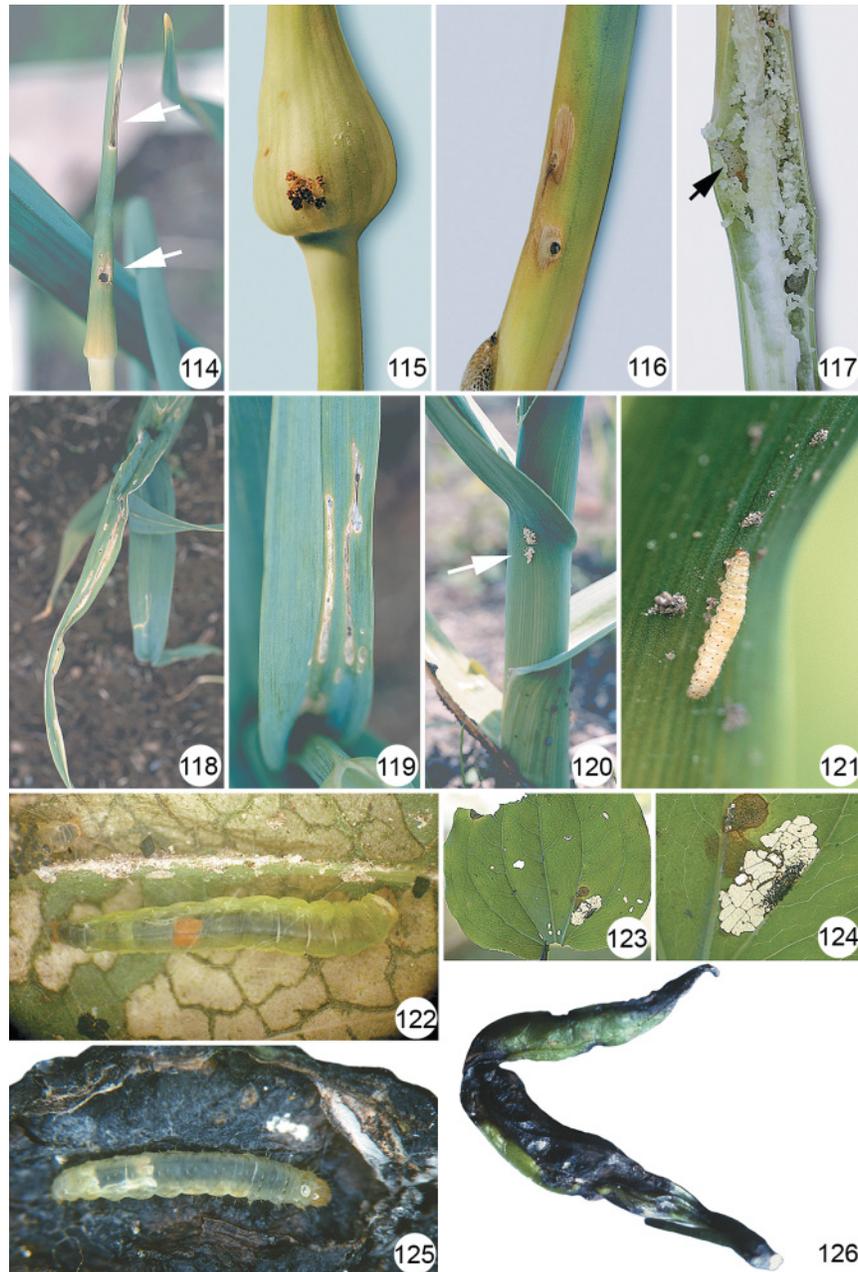
2 ♂, 3 ♀.

United States of America, Hawaii, Honolulu [21.3°, -157.85°], ex green onion, 1 ♀, ix.1967, CNCLEP00002748, genitalia slide MIC 4698 (CNC); Japan, Honsyu, Kinki, Ikeda [34.82°, 135.43°], S. Issiki, 1 ♂, 2.vii.1949, CNCLEP-00018263, genitalia slide USNM 15930 (USNM); 1 ♂, 5.vii.1949, CNCLEP00018264, genitalia slide USNM 15937 (USNM); 1 ♀, 30.vi.1949, CNCLEP00018265 (USNM); Honsyu, Izumi, Sakai [34.57°, 135.48°], S. Moriuti, 1 ♀, 23.vii.1958, CNCLEP00018262, genitalia slide USNM 15931 (USNM).

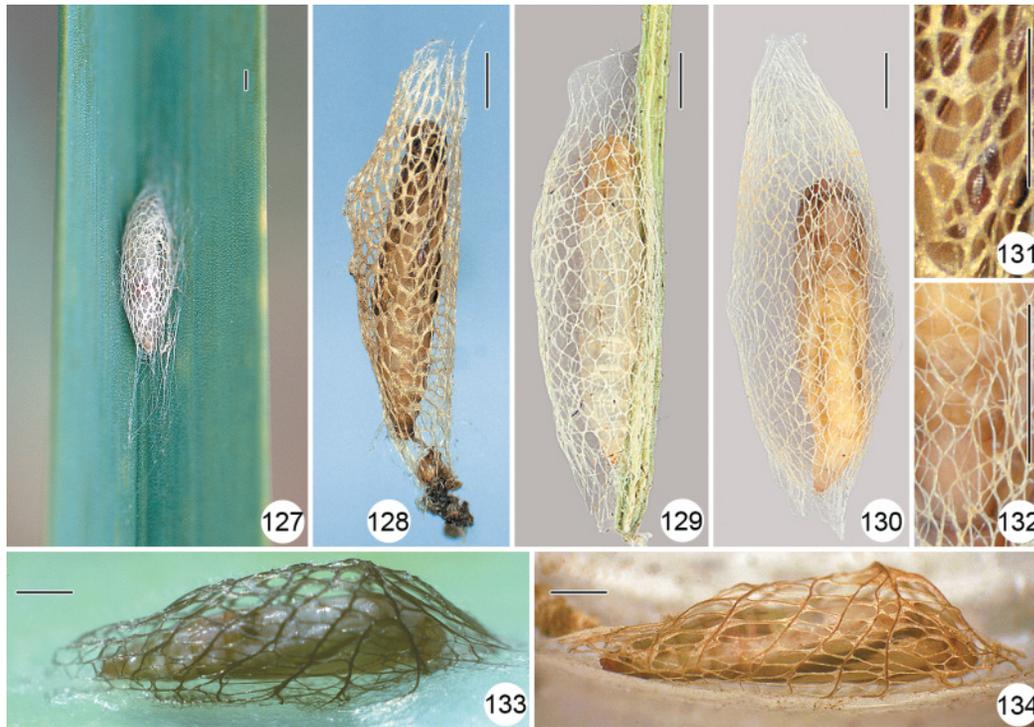
Barcoding and species identification

A total of 37 *Acrolepiopsis* and 30 *Plutella* specimens were processed for barcoding. For *Acrolepiopsis*, COI sequences were recovered from 81.1% (30) of specimens analyzed. Full-length PCR products (>550 bp) were amplified from 70.3% (26) of these specimens and shorter fragments (<400 bp) were amplified from the remainder (4). Failure to obtain PCR products that could be sequenced occurred with specimens

Figs. 114–126. Larval feeding damage and larvae of *Acrolepiopsis* species: 114, *A. assectella* larval exit holes in elephant garlic head, eastern Ontario, June 2000; 115, *A. assectella* extruded frass from garlic scape, eastern Ontario, June 2003; 116, *A. assectella* hole and feeding damage on garlic stem, with cocoon (partly visible at bottom left), eastern Ontario, June 2003; 117, split garlic stem showing larva of *A. assectella* (arrow) and feeding damage; 118–119, lacerations from early larval mining by *A. assectella* on elephant garlic leaves, eastern Ontario, June 2000; 120, exit hole and extruded frass of *A. assectella* on stem of elephant garlic, eastern Ontario, June 2000; 121, larva of *A. assectella* walking on stem of elephant garlic, eastern Ontario, June 2000; 122, larva of *A. heppneri* on underside of leaf of *Smilax tamnoides*, Illinois, September 2006; 123–124, skeletonized feeding by larva of *A. heppneri* on underside of leaf of *Smilax tamnoides*, Illinois, September 2006; 125, larva of *A. incertella* inside unrolled terminal leaf of *Smilax tamnoides*, Illinois, May 2006; 126, blackened young terminal shoot of *Smilax tamnoides* sheltering a larva of *A. incertella*, Illinois, May 2006.



Figs. 127–134. Cocoons and pupae of *Acrolepiopsis* and *Plutella* species: 127, *A. assectella* cocoon on leek leaf; 128, *A. assectella* cocoon showing enclosed pupa and last larval skin (bottom), lateral aspect; 129, *P. xylostella* cocoon showing enclosed pupa, lateral aspect; 130, ditto, dorsal aspect; 131, *A. assectella*, enlarged view of cocoon meshes; 132, *P. xylostella*, ditto; 133, *A. incertella* cocoon, lateral aspect; 134, *A. heppneri* cocoon, lateral aspect. Scale bars = 1 mm.



collected in 1990 and earlier. Failures with three specimens of *A. incertella* reared in 2006 remain unexplained at present. All 30 specimens of *Plutella* yielded full-length barcodes.

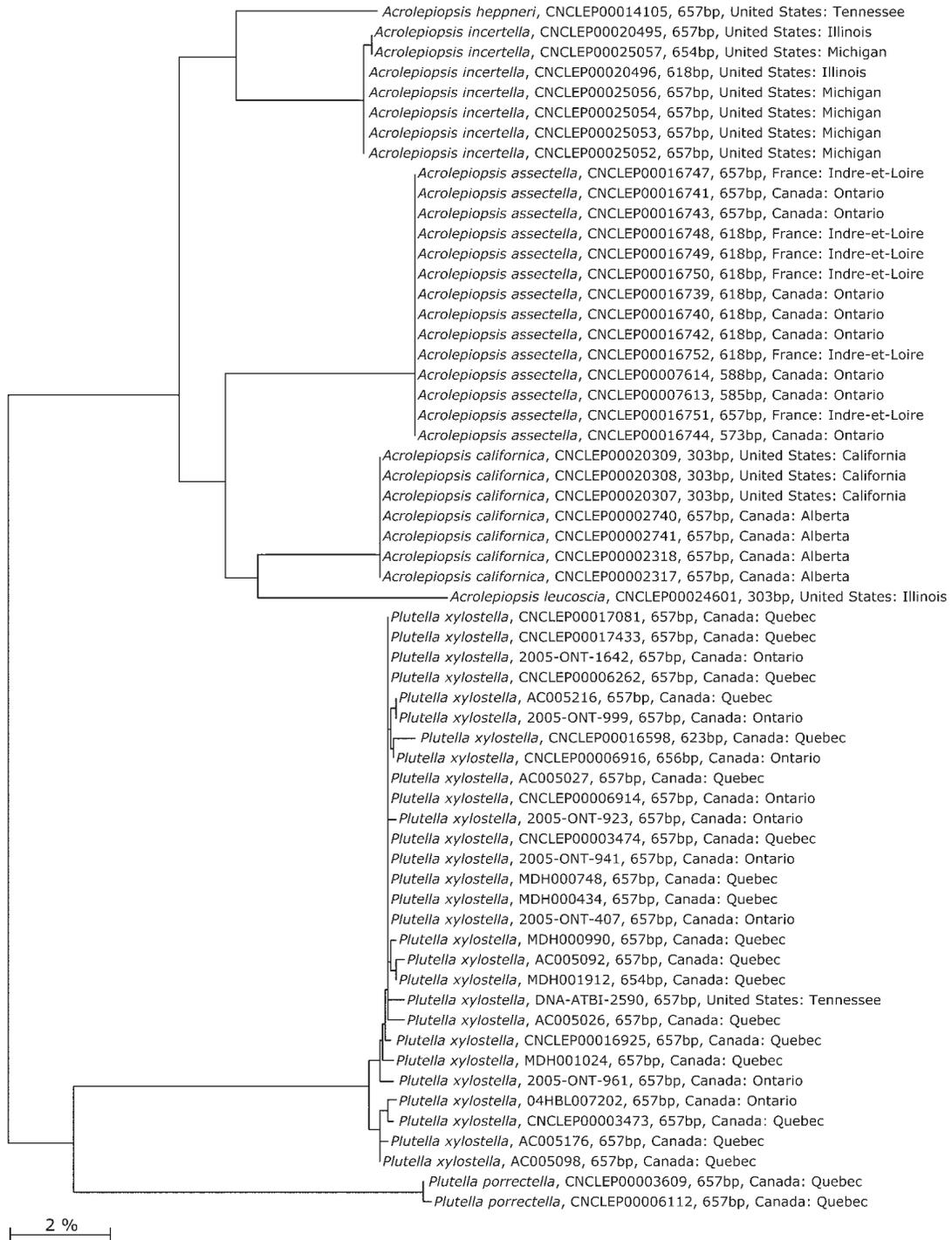
All barcoded specimens clustered consistently with their respective morphologically defined species (Fig. 135). In *Acrolepiopsis*, pairwise interspecific divergences ranged from 5.39% to 10.29% (average = 8.17%, SE = 1.78, 207 pairwise NJ comparisons). In *Plutella*, interspecific divergences ranged from 12.83% to 14.78% (mean = 13.52%, SE = 0.28). Clustering was unequivocal, as intraspecific variation was much less than interspecific divergence. It should be noted that the NJ analysis is strictly phenetic and was used only to estimate genetic distance, not to recover phylogenetic signals.

Within *Acrolepiopsis* species, variation in sequence divergence was 0%–0.16% (mean = 0.01%, SE = 0.04, 118 pairwise NJ comparisons). No variation was found in *A. assectella*, as might be expected in populations originating

from a recent introduction, but it is significant that specimens from France were genetically identical to those from Canada. Intraspecific variation was higher in *P. xylostella* (0%–1.63%, mean = 0.44%, SE = 0.37, 378 pairwise NJ comparisons). In a broad geographical study of genetic variation in *P. xylostella*, Chang *et al.* (1997) found that intraspecific divergence in a 365-bp region of mtDNA ranged from 0% to 0.82% among strains from different continents.

There were no questionable identifications even in cases of abbreviated barcodes. Short barcodes, <400 bp, were obtained for older (1994) specimens of *A. californica* and *A. leucoscia*, yet provided unequivocal separation. Recently it was shown that short barcodes can be effective in specimen identification provided that the comparisons are within a confined taxonomic group (Hajibabaei *et al.* 2006b). Significantly, the *A. californica* specimens from Alberta clustered closely with the specimens from California reared from *Lilium pardalinum*, confirming their conspecificity and

Fig. 135. Neighbor-joining tree of genetic distance (Kimura 2-parameter) for 30 *Acrolepiopsis* and 30 *Plutella* specimens. For each specimen, the voucher number, sequence length (bp = base pairs), and provenance are given. Full specimen and genetic data, including trace files, photographs, and georeferenced collecting sites, are available at <http://www.barcodinglife.com> (project: Lepidoptera: Acrolepiidae and Plutellidae, under the “Published Projects” tab).



genitalia-based identification. Results indicate that barcoding can be used fruitfully to distinguish North American species of *Acrolepiopsis* and to identify other life stages and might be useful in recognizing other species such as *A. sapporensis*. No recent specimens of *A. sapporensis* and *A. reticulosa*, nor suitably preserved immatures of any of the species (except *A. assectella*), were available for genetic analysis.

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