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Authors: Adamski, David, Landry, Jean-François, Nazari, Vazrick, and Priest, Ronald J.

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THREE NEW SPECIES OF LEAF-MINING GELECHIIDAE (LEPIDOPTERA) FROM CANADA AND NORTHEASTERN UNITED STATES

DAVID ADAMSKI

Department of Entomology, National Museum of Natural History, P. O. Box 37012, NHB - E526, MRC-168, Smithsonian Institution, Washington, D.C. 20013–7012; email: adamskid@si.edu (corresponding author)

JEAN-FRANÇOIS LANDRY AND VAZRICK NAZARI

Agriculture and Agri-Food Canada, C.E.F., 960 Carling Avenue, Ottawa, Ontario K1A 0C6, Canada; emails: landryjf@agr.gc.ca; nazariv@agr.gc.ca

AND

RONALD J. PRIEST

Department of Entomology, Michigan State University, 288 Farm Ln., East Lansing, MI 48824–1115; email: priest@msu.edu

ABSTRACT. Three new species of leaf-mining Gelechiidae are described: *Xenolechia ceanothiae* Priest, whose larvae feed on *Ceanothus americanus* L. (Rhamnaceae); *Gnorimoschema shepherdiae* Priest, on *Shepherdia canadensis* (L.) Nutt. (Elaeagnaceae); and *Scrobipalpula manierreorum* Priest, on *Eurybia* (*Aster*) *macrophylla* (L.) Cassini (Asteraceae). Their leaf mines were initially discovered in the understory in Michigan forests. Barcoding revealed additional records for two of these species from several regions of Canada. Photographs of the imagos and illustrations of the male and female genitalia, larval and pupal chaetotaxal maps are provided. Scanning electron micrographs of selected features of the larva for each species supplement illustrations. Comparative diagnoses of adult morphological characters are presented to distinguish the new species from other North American congeners. Photographs of the leaf-mines for each species are also included. DNA barcodes for each species are shown to be distinct from related North American congeners. The first occurrence of *Gnorimoschema vibei* Wolff in North America is confirmed by barcoded specimens from Kuujjuarapik in northern Quebec, Canada.

Additional key words: chaetotaxy, DNA barcode, Gelechiidae, leaf-miners, taxonomy

Occurrence of leaf-mining life style in larvae of Gelechiidae is widespread but scattered among several, unrelated genera in different tribes (Powell 1980). Among Litini for example, leaf-mining is prevalent in the genus *Coleotechnites*, which are primarily miners in conifer needles (Powell & Opler 2009). Some species in several gelechiid genera are leaf-miners whereas other congeners have different larval habits such as leaf-tiers, webbers, or stem borers: the genera *Chrysoesthia*, *Nealyda, Stereomita* (Anomologini), some *Gnorimoschema, Scrobipalpopsis, Scrobipalpa*, and *Scrobipalpula* (Gnorimoschemini) all comprise several species with leaf-mining larvae (Huemer & Karsholt 1999, 2010; Povolný 1991; Powell & Povolný 2001).

Among leaf-miners discovered and reared by RJP during a long-term survey of leaf-mining Lepidoptera at two sites in Michigan were three species of Gelechiidae. DA determined that they were undescribed, one being a species of *Xenolechia* (Litini), the other two being Gnorimoschemini. JFL and VN recognized the Gnorimoschemini as conspecific with two undescribed species of Gnorimoschemini from Canada that they had previously DNA barcoded and studied as part of an overview of the Gnorimoschemini of Alberta (Nazari & Landry 2012). Thus we decided to combine our results to present a more complete picture of these new species.

The purpose of this paper is to describe these three new species, compare their adult external features, genitalia morphology, immature features, and DNA barcodes to congeners, and present observations on their life history.

MATERIALS AND METHODS

Michigan study sites. The study site where leaf-mines of *Xenolechia ceanothiae* and *Gnorimoschema shepherdiae* were found is located near Lake Huron in northeastern Lower Michigan, Presque Isle County (T34N-R07E, Sec. 14 ne ¼ ; N 45° 20.819' W 83° 32.061'). This State Park was originally purchased by the Nature Conservancy for protection of one of the largest known occurrences of Dwarf Lake Iris. Soil at this site is well drained, dark brown, and a very gravelly sandy loam (Knapp 1993). The host plants of *X. ceanothiae* and *G. shepherdiae* grow in a second growth forest of *Betula papyrifera* Marsh. (Paper Birch), *Populus tremuloides* Michx. (Quaking Aspen), *Prunus virginiana* L.(Choke Cherry) and *Quercus rubra* L. (Red Oak). The understory is composed of *Amelanchier* spp.

(Serviceberry), *Ceanothus* spp. (New Jersey Tea) *Cornus* spp. (dogwood), *Viburnum* spp. (Arrow-wood), *Shepherdia canadensis* (L.) (Soapberry), and various forbes.

Larvae of *X. ceanothiae* and *G. shepherdiae* were first recovered in July 1998. This site was visited an additional 25 times between June and October from 1998–2010. Two trails, each approximately 1 km lined intermittently with host shrubs, were visually searched for mines.

The study site where leaf-mines of *S. manierreorum* were found is located at the Huron Mountain Club, Marquette County, Michigan. This private holding, located along south central Lake Superior, encompasses most of the Huron Mountains and several lakes. It is approximately 20,000 acres (8,094 ha) with about 8,000 acres (3,237 ha) of virgin forest. This old growth forest is a habitat for a diverse combination of hemlock-northern hardwood ecosystems (Simpson et al. 1990).

Larvae of *S. manierreorum* were first recovered in August 2004 (Lot 1523). This site was visited an additional 13 times between June and October from 2004–2010. Host plants were found growing along the sides of a gravel road for a distance of approximately 1 km. This road segment was visually searched for mined leaves.

Rearing method. Field collected leaves with mines were placed in 1-quart clear plastic freezer bags. Each live miner was assigned a specimen number, placed in a separate freezer bag to rear. Sample active miners were photographed according to Priest (2007). Individual pupae were placed in vented glass vials. Vials were then placed on slightly moistened paper toweling in a 1-gallon plastic box with tight fitting lid. Larvae recovered from late June to mid-July emerged as adults from late July to early August. Larvae recovered from late August to late October were wintered in a 1-gallon plastic box. The box was sheltered out-of-doors and checked weekly for adequate moisture. Warming began by mid-February to force emergence. Vacated mines were preserved in glassine envelops, some larvae, pupae, and all parasitoids were preserved in 80% EtOH, and adults spread according to Landry & Landry (1994).

A portion of the viable larvae were carefully extracted from their leaf-mines, placed in mildly boiling H_20 for a few seconds, and stored in 40 % EtOH for 24 hrs. After a day, all larvae were stored in 80 % EtOH. Pupae were collected and stored directly in 80 % EtOH. Preserved larvae and pupae were used for studies using light-microscopy and scanning electron microscopy and for making associations with the reared adults.

Specimen preparation. For SEM study, larvae and pupae were cleaned in a full-strength solution of Formula 409™ detergent, and subsequently rinsed in water and dehydrated in increasing concentrations of ethanol (10, 25, 50, 70, 95 %), ending with absolute ethanol. After dehydration, specimens were critical point dried using a Tousimis critical point dryer, mounted on SEM stubs using carbon paste, and coated with gold-palladium (40/60 %), using a Cressington sputter coater. Forewings were disarticulated from the mesothorax of pinned specimens and mounted on stubs using carbon adhesive tabs. The fine-structure of the larva and pupa, and the male sex scales on the undersurface of the forewing was studied with an Amray 1810 scanning electron microscope at an accelerating voltage of 10 kV.

Morphological examinations and measurements of the adults, larvae, and pupae were made using a Leitz RS dissecting microscope with a calibrated micrometer. Genitalia were dissected by DA as described by Clarke (1941), except that Mercurochrome™ and Chlorazol Black were used as stains; those dissected by JFL and VN were prepared as described by Landry (2007). The male and female genitalia are described as how they are oriented naturally on the body and not how they are figured. The Methuen Handbook of Colour (Kornerup and Wanscher 1978) was used as a color standard. The larval description is based upon the last instar. Larval nomenclature follows Stehr (1987). Pupal nomenclature follows Mosher (1916). Plant names follow Voss & Reznicek (2012).

DNA barcode analysis. Specimens or tissue samples (a leg) were shipped to the Canadian Centre for DNA Barcoding in Guelph for sequence analysis. Laboratory protocols at this facility have been greatly optimized, and the current iteration can be accessed at http://www.ccdb.ca. In short, a small tissue sample is lysed and genomic DNA extracted using an automated, silica-based method; the COI barcode region is amplified via PCR using one or more primer sets (Hebert et al. 2013) and successful amplicons are then bi-directionally sequenced (deWaard et al. 2008). The resultant sequences, along with the voucher data, images, and trace files, are deposited in the Barcode of Life Data Systems (BOLD) (Ratnasingham & Hebert 2007; www.barcodinglife.org), with sequences > 600bp subsequently deposited in GenBank.

Two 'technical' outgroup taxa were selected for each of the three new species to illustrate the level of intraspecific variation versus interspecific divergence. The two taxa with the closest Barcode Identification Numbers (BINs) (Ratnasingham & Hebert 2013) in BOLD were used: on average selected species showed more than 5% divergence. Neighbor-joining trees and genetic distances were calculated with MEGA 5.05 (Tamura et al. 2011) using the Kimura two-parameter (K2P) model of base substitution (Kimura 1980). Details

of the barcoded specimens and their photographs are available through the following dataset (http://dx.doi.org/10.5883/DS-3GELECHI). The same DOI provides access to the sequence records, trace files, and primer sequences used for PCR amplification, together with GenBank accession numbers.

Photography. Pinned specimens were photographed with a Canon EOS 60D with a MP-E 65mm macro lens. They were placed on the tip of a thin plastazote wedge mounted on an insect pin, with the head facing toward the pin and the fringed parts of the wings facing outward. This ensured that there was nothing between the fringes and the background. Specimens were photographed over a white background. Lighting was provided by a ring of 144 LEDs covered with a white diffuser dome (Fisher 2012 and references therein). The camera was attached to a re-purposed stereoscope fine-focusing rail. Sets of 20–35 images in thin focal planes were taken for each specimen and assembled into deep-focused images using Zerene Stacker and edited in Adobe Photoshop.

Slide-mounted genitalia were photographed with a Nikon DS-Fi1 digital camera mounted on a Nikon Eclipse 800 microscope at magnifications of 100–400×. Nikon's NIS 2.3 Elements was used to assemble multiple photos of different focal planes into single deep-focus images which were further adjusted with Adobe Photoshop.

Leaf mines were photographed (Priest 2007) with a Canon EOS Digital Rebel and EF-S60mm f/2.8 macro USM lens.

Deposition of specimens. Holotypes are deposited in the United States National Museum of Natural History, Smithsonian Institution, Washington, D.C. (USNM). Paratypes and immature stages obtained from this study are deposited in the USNM, the Canadian National Collection of Insects, Arachnids, and Nematodes, Ottawa (CNC), and Michigan State University, East Lansing, Michigan (MSUC); some specimens used in the DNA analysis are deposited in the Biodiversity Institute of Ontario, University of Guelph, Ontario (BIOUG). The authorship of the new species is attributed to Ron Priest.

RESULTS

Gelechiinae: Litini

Xenolechia ceanothiae Priest, **new species**

(Figs. 1, 4, 9–25)

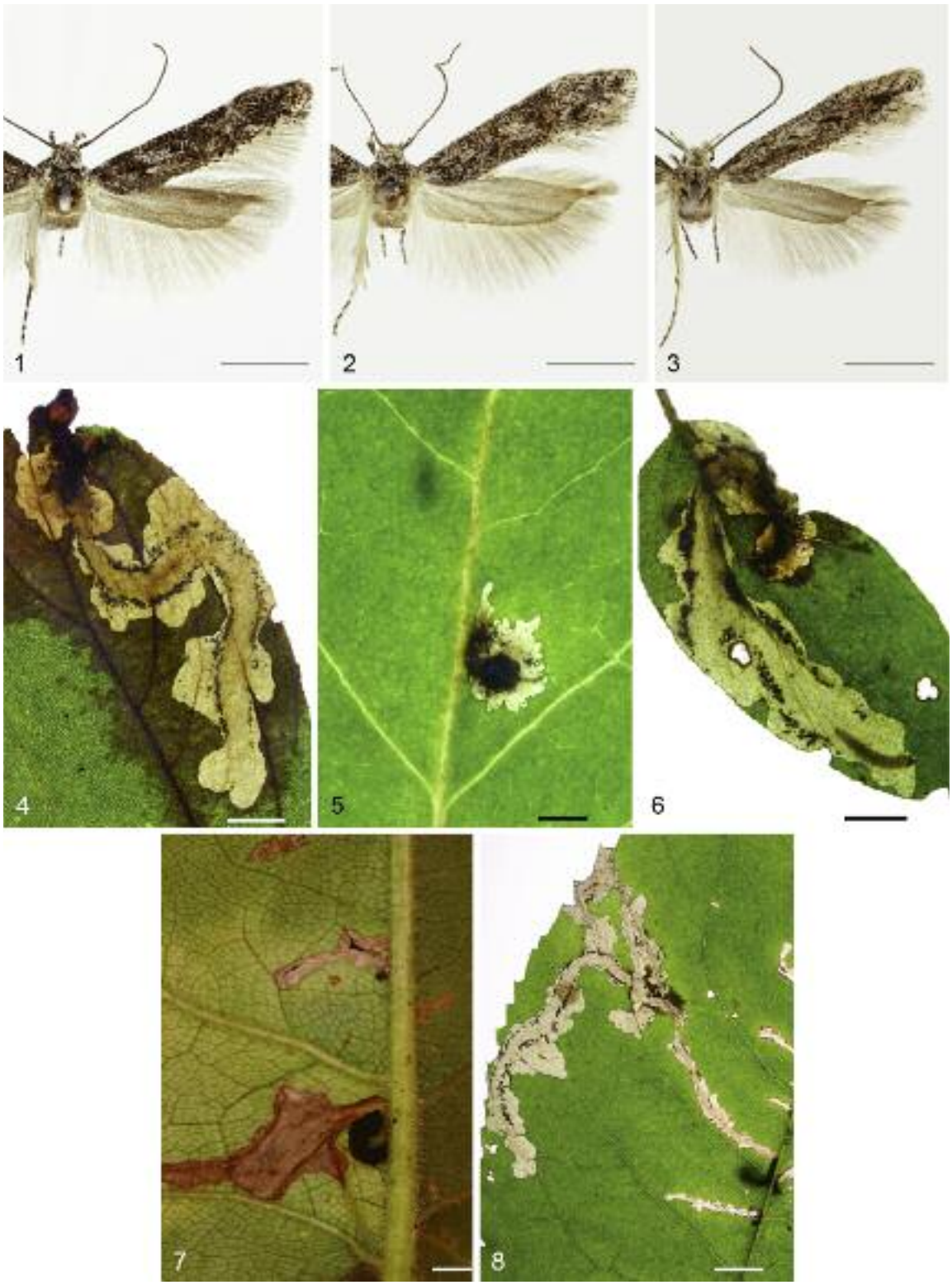
Adult diagnosis. *Xenolechia ceanothiae* is similar to *X. ceanothiella* (Braun) in forewing coloration and pattern with five tufts of black scales but *X. ceanothiella* is overall paler from more extensive white suffusion. *Xenolechia ceanothiella* also uses *Ceanothus* as host plant but is so far known only from California. In *X. ontariensis* Keifer, which geographically overlaps *ceanothiae*, the scale tufts are less contrastingly dark than in *X. ceanothiae/ceanothiella* and the ground color is pale grey rather than white, with a pronounced pattern of dark grey irrorations, giving an overall speckled aspect. However, because of possible variation and wear, the only sure way to identify the species is by examination of the genitalia.

In male genitalia, *X. ceanothiae* is markedly different from all other *Xenolechia* in having the uncus lobes darkly melanized with a scabrous inner margin, subangular medial incision, and latero-apical notch, the tegumen with anterior arms narrower (< ½ width) than the dorso-medial portion, the paired processes of the juxta are incurved and shaped like heavy pincers with the apices mucronate and darkly melanized, the vinculum-juxta junction constricted, and the phallus slenderly tubular, markedly arched and hinged on a elongate ventral juxta lobe. Other *Xenolechia* have the uncus lobes evenly melanized with a smooth inner margin, pointed apex and either an evenly U-shaped or V-shaped medial incision, the tegumen arms are at least as wide as the dorso-medial portion, the paired processes of the juxta are digitate and distally tapered, the vinculum-juxta junction is broad, and the phallus is a broad, stout, straight tube with an extremely short, nearly indistinct ventral lobe connected to the juxta.

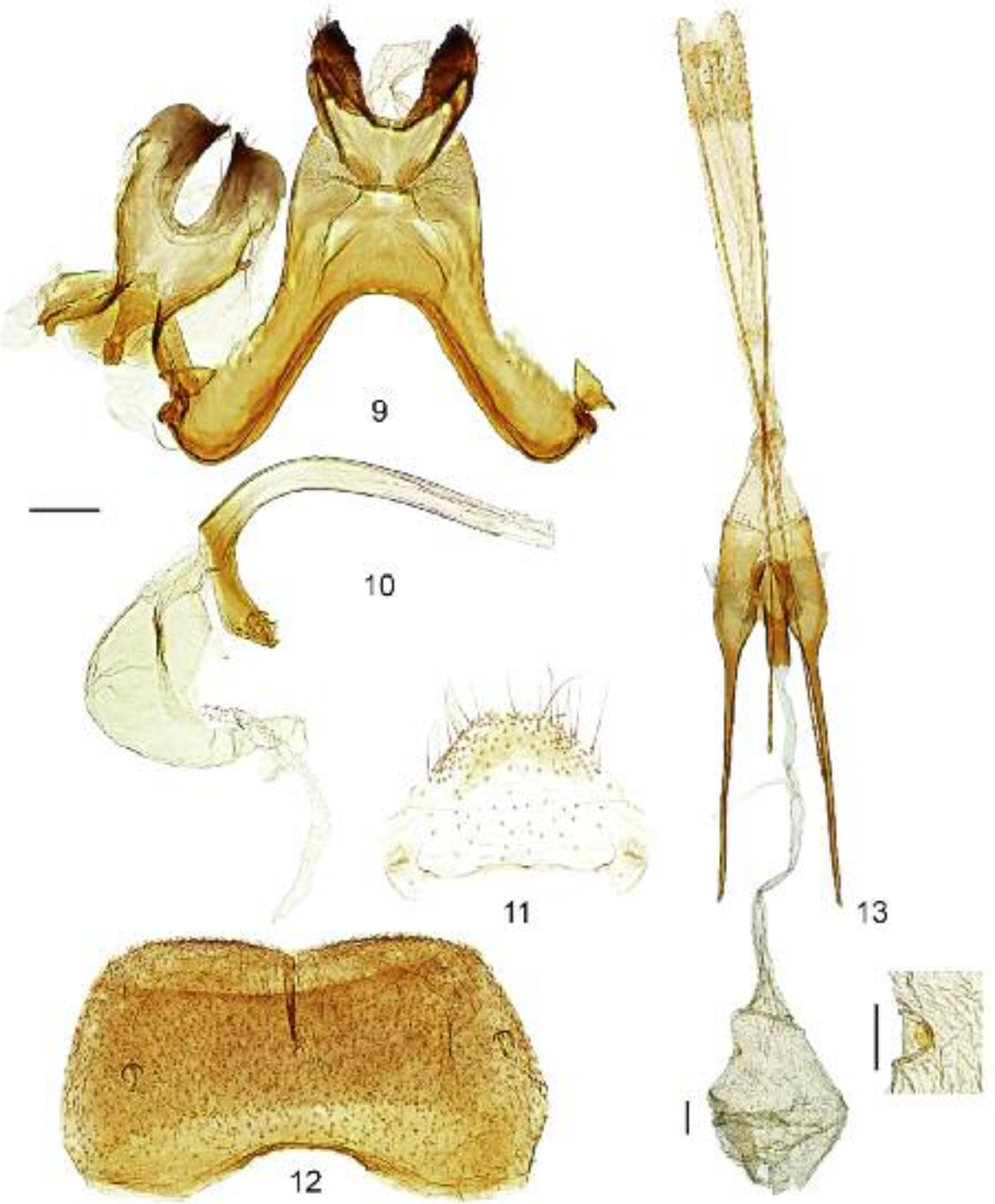
In female genitalia, *X. ceanothiae* has sternum 8 longer than wide, nearly as long as segment 7 with the posterior margin lined with a row of setae; an elongate sclerotized antrum which is about as long as sternum 8; sterigma a pair of elongate plates joined caudo-medially; and greatly reduced or absent signum. Other *Xenolechia* have sternum 8 wider than long and shorter than segment 7, without setae along the posterior margin; no sclerotized antrum; differently shaped sterigma, either with transverse, narrowly elongate, or tongue-like sclerites; and well developed, rhomboid signum with serrate edges.

Adult description. *Head*: Fronto-clypeus white. Scales on vertex with basal 2/3 white, apical 1/3 dark gray or basal 2/3 brownish gray, apical 1/3 dark brownish gray (some specimens intermixed with few white scales). Scape of antenna dark brownish gray with gray scales along apical margin, flagellomeres of flagellum dark brownish gray basally, brownish gray or pale gray apically on upper surface, brown on undersurface. Outer and inner surfaces of labial palpus dark brownish gray, segment 2 with a diagonal white band near 2/3 and white scales along apical margin, terminal segment with a white basal band, a white band near 2/3, and white apically. Proboscis white.

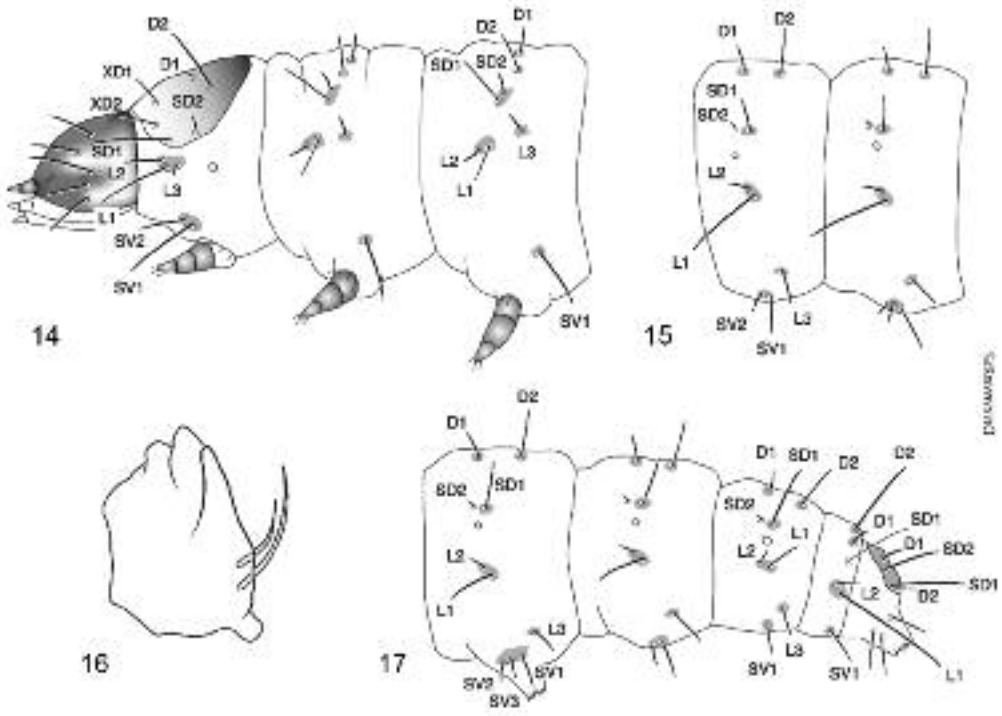
Thorax: Scales on mesonotum with basal 2/3 white, distal 1/3 dark brownish gray. Tegula patterned as mesonotum or basal 1/4 dark brownish gray, distal 3/4 with white scales with dark brownish gray on distal 1/4–1/5. Foreleg dark brownish gray with a suffuse white apical tuft on femur; tibia with a suffuse white band slightly beyond base, a



FIGS. 1–8. Adults, dorsal aspect. Scale = 2 mm. **1.** *Xenolechia ceanothiae*, holotype. **2.** *Gnorimoschema shepherdiae*, holotype. **3.** *Scrobipalpula manierreorum*, holotype. Figs. **4–8.** Larval leaf mines. **4.** *Xenolechia ceanothiae*, leaf mine of late-instar larva on *Ceanothus americanus*; scale = 5 mm. Figs. **5–6.** Leaf mines of *Gnorimoschema shepherdiae* on *Shepherdia canadensis*. **5.** Early instar; scale = 2.5 mm. **6.** Late instar; scale = 5 mm. Figs. **7–8.** Leaf mines of *Scrobipalpula manierreorum* on *Eurybia* (*Aster*) *macrophylla*. **7.** Early instar; scale = 2.5 mm. **8.** Late instar; scale = 5 mm.



FIGS. 9–13. *Xenolechia ceanothiae* genitalia. **9.** Male genitalia, ventral view, with vinculum-valvae unrolled to the left (slide MIC6817, specimen CNCLEP00099605). **10.** Phallus, lateral view. **11.** Eight tergum. **12.** Eight sternum. **13.** Female genitalia (slide MIC6818, specimen CNCLEP00098457); inset, close-up view of rudimentary signum. Scale = 100 µm, except inset = 50 µm.



FIGS. 14–17. *Xenolechia ceanothiae*, larval mandible and chaetotaxal maps. **14.** Head and T1–T3. **15.** A1–A2. **16.** Mandible. **17.** A6–A10.

suffuse white band near middle, and a white tuft along apical margin; tarsomeres with a narrow white band along apical margin. Midleg dark brownish gray with a suffuse white apical band on femur; tibia with a suffuse white band slightly beyond base, a suffuse white band near middle, and a white band on apical end adjacent to paired spurs; tarsomeres as above. Hindleg dark brownish gray a suffuse white apical tuft on femur; tibia with a suffuse white band slightly beyond base, a white band adjacent to middle pair of spurs, and a white band adjacent to apical pair of spurs; tarsomeres as above. Forewing (Fig. 1), length 4.5–6.0 mm (n = 21) dark brownish gray with a suffuse, white oblique band from 1/5–2/5, a suffuse white costal spot near 4/5, and a suffuse, white spot on tornus, and six black scale tufts; basal tuft small, near proximal end of CuP; three tufts above CuP (one small tuft within oblique band above radius, one large tuft along distal margin of band beneath radius, and one large tuft near distal end of CuP, proximal to tornus), two tufts below CuP (one large tuft along basal margin of band, one large tuft along distal margin of band). Fringe scales white, tipped with dark brownish gray. Undersurface brown except, anal area pale brown. Hindwing translucent pale gray.

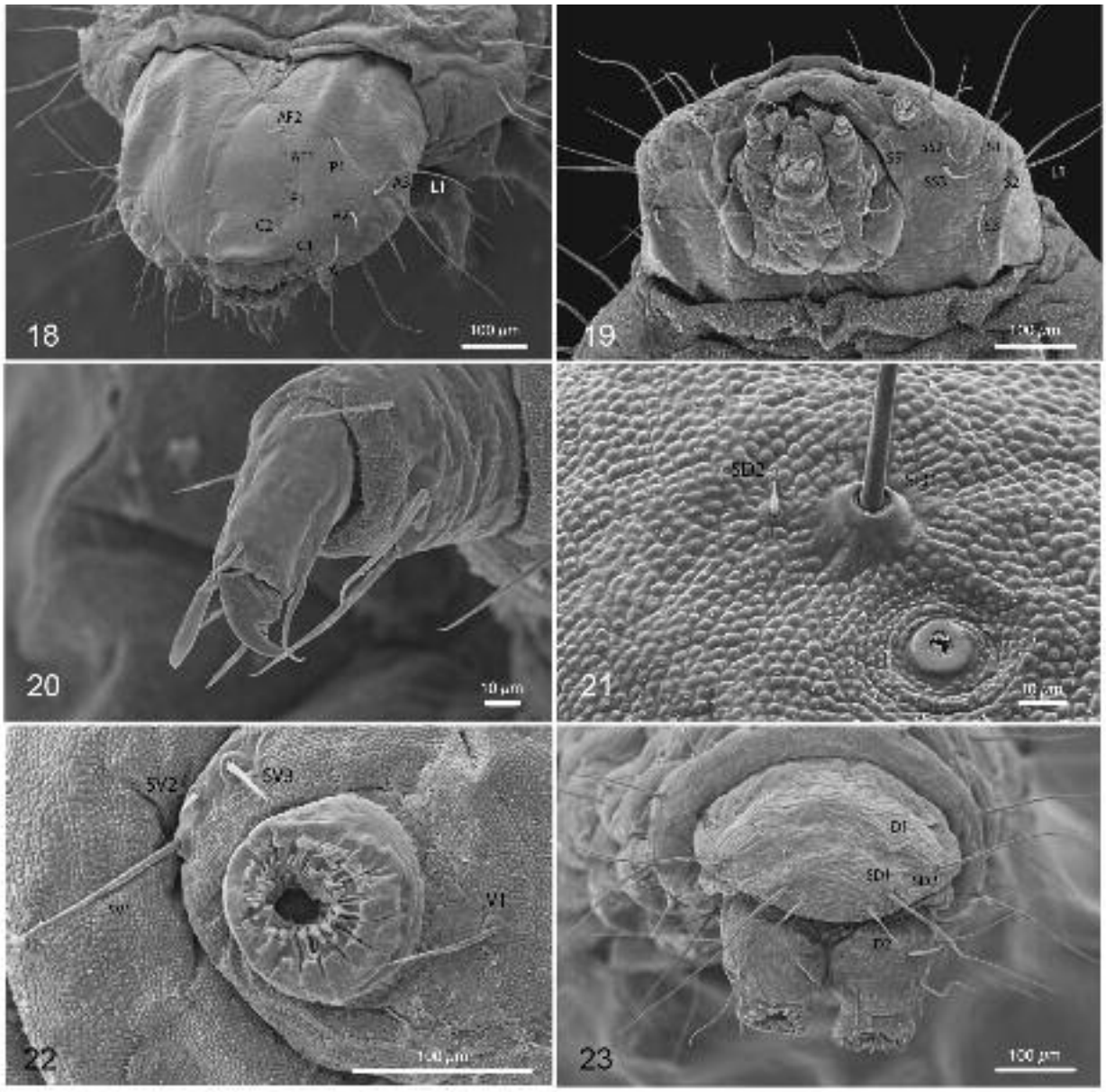
Male abdomen (Figs. 11–12): Tergum 8 broadly conical, wider than long, without coremata. Sternum 8 transversely subrectangular, posterior margin roundly emarginate.

Male genitalia (Figs. 9–10): Uncus lobes darkly melanized, inner margins finely serrate, medial incision subangular, latero-apical corners notched (side view). Tegumen with anterior arms narrower (< ½ width) than dorso-medial portion, anterior notch slightly deeper than length of dorso-medial portion. Paired processes of juxta incurved, shaped like heavy pincers, apices mucronate and darkly melanized. Vinculum with short antero-medial process, junction with juxta constricted. Phallus slenderly tubular, arched, with slender anterio-ventral lobe hinged to juxta; cornuti absent; ductus ejaculatorius with thin sclerite inside crescentic bulbus.

Female genitalia (Fig. 13): Ovipositor about 5× length of sternum 8. Apophysis anterioris straight, extended from gradually widened base. Apophysis posterioris about 2.5× length of apophysis anterioris, very thin. Sternum 8 elongate, nearly as long as segment 7, posterior margin lined with a row of setae, anteriorly with deep medial incision with sides forming pair of elongate sclerotized lateral plates posterad of ostium, caudally joined. Antrum sclerotized, straight-sided, nearly as long as sternum 8. Ductus bursae about as long as S8+AA, membranous, narrow, anterior end widened into corpus bursae, inception of ductus seminalis at 1/3 anterad of antrum. Corpus bursae subspherical, signum minute or absent.

Larva description. (Figs. 14–23): Length 8.0–10.2 mm (n = 7). Body pale gray; head with epicranium reddish brown; frons and basal area flanking frons dark orange; ecdysial line, stemmatal area, and dorso-posterior and ventrolateral margins dark brown; thoracic legs brown; pinacula unpigmented or pale brown; prothoracic shield with a wide unpigmented area demarcating dorso-longitudinal axis, bisecting two pale golden-yellow halves mottled with many brown spots, posterior and postero-lateral margins brown gradually becoming pallid anteriorly; anal shield pale golden yellow; spiracles on A2–A7 about same diameter of setae sockets on segments; spiracles on T1 and A8 about twice diameter of spiracles on A2–A7.

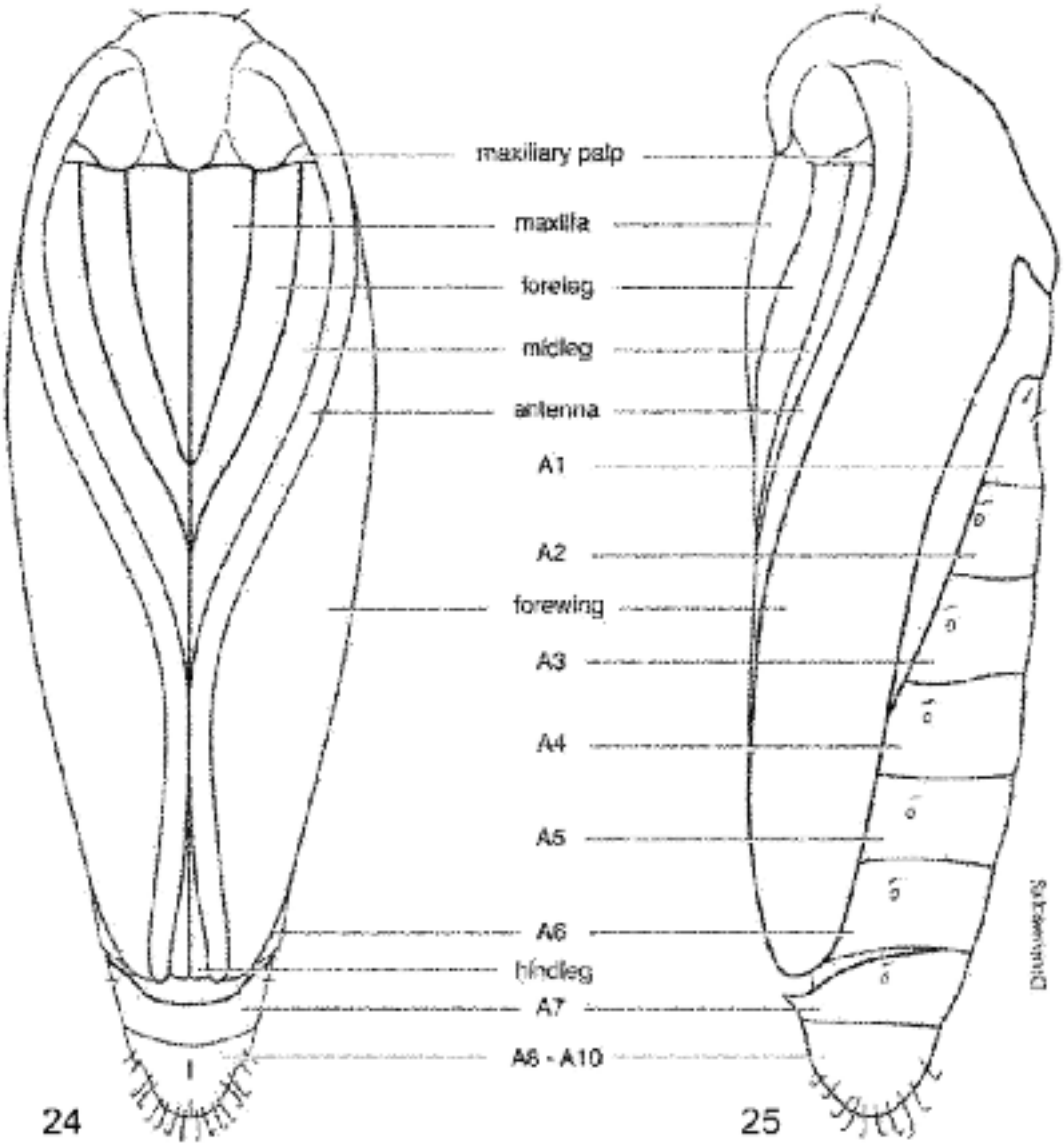
Head (Figs. 14, 16, 18–19): Epicranium slightly flattened dorso-ventrally; mouthparts semi-prognathous; an elongate, triangular frons demarcated by afrontal sclerites; sclerited widened distally, forming a broadly rounded ecdysial line; ecdysial suture short, bisecting adfrontal sclerites disto-medially; epicranial notch deep forming two large hemispheres; AF2 near apex of adfrontal sclerite, at least 5× longer than AF1; distance between AF2 and AF1 about 1/2 distance between AF1 and P1; P1 slightly longer than AF2; P2 approximate, dorso-lateral to, and about 1/3 length of P1; distance between AF1 and F1 about 2–3× distance between AF2 and AF1; C2 about 5× longer



FIGS. 18–23. *Xenolechia ceanothiae*, scanning electron micrographs of larva. **18.** Head chaetotaxy, frontal view. **19.** Head chaetotaxy, ventral view. **20.** Right tarsus on T2. **21.** SD1 and SD2 on A8, left side. **22.** Right proleg on A5. **23.** Anal plate chaetotaxy on A10.

than C1; A3 dorso-posterior to stemma 2, about 5–6× A2 and about 1/3 longer than A1; six stemmata in a C-shaped pattern; S3 ventral to S2; S2 approximate and below stemma 1; S1 below stemmata 3; L1 posterior to stemma 1; SS1 beneath area between antenna and condyle of mandible; mandible with two apical dentitions, one dentition along dorsal surface, and two subequal setae near base of condyle (Fig. 16); SS2 and SS3 approximate, both beneath area between stemmata 5–6; labrum with six pairs of setae, two subequal median pairs, two equal fronto-marginal pairs, and two subequal latero-marginal pairs

Thorax (Figs. 14, 20): Prothoracic shield (Fig. 14) with SD1 about 2–2.5× longer than XD2 and XD1; SD1 posterior to XD2, XD1 posterior XD2; distance between XD2 and SD1 about 1/2 distance between XD2 and SD2; D2 about 4× longer than SD2; SD2 about 1/3 length of XD1 and XD2; D2 slightly shorter than SD1, posterior to SD2 and D1; distance between D2 and D1 at least 1/2 distance between D2 and SD2; D1 slightly shorter than SD2, closer to median longitudinal axis than XD1; L-group with L1 slightly ventral to L2 and L3, and about 2× longer than L2 and 5× longer than L3, pinaculum anterior and slightly dorsal to spiracle; SV2 slightly shorter than SV1; V1s along a transverse line across posterior margins of coxae (not shown), about 1/3–1/4 distance as distance between V1s on T2–T3; tarsus (Fig. 20) with two pairs of setae ventro-posterior and dorso-posterior to claw; ventro-posterior setae equal in lengths, dorso-posterior pair subequal, with a flattened seta with an obtuse apical margin. T2–T3 (Fig. 14): D2 about 2× length of D1, each seta on same pinaculum; SD1 3× longer than SD2, SD2 equal in length to D1, each seta on separate pinacula, anterior to D-group pinaculum; L1 2–2



FIGS. 24–25. *Xenolechia ceanothiae*, pupa. **24.** Ventral view. **25.** Lateral view.

1/2× longer than L2 and L3; L1 and L2 on same pinaculum, anterior to SD-group pinaculum; L3 slightly dorsal and posterior to L1, slightly anterior to SV1; V1s between coxae near middle (not shown).

Abdomen: A1-A2 (Figs. 15, 21–23): D2 about 2× longer than D1; SD1 dorso-posterior to spiracle on A1, and about 1/2 distance to spiracle on A2; SD2 minute, anterior to SD1 pinaculum; L1 about 6× longer than L2, both on same pinaculum; L2 ventral to spiracle on A2, L2 ventro-posterior to spiracle on A1; L3 about equal in length to L2, in straight line with or slightly anterior to D2; SV-group bisetose on A1, trisetose on A2, each group on same pinaculum; A3–A6 as above except, SV-group on a sclerotized band at base of proleg, and crochets uniserial, uniordinal, in a circle (Fig. 22). A7 (Fig. 17): as above except, SV-group bisetose (on same pinaculum), with SV1 2× length of SV2, and V1s slightly closer (not shown); A8 as above except, SV-group unisetose; A9 with all setae in near straight line, D2 about 4× D1; SD1 hairlike, slightly shorter than D2; L-group bisetose, with L2 about 6× longer than L1, each slightly diagonal on same pinaculum; SVs and Vs as above. A10 (Figs. 17, 23): anal plate with SD2 and SD1 about 2× distance apart than distance between SD1 and D2; SD2 and SD1 of equal lengths, about 4× D2; D2 straight or slightly divergent; D1 equal in length to D2, anterior to SD1 and posterior to SD2; prolegs with crochets uniordinal.

Pupa description (Figs. 24–25). Length 5.5 – 6.3 mm (n = 3): smooth; golden yellow, with thin brown lines demarcating sclerites; vertex rounded; fronto-clypeus convergent, broadly rounded distally; labial palpi slightly visible; antennae broadly rounded encircling sclerites of maxillae, forelegs and midlegs, meeting medially slightly beyond midlength, extending distally in parallel, diverging distally slightly exposing mesothoracic legs; mesothoracic legs shorter or extending to lengths of antennae and forewings; maxillary palpi and forelegs extending to a common point anterior to midlegs; abdominal spiracles slightly raised; segments A6 and A7–10 movable; A6 divided ventrally, scars of prolegs absent; cremaster with 6 pairs of hooked setae present on dorsal and ventral surfaces of A9+A10.

Type material. Holotype ♂, "MICHIGAN, Presque Isle Co[unty], NE, T34N-R07E, S 14 [= 45.349°N, 83.541°W], Em[er]g[e]d: 26 Feb. 2006, Surv[eyor] [= Collector]: RJ Priest", "Reared Ex. *Ceanothus americanus*, Rec[o]v[red] [= date collected]: 25 Oct. 2005, Lot: RJP1689.11", [specimen #] "USNMENT 00719471", "DNA 2011 [blue label]", "♂ Genitalia Slide by D. Adamski, USNM 83529" [green label] (USNM).

Paratypes: 13 ♂, 8 ♀. MICHIGAN: same data as holotype except: ♂, em. 28 Feb 2006, larva 25 Oct 2005, lot RJP1689.18, specimen # USNMENT 00719470, DNA barcoded, genitalia slide USNM 83553 by D. Adamski (USNM); 1 ♂, em. 27 Feb 2006, larva 25 Oct 2005, lot RJP1689.8 (MSUC); 1 ♂, em. 27 Feb 2006, larva 25 Oct 2005, lot RJP1689.7 (MSUC); 1 ♂, em. 27 Feb 2006, larva 25 Oct 2005, lot RJP1689.6 (MSUC); 1 ♂, "26 Feb 2006, larva 25 Oct 2005, lot RJP1689.19 (MSUC); 1 ♂, em. 25 Feb 2006, larva 25 Oct 2005, lot RJP1690.2 [pupal exuvium in gelatin capsule beneath specimen] (MSUC); 1 ♂, em. 25 Feb 2006, larva 25 Oct 2005, lot RJP1689.14 (MSUC); 1 ♂, em. 1 Mar 2006, larva 25 Oct 2005, lot RJP1690.4, genitalia slide by D. Adamski, USNM 83528 (USNM); 1 ♀, em. 3 Mar 2006, larva 25 Oct 2005, lot RJP1689.9, specimen # USNMENT 00719473, genitalia slide by D. Adamski, USNM 83531 (USNM); 1 ♀, em. 5 Mar 2006, larva 25 Oct 2005, lot RJP1690.6 (MSUC); 1 ♀, em. 7 Mar 2006, larva 25 Oct 2005, lot RJP1690.5, specimen # USNMENT 00719472, DNA barcoded, genitalia slide by D. Adamski, USNM 83530 (USNM); 1 ♀, em. 7 Mar 2006, larva 25 Oct 2005, lot RJP1689.3, specimen # CNCLEP00098457, genitalia slide MIC 6807 (CNC); 1 ♀, em. 10 Mar 2006, larva 25 Oct 2005, lot RJP1689.4 (MSUC); 1 ♀, em. 7 Mar 2006, larva 25 Oct 2005, lot RJP1689.1 (MSUC); 1 ♂, em. wintered, larva 26 Sept. 2006, lot RJP1777.1 (MSUC); 1 ♀, em. wintered, larva 26 Sept. 2006, lot RJP1777.2 (MSUC); 1 ♀, em. wintered larva 26 Sept. 2006, lot RJP1777.3 (MSUC); 1 ♂, em. wintered, larva 12 Oct 2007, lot RJP1855.11 (MSUC); 1 ♂, em. wintered, larva 12 Oct 2007, lot RJP1855.1 [pupal exuvium on minuten beneath specimen], specimen # CNCLEP00098456, slide MIC (CNC); 1 ♂, em. wintered, larva 12 Oct 2007, lot RJP1855.10 (MSUC); 1 ♂, em. 28 Feb 2006, larva 25 Oct 2005, lot RJP1689.10 (MSUC).

Molecular data (Table 1, Fig. 60). BIN = BOLD:AAV3168. Full barcodes from three paratypes of the new species were obtained which were compared to those of *X. aethiops* (Humphreys & Westwood) (BOLD:AAE1445) and *X. ontariensis* (BOLD:AAC6357). The former is a Holarctic species and we analyzed barcodes of 14 specimens from Alberta, Ontario, Saskatchewan, British Columbia, France, and Spain. For *X. ontariensis*, we analyzed 26 barcodes of specimens from Alabama, Arkansas, Michigan, Manitoba, Oklahoma, Quebec, and Tennessee. *Xenolechia ceanothiae* differs by 11–12.5% (72–82 base pairs) from the other two species (which differed from each other by 6.85%, or about 45 base pairs). Intraspecific haplotype divergence was nil for *X. ceanothiae* and ≤ 0.5% for the other two species.

Etymology. The species epithet, *ceanothiae*, is derived from the generic name of host, *Ceanothus*.

Placement of *ceanothiae*. Diagnostic characters of *Xenolechia* (Lee & Brown 2008a), which are shared by the new species, include the deeply bifid uncus, the absence of gnathos and valvae (or the latter undistinguishably fused with the vinculum), and hindwing veins M_3 and CuA_1 separate. However, none of these states is unique to the genus and the hindwing venation state is probably plesiomorphic. Placement of *ceanothiae* in *Xenolechia* is tentative and represents a best fit among currently recognized genera of Litini. The new species differs markedly from all other species of *Xenolechia* in several features of male and female genitalia, notably the slender, dorsally arched phallus with a distinct, hinged, vertically oriented juxta, and rudimentary or absent signum. It is also hugely divergent in DNA barcode from either *X. ontariensis* or *X. aethiops*. This suggests that it may represent a distinct lineage which may warrant generic recognition. Although a phylogenetic analysis of the Litini showed strong support for the the monophyly of the *Xenolechia* (Lee & Brown 2008b), only one species out of eight described, *X. ontariensis*, was analyzed. A more encompassing species-level phylogenetic analysis would be required to re-assess generic limits.

Biology. Host: *Xenolechia ceanothiae* is a leaf-miner of *Ceanothus americanus* L. and *C. herbaceus* Raf. [Rhamnaceae].

Mine and larval behavior (Fig. 4). The mine is initiated at the leaf apex. It is full depth with the larva consuming all chlorophyll tissue between both epidermal surfaces. Frass is accumulated internally at the basal area. This frass area serves as a retreat when the larva is not feeding or disturbed. The mine is enlarged as a wide lobed track. As it develops, subsequent frass particles are aligned in long double rows laterad of the mine axis (Fig. 4). These rows guide the larva as it quickly retreats backwards to its basal frass retreat. This species feeds with its ventral side upward. Pupation was observed (RJP lot 0948) both inside and outside their mines.

Seasonal occurrence. *Xenolechia ceanothiae* was first recovered from the type locality in mid-September 1999. Since that recovery an additional 24 visits, at irregular times between mid-June and late October, were made. Seventeen visits were made between mid-June to early September without mines seen. They were only observed from mid-September into late October. Adults emerged only after wintering. It appears that *X. ceanothiae* has one generation per year in northeastern Lower Michigan. No adults were collected or observed under field conditions.

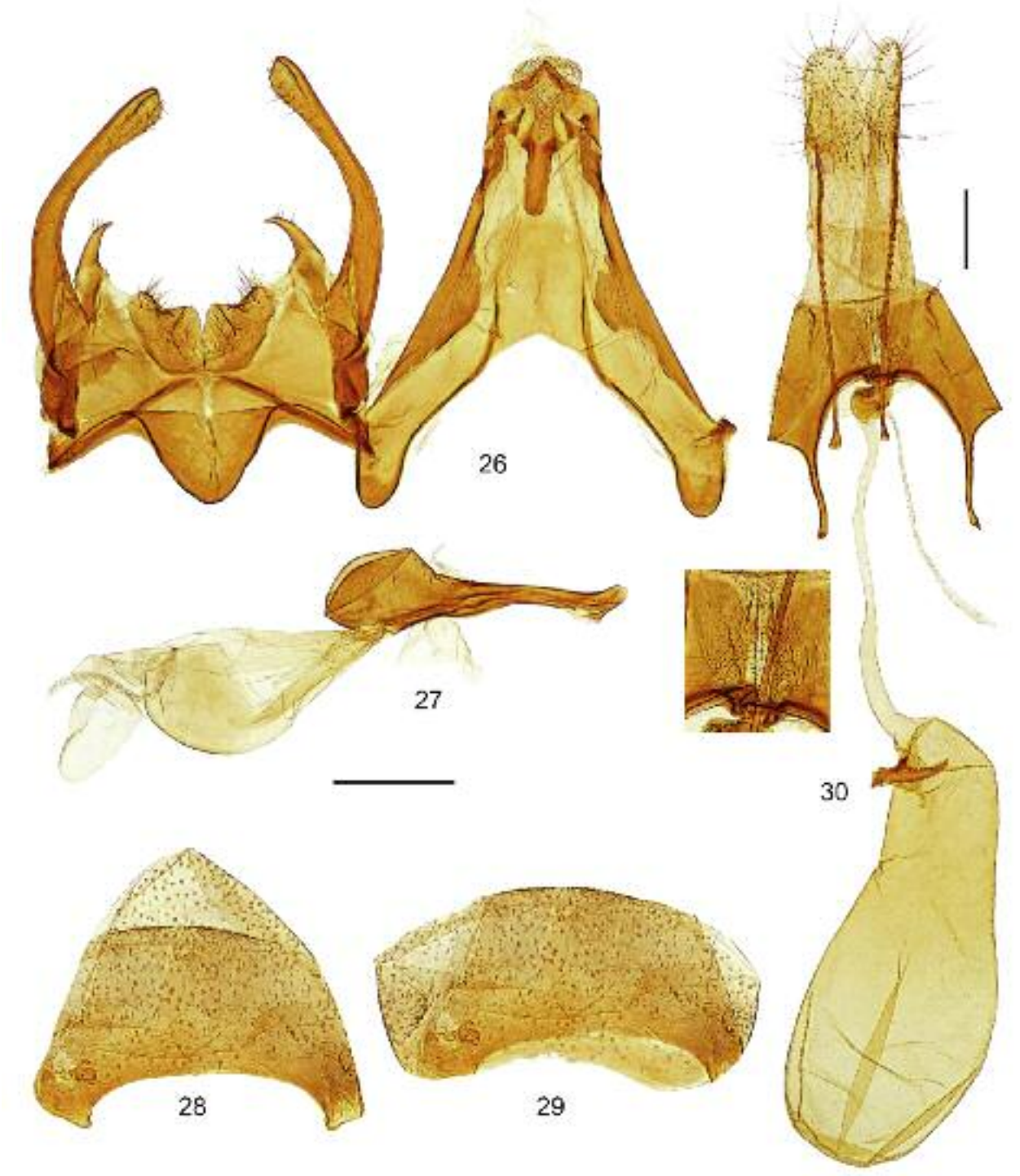
Parasitoid. *Hypomicrogaster ecdytolophae* (Muesebeck) (Braconidae).

Distribution (Fig. 59). The species is recorded only from the type locality in upper Michigan but may be expected to occur more widely given that its larval host is distributed over the eastern half of North America; in Canada the host plant is restricted to southern Ontario and Quebec.

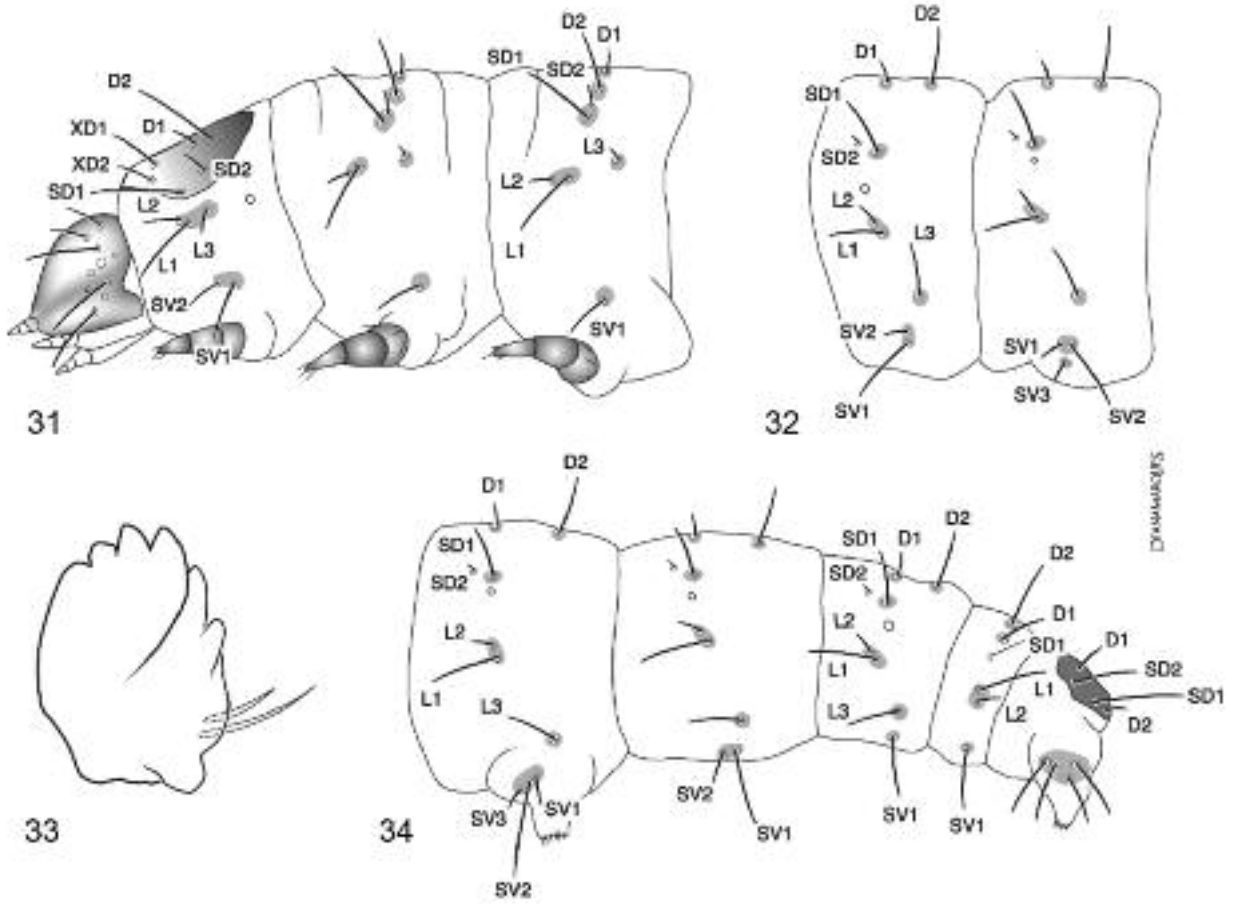
Gelechiinae: Gnorimoschemini

Gnorimoschema shepherdiae Priest, **new species**
(Figs. 2, 5–6, 26–40)

Adult diagnosis. There are no distinguishing external characters to recognize members of



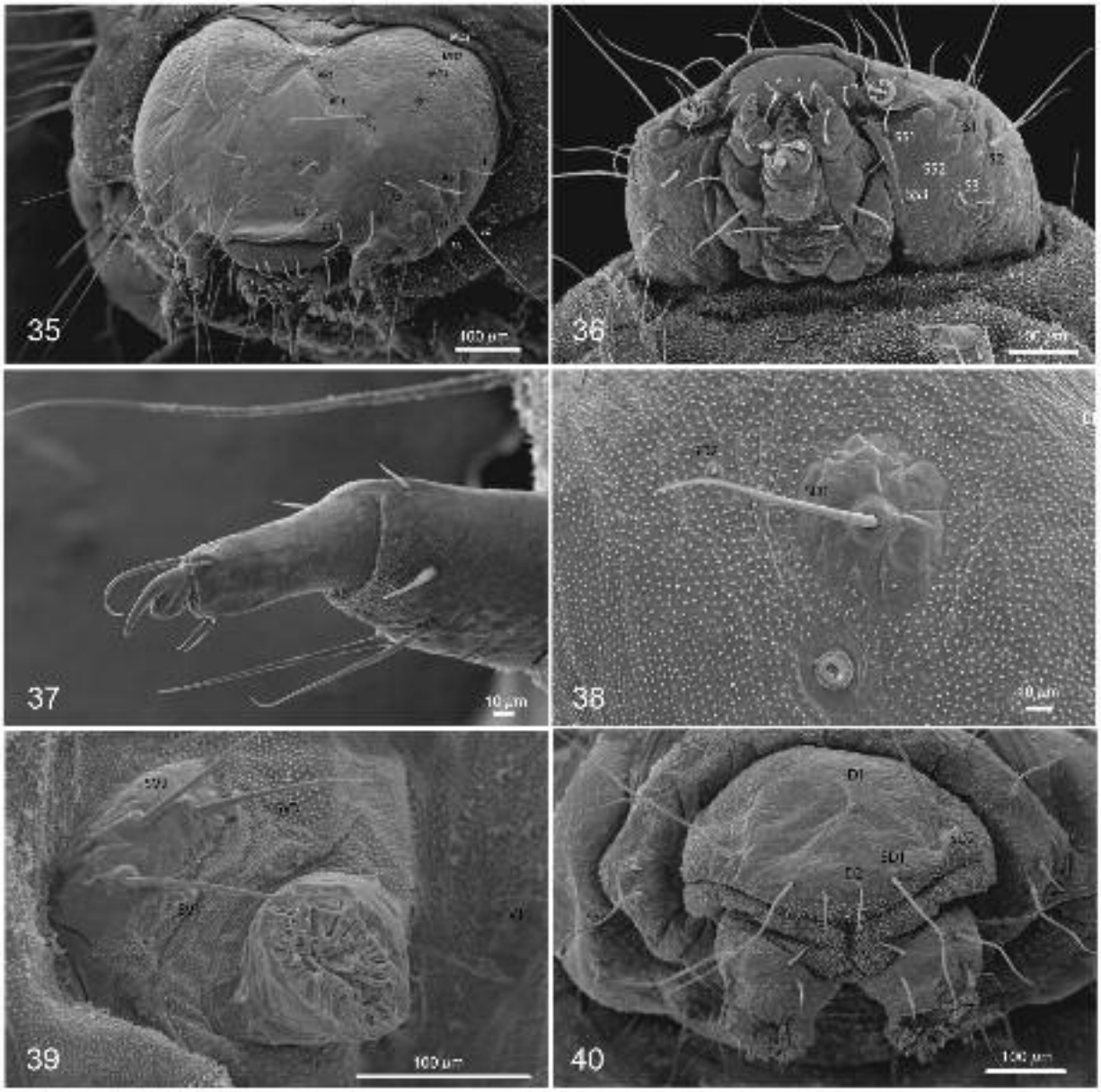
FIGS. 26–30. *Gnorimoschema shepherdiae* genitalia. **26.** Male genitalia, ventral view, with vinculum-valvae unrolled to the left (slide MIC5298, specimen CNCLEP00061397). **27.** Phallus. **28.** Eight tergum. **29.** Eight sternum. **30.** Female genitalia (slide MIC5931, specimen JD0263); inset, close-up view of ostium bursae area. Scale = 100 µm.



FIGS. 31–34. *Gnorimoschema shepherdiae*, mandible and chaetotaxal maps. **31.** Head and T1–T3. **32.** A1–A2. **33.** Mandible. **34.** A6–A10.

Gnorimoschema, but the species share an overall more or less diagnostic configuration of the genitalia. In male genitalia, they are recognized by the combination of a medio-apically pointed uncus, tongue-like gnathos, markedly V-shaped tegumen from divergent pedunculi, incurved valva with a slight medial constriction and subclavate or clavate apex, sacculus lobes prominently developed, vincular processes reduced or stumpy, and phallus with a markedly bulbous base. In female genitalia, the antrum is not developed, the signum has a short and thick base and a thick spine and is near the point of inception of the ductus bursae. Most species of *Gnorimoschema* cannot be confidently identified from external aspect, and many display a tremendous amount of intraspecific variation in forewing pattern and colouration. However, the genitalia afford good differences and usually differ in a combination of features of proportions and shapes of structures that define species-specific, diagnostic appearances.

Among the numerous Nearctic species of *Gnorimoschema, G. shepherdiae* is most similar to *G. vibei* Wolff (known from Greenland and northern Quebec) in both male and female genitalia. In male *G. shepherdiae*, the distal process of the gnathos is very straight-sided, the sacculus is moderately incurved with the apex sharply pointed, and the vincular processes have an angulate margin and are separated by narrowly V-shaped median incision; in *G. vibei*, the distal process of the gnathos is slightly but distinctly tapered, the sacculus is sharply incurved with a rounded apex, the vincular processes have a slightly sinuate margin and a wide V-shaped incision. In female *G. shepherdiae*, S8 is transverse with the anterior margin roundly concave, the antrum is not prominent (indistinct), the corpus bursae is distinctly widened, ovoid in its anterior two-thirds, and the signum has a more slender, less curved hook; in *G. vibei*, S8 is elongate with the anterior margin forming a double concavity caused by a short but



FIGS. 35–40. *Gnorimoschema shepherdiae*, scanning electron micrographs of larva. **35.** Head chaetotaxy, frontal view. **36.** Head chaetotaxy, ventral view. **37.** Right tarsus on T2. **38.** SD1 and SD2 on A5, right side. **39.** Right proleg on A5. **40.** Anal plate chaetotaxy on A10.

distinctly protruded antrum, the corpus bursae is more narrow with the anterior third very slightly widened, and the signum has a thicker, more sharply curved hook.

We report here the first occurrence of *G. vibei* in Canada based on barcoded specimens from Kuujjuarapik in northern Quebec (CNC). This species was so far known only from western Greenland (Wolff 1964). New, unpublished information about its life history will be provided by in an upcoming book on the Lepidoptera of Greenland (Karsholt et al. in press).

Adult description. *Head*: Fronto-clypeus and vertex white, some scales agouti patterned with basal 2/3 white, tipped with brown with a narrow white margin. Scape white intermixed with brown scales or brown intermixed with few white scales; flagellomeres of flagellum basally brown, apically white on upper surface, white on undersurface. Ocellus behind antennal base along margin of compound eye. Outer surface of labial palpus with segment 2 brown intermixed with white scales along apical margin; scales agouti-pigmented, giving a "calico" pattern to ground color; scales divergent from midline on undersurface, forming a brushlike appearance; terminal segment with variable pattern, white with brown mid and subapical bands, or suffused; inner surface of labial palpus as above or paler. Proboscis white.

Thorax: Mesonotum and tegula with white scales tipped with brown. Legs calico patterned. Foreleg: femur brown; tibia with a suffuse white band slightly beyond base, a suffuse white band near middle, and a white tuft along apical margin; tarsomeres with a narrow white band along apical margin. Midleg with femur white intermixed with few brown scales; tibia with a suffuse white band slightly beyond base, a suffuse white band near middle, and a white band on apical end adjacent to paired spurs; tarsomeres as above. Hindleg with femur white; tibia with a suffuse white band slightly beyond base, a white band adjacent to middle pair of spurs, and a white band adjacent to apical pair of spurs; tarsomeres as above. Forewing (Fig. 2), length 5.0–6.3 mm (n = 52) calico patterned; brown intermixed with white and few grayish-orange scales; three suffuse white bands alternate from base with three bands (with brown scales intermixed with grayish-orange scales) to 2/3; distal 1/3 mostly white intermixed with white scales tipped with brown and brown scales and few grayish orange scales. Fringe scales white tipped with brown. Undersurface brown except for pale-brown fringe scales. Hindwing translucent pale brown.

Abdomen: Upper surface pale brown, undersurface white.

Male abdomen (Figs. 28–29). Tergum 8 subtriangular, weakly sclerotized, anteriorly roundly emarginate, antero-lateral angles inwardly directed. Sternum 8 transverse, about 2× wider than long, weakly sclerotized, posterior margin even rounded.

Male genitalia (Figs. 26–27). Tegumen with depth of anterior notch about two-thirds length of dorso-medial portion, apical part straight-sided and demarcated by constriction from rest of dorso-medial portion, pedunculi divergent forming broad V-shape. Uncus transverse, about 1.5× wider than long, apical margin medially produced into triangular point, sides parallel, without setae. Gnathos with short, triangular proximal arms, distal process tongue-shaped, parallel-sided. Culcitula developed, with dense, coarse microtrichiae. Vinculum transverse, about 1.8× wider than long, vincular processes short, hump-like, setose, medially separated by shallow, V-shaped incision, area around processes with wrinkled cuticle delineating an inverted trapezoid area. Saccus conical, broad, short, extended slightly anterad of antero-lateral angles of vinculum. Sacculus of valva pincer-like, inwardly curved, sharply pointed, extended to about half-length of cucullus, with a few sparse apical setae. Cucullus of valva incurved, apex extended slightly beyond apex of uncus, medial section constricted, apex somewhat dilated, with sparse, fine setae. Phallus with bulbous basal third, distal two-thirds straight with apex slightly upcurved and ended in short hook.

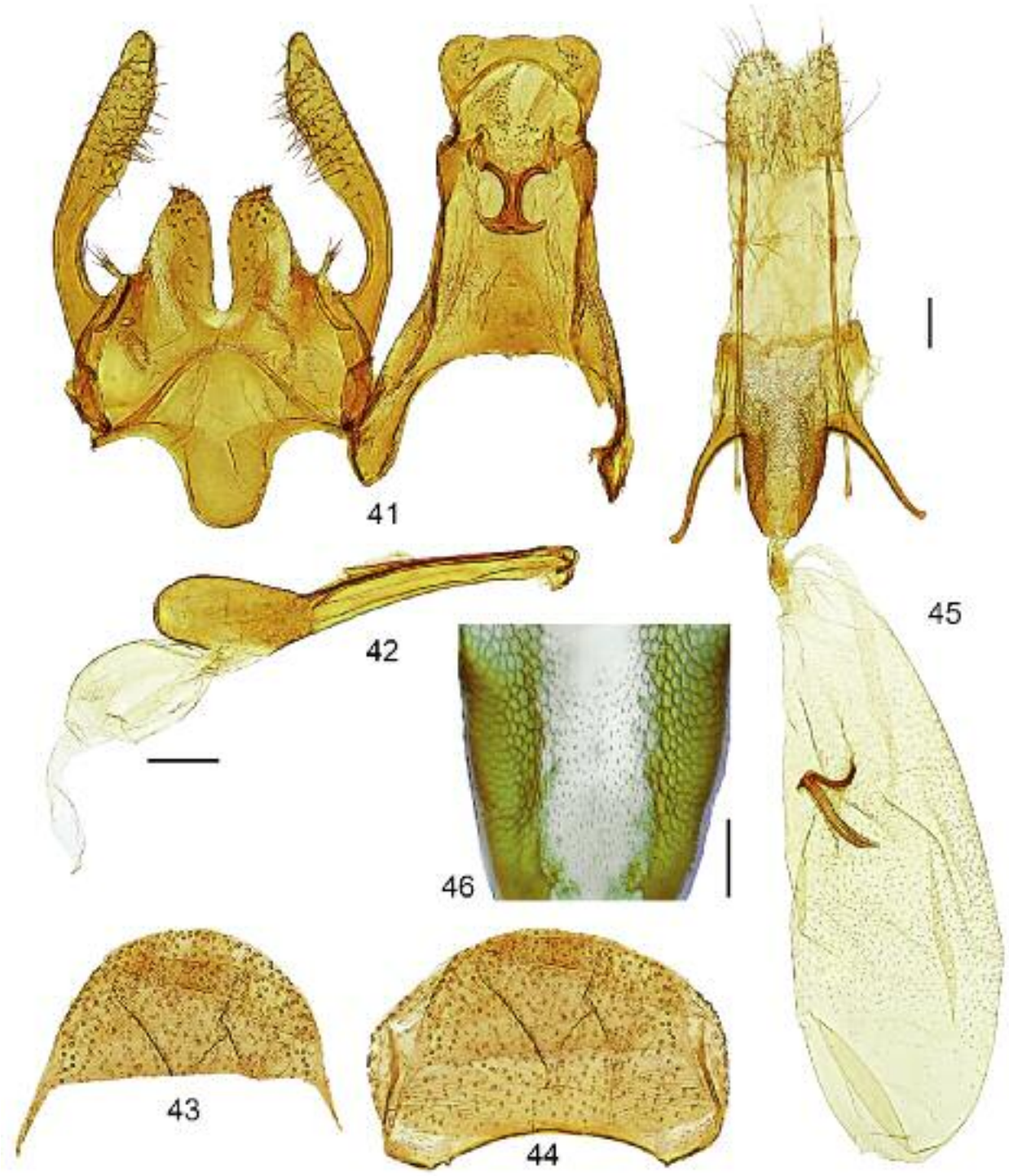
Female genitalia (Fig. 30). Ovipositor 1.8× length of S8 (to antero-lateral angle), papillae anales membranous. Anterior apophysis nearly straight, slightly shorter than S8. Posterior apophysis about 2.5× length of anterior one. S8 sclerotized, distal half transverse, anterior margin thickened, deeply, semi-circularly concave, depth of concavity about equal to length of distal half, antero-lateral angles prominent; postero-lateral angle with small, shallow invagination and a few very short setae; median area unmelanized, through-like, covered with very fine microtrichiae. Ostium bursae rimmed by extension of thickened S8 margin. Ductus bursae with membranous section about as long as S8 + ovipositor, with globular colliculum with sclerotized inner wall with insertion of ductus seminalis. Corpus bursae elongate-obovoid, broader in anterior two-thirds, wall membrane smooth, without microtrichae nor spicules but with very fine, almost faint transverse wrinkles. Signum with thick, straight base and slightly curved, finely serrate hook, situated near inception ductus bursae.

Larva description (Figs. 31–40). Length 7.0–7.9 mm (n = 8). Body pale gray; head golden yellow except, clypeus, labrum, ecdysial line, genal and stemmatal areas, and dorso-posterior and ventro-posterior margins brown; thoracic legs and all pinacula brownish orange; prothoracic shield with a wide unpigmented area demarcating dorso-longitudinal axis, bisecting two pale golden-yellow halves, posterior and postero-lateral margins brown gradually becoming pallid anteriorly; anal shield pale golden yellow with a large brown spot anterior to D1 spiracle on T1 slightly larger than spiracles on A2–A7; spiracle on A8 about twice diameter of spiracles on A2–A7.

Head: (Figs. 31, 35–36): Epicranium slightly flattened dorso-ventrally; mouthparts semi-prognathous; an elongate, triangular frons demarcated by afrontal sclerites; sclerited widened distally, forming a broadly rounded ecdysial line; ecdysial suture short, bisecting adfrontal sclerites disto-medially; epicranial notch deep forming two large hemispheres; AF2 slightly longer than AF1; AF1 and AF2 equidistant to distance between AF1 and P1; P1 slightly above and about 3× P2; distance from F1 to AF1 nearly equidistant to distance between F1 and C2; C2 slightly longer than C1; A3 above stemma 2, about 5–6× A2, and about 1/3 longer than A1; six stemmata in a C-shaped pattern, with stemma 3–4 approximate; S3 ventral and slightly posterior to S2; S2 approximate and below stemma 1; S1 below area between stemmata 3–4; L1 posterior to stemma 1; SS1 beneath area between antenna and condyle of mandible; mandible with three apical dentitions, two subequal dentitions along dorsal surface, and two subequal setae near condyle (Fig. 33); SS2 and SS3 approximate, both beneath area between stemmata 5–6; labrum with six pairs of setae, two equal median pairs, two equal fronto-marginal pairs, and two subequal latero-marginal pairs; SS2 and SS3 approximate, both beneath area between stemmata 5–6.

Thorax (Figs. 31, 37): Prothoracic shield with SD1 about 2–2.5× longer than XD2 and XD1; XD2 anterior to SD1 and XD1; distance between XD2 and XD1 about 2× distance between XD2 and SD1; SD2 about 1/4 as long as D2; distance between SD1 and SD2 equal to distance between SD1 and XD2; D2 slightly shorter than SD1, posterior to SD2 and D1; distance between D2 and SD2 at least twice distance between D2 and D1; D1 slightly shorter than SD2, closer to median longitudinal axis than XD1; L-group pinaculum and L-group diagonally oriented, with L2 more dorsal than L1 and L3 or L1 slightly lower than L2 and L3; L1 about 2.5× longer than L2, with L3 slightly shorter than L2, on same pinaculum anterior to spiracle; SV-group bisetose, with SV2 1/3–1/2× as long as SV1; V1s approximate, close to a transverse line across posterior margins of coxae (not shown). T2–T3 (Fig. 31): D2 about 2× length of D1, each seta on separate pinaculum, with D2 pinaculum slightly larger than D1 pinaculum; SD1 3–4 times of SD2, each seta on same pinaculum, on slight diagonal, anterior to D-group pinaculum; L1 2–2 1/2× longer than L2, each seta on same pinaculum, on acute diagonal, anterior to SD-group pinaculum; L3 slightly shorter than L2, on pinaculum posterior to area between SD-group pinaculum and L-group pinaculum, and slightly anterior to or in straight line with SV1; V1s between coxae near middle, about 2–2 1/2 × distance between V1s on T1 (not shown); tarsus (Fig. 37) with two pairs of setae ventro-posterior and dorso-posterior to claw; ventro-posterior setae equal in lengths, dorso-posterior pair subequal, with a broad hooklike seta on outer surface.

Abdomen: A1–A2 (Figs. 32, 34, 38–40): D2 2–2 1/2 × longer than D1; SD1 on pinaculum dorso-posterior to spiracle; SD2 minute, dorso-anterior to SD1 (Fig. 32); spiracle about 3× distance from SD1 on A1 than on A2; L1 2–2 1/2 × longer than L2, each seta on same pinaculum; L-group pinaculum on A2 at least twice distance from spiracle as distance from L-group pinaculum to spiracle on A1; L3 about equal in length to L1, in straight line with or slightly anterior to D2; SV-group on A1 bisetose, SV1 about 3× length of SV2, each seta on same pinaculum, slightly posterior to L-group pinaculum (L1–L2); SV-group on A2 trisetose, SV1 and SV2 on same pinaculum, parallel with longitudinal body axis; SV3 on separate pinaculum; distance between V1s as in T2 and T3 (not shown). A3–A6 (Fig. 34): as above except, SD-pinaculum directly above spiracle, SV-group on a sclerotized band at base of proleg, and crochets uniserial and biordinal; A7–A10 (Fig. 34, 40): as above except, SV-group bisetose, with SV1 2× length of SV2, and V1s slightly closer; A8 as above except, SV-group unisetose; A9 with all setae in near straight line, D2 about 2× D1; SD1 hairlike, shorter than D2; L-group bisetose and on same pinaculum, with L1 at least 3× length of L2 (setae and pinaculum slightly diagonal); SVs and V1s as above (V1s not shown); A10 (Figs. 34, 40): anal plate with SD2 and SD1 at least 2× distance apart than distance between SD1 and D2; SD2 and SD1 of equal lengths, about 4–5× D2; D2 convergent; D1 anterior to space between D2 and SD1; crochets biordinal.



FIGS. 41–46. *Scrobipalpula manierreorum* genitalia. **41.** Male genitalia, ventral view, with vinculum-valvae unrolled to the left (slide MIC5722, specimen POHL-10-00172). **42.** Phallus. **43.** Eight tergum. **44.** Eight sternum. **45.** Female genitalia (slide MIC5784, specimen 08BBLEP-00325). **46.** Close-up view of antrum near ostium bursae. Scale = 100 µm, except inset = 50 µm.

Pupa. Undescribed. Although pupal exuviae were obtained during this study, we prefer not to describe this stage until freshly preserved pupae are available.

Type material. Holotype ♂, "MICHIGAN: Presque Isle Co[unty],NE, T34N-R07E, S 14, [= 45.349°N, 83.541°W], Em[er]g[e]d: 15 Feb. 2006, Surv[eyor] [= Collector]: RJ Priest", "Reared Ex. *Shepherdia canadensis*, Rec[o]v[red] [date collected]: 25 Oct. 2005, Lot: RJP1688.4", [specimen #] "USNMENT 00719474", "DNA 2011" [blue label], "♂ Genitalia Slide by D. Adamski, USNM 83549", [green label], [pupal exuvium attached to pin] (USNM).

Paratypes: 13 ♂, 18 ♀. MICHIGAN: 2 ♂, 6 ♀, same data as holotype except: 1 ♂, em. 15 Feb 2006, larva 25 Oct 2005, lot RJP1688.5 [metathorax and abdomen attached to paper card beneath specimen] (MSUC); 1 ♂, em. wintered, larva 12 Oct 2007, lot RJP1854.5, specimen # USNMENT 00719450, genitalia slide by D. Adamski, USNM 83550 (USNM); 1 ♀, em. 16 Feb 2006, larva 25 Oct 2005, lot RJP1688.44, specimen # USNMENT 00719452, genitalia slide by D. Adamski, USNM 83551 (USNM); 1 ♀, em. 16 Feb 2006, larva 25 Oct 2005, lot RJP1688.13 [pupal exuvium in gelatin capsule beneath specimen] (MSUC); 1 ♀, em. 20 Jul 2007, larva 29 Jun 2007, lot RJP1815.1 [pupal exuvium attached to minuten beneath specimen] (MSUC); 1 ♀, em. wintered, larva 24 Aug 2006, lot 1743.1 [pupal exuvium attached to minuten beneath specimen] (MSUC); 1 ♀, T34N-R07E, S 15 [= 45.343°N, 82.572°W], em. 1 Aug 2002, larva 18 Jul 2002, lot RJP1305.1, specimen # USNMENT 00719451, genitalia slide by D. Adamski, USNM 83552, USNM (USNM); 1 ♀, em. 29 Jul 2002 larva 18 Jul 2002, lot RJP1305.2 [pupal exuvium attached to minuten beneath specimen] (MSUC). ALBERTA: 1♀, Banff Nat Pk, Storm Mountain, low alpine dry slope, adjacent to train track and Bow River, 15–20 Jun 2012, BIOBus 2012, 2 malaise traps, specimen # BIOUG03504-A02 (CNC); 1♂, Banff Nat Pk, 2km North from Johnston Lake, 6–13 Jul 2012, Whittington, wetland, lodgepole pine/spruce, specimen # BIOUG06777-A01 (CNC); 1♀, Jasper Nat Pk, dunes,18 May 2006, J. J. Dombroskie, C. Schmidt, specimen # JD0263 (CNC); 1♂, Jasper Nat Pk, dunes,18 May 2006, J. J. Dombroskie, C. Schmidt, specimen # JD0182 (CNC); 1♀, Jasper Nat Pk, highway 16 / 93A junction, 20–27 Jun 2012, Clayton SyFchuk, thinned out lodgepole pine stand, valley basin, specimen # BIOUG02884-D11 (CNC); 1♀, Jasper Nat Pk, highway 16 / 93A junction, 4–11 Jul 2012, B. Sharp, thinned out lodgepole pine stand, valley basin, specimen # BIOUG03585-B07 (CNC); 1♀, Jasper Nat Pk, Palisades Centre, 02 Jun 2007, J.J. Dombroskie, specimen # JD2414 (CNC); 1♀, Jasper Nat Pk, Palisades Centre, 02 Jun 2007, J.J. Dombroskie, specimen # JD2415 (CNC); 1♀, Jasper Nat Pk, Whistlers Cmpgrd., Pine forest, 23 Jun 2010, BIObus 2010, UV Light Trap, specimen # 10BBCLP-3075 (CNC); 1♂, Jasper Nat Pk, Whistlers Cmpgrd., Pine forest, 27 Jun 2010, BIObus 2010, UV Bucket Trap, specimen # 10BBCLP-3108 (CNC); 2♂, Nordegg, 12 Jun 1921, J McDunnough, specimens # CNCLEP00084604 (not barcoded), genitalia slide MIC 6363, # CNCLEP00090702 (not barcoded), genitalia slide MIC 6311 (CNC); 1♀, Nordegg, 13 Jun 1921, J McDunnough, specimen # CNCLEP00090701 (not barcoded), genitalia dissection MIC 6310 (CNC); 1♀, Nordegg, 19 Jun 1921, J McDunnough, specimen # CNCLEP00090703 (not barcoded), genitalia slide MIC 6312 (CNC); 1♀, Nordegg, 20 Jun 1921, J McDunnough, specimen # CNCLEP00084579 (not barcoded), genitalia slide MIC 6350 (CNC); 1♀, Tolman Bridge, E bank of Red Deer River, 24 Jul 2003, J.-F. Landry, at mercury light, specimen # CNCLEP00007388 (CNC); 1♂, Abraham Lake, Allstones Lake trail, 01 Jul 2007, Pohl, G. R., specimen # POHL-10-00147 (CNC); 1♀, Wood Buffalo Nat Pk, Benchmark weather station, 31 May–07 Jun 2012, Nicole Labine, aspen stand, specimen # BIOUG05849-A05 (CNC). BRITISH COLUMBIA: 1♂, Lumby, 15 Jul 1957, Freeman & Lewis, specimen # CNCLEP00087115 (not barcoded), genitalia slide MIC 7029 (CNC). MANITOBA: 1♂, Churchill, 13 km E Churchill, Eastern Creek, 16 Jul 2007, P.D.N. Hebert, specimen # 07PROBE-10061, genitalia slide MIC 5442 (CNC); 1♂, Churchill, summer 2007, P.D.N. Hebert, specimen # 07PROBE-10739 (CNC). QUEBEC: 1♂, Gatineau, Aylmer, 48 rue Notre-Dame, 13 Jun 1996, J.-F. Landry, at MVL, specimen # CNCLEP00086250, genitalia slide MIC 4656 (CNC). YUKON: 1♂, 2 km N Carcross, sand dunes, 23 Jun 2004, B.C. Schmidt, specimen # CNCLEP00061397, genitalia slide MIC 5928 (CNC).

Molecular data (Table 1; Fig. 60). BIN = BOLD:AAI5479. Full barcodes from 20 specimens, including the holotype and three paratypes of *G. shepherdiae* were obtained which were compared to those of *G. saphirinella* (BOLD:AAI5502) and *G. vibei* (BOLD:AAY0935). We analyzed barcodes of 8 specimens of *G. vibei* from Greenland and Quebec. For *G. saphirinella*, we analyzed 20 barcodes of specimens from Arizona, California, Colorado, Kansas, Mississippi, New Mexico, Oklahoma, and Texas. *Gnorimoschema shepherdiae* differs by 8.7% (57 base pairs) from *G. vibei* and 10.9% (71 base pairs) from *G. saphirinella*. The two 'outgroup' species differ from each other by 9.1%, or about 60 base pairs), whereas intraspecific haplotype variation was <1%.

Etymology. The species epithet, *shepherdiae*, is derived from the generic name of host, *Shepherdia*.

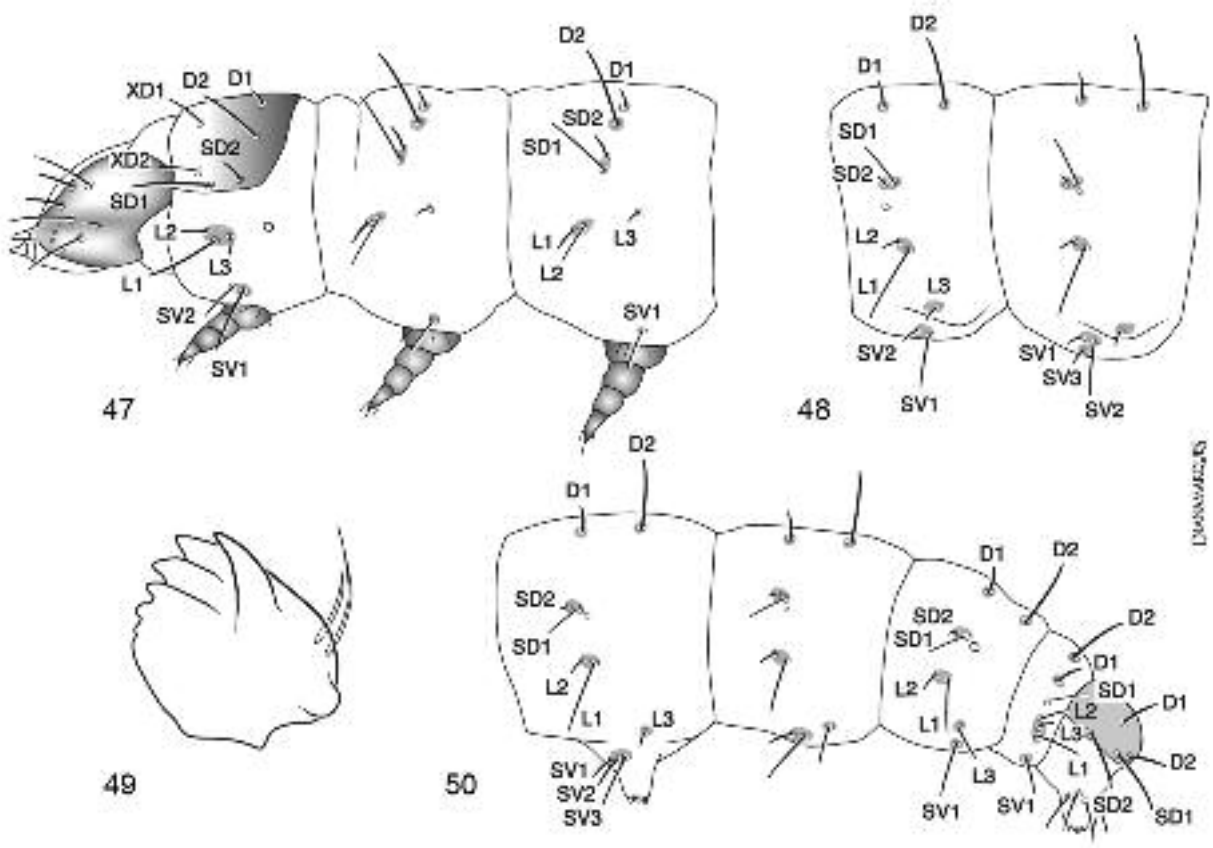
Biology. Host: *Gnorimoschema shepherdiae* is a leaf-miner of *Shepherdia canadensis* (L.) Nutt. (Elaeagnaceae).

Mine and larval behavior (Figs. 5–6). The mine usually begins at the midvein. Frass is concentrated at the base forming a retreat for the larva when not feeding or when it is disturbed (Fig. 5) (rearing lot RJP1828.1). Expansion of this full depth mine continues as a wide track with a series of short lobes. A shelter is constructed within the base of the mine where frass is concentrated. When the shelter is large enough to conceal the larva subsequent frass is arranged into two parallel rows along the primary mine axis (Fig. 6). These rows provide a guide for the larva to quickly retreat into its frass tube. The mature mine is tentiform with many small wrinkles on the upper surface. From early instar to mature larva, feeding occurs with the larval body ventral side upward. Most leaves can support full development of only one larva although two may mature in larger leaves. When the larvae of the June–July generation stop feeding they exit via a crescent-shaped cut at the terminus of their mines. An off-white cocoon is constructed presumably in the soil or leaf litter prior to pupation. Larvae of the next generation overwinter in their mines and exit during the spring.

Seasonal occurrence. Two generations were observed in Michigan. Larvae occurring from late June to mid-July produced adults by late July. Larvae occurring from late August to early October produced adults only after overwintering. The timing of observations of larval mines in the field in Michigan and flight periods of moths collected in Canada suggests that *Gnorimoschema shepherdiae* is bivoltine.

Parasitoids. *Pnigalio maculipes* (Crawford) (Eulophidae) and *Agathis gibbosa* (Say) (Braconidae).

Distribution (Fig. 59). The species is here recorded from Alberta, British Columbia, Manitoba, Michigan, Quebec, and Yukon. Its host plant is widespread across Canada and the northern half of United States and known records suggest that *G. shepherdiae* may be distributed as widely as its host.



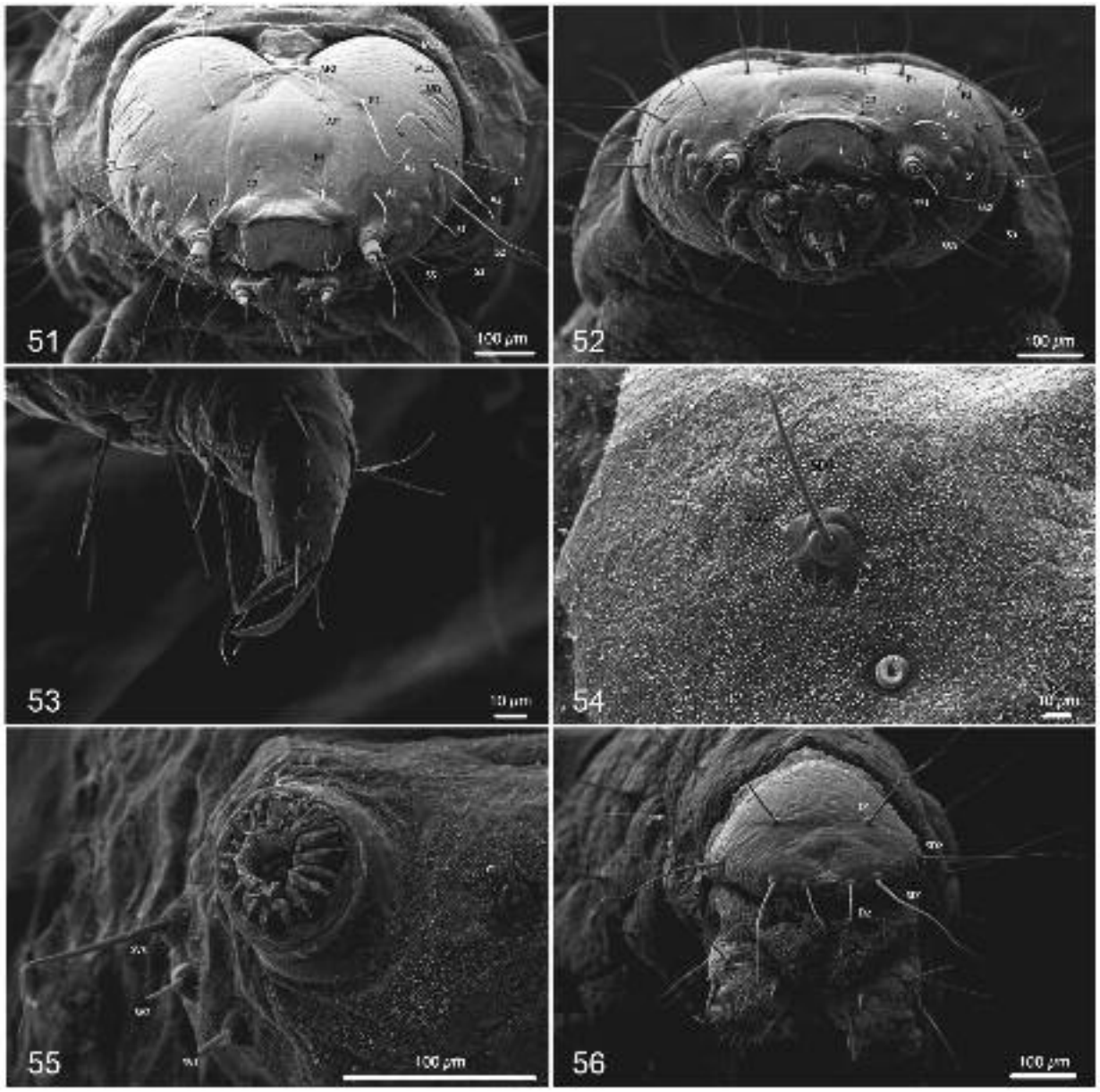
FIGS. 47–50. *Scrobipalpula manierreorum*, mandible and chaetotaxal maps. **47.** Head and T1–T3. **48.** A1–A2. **49.** Mandible. **50.** A6–A10.

Scrobipalpula manierreorum Priest, **new species**
(Figs. 1, 7–8, 41–58)

Adult diagnosis. In male genitalia, members of *Scrobipalpula* are recognized by the shape of the distal process of the gnathos which is expanded, forming an ax-blade-like structure; the paired processes of the vinculum are broad, elongate, extended to about 1/3 the length of the valva (cucullus) with a deep, median incision; the sacculus is very short, reduced, stub-like. There are no external diagnostic characters to recognize members of this genus.

Scrobipalpula manierreorum is similar to *S. artemisiella* (Kearfott) in forewing pattern but the latter has markedly different genitalia in both sexes. The male and female genitalia are most similar to those of *S. polemoniella* (Braun) [whose larvae are leaf-miners on *Polemonium*, (Polemoniaceae) and which probably overlaps geographically where both food plants occur]. *Scrobipalpula manierreorum* has the uncus slightly wider than long with the distal edge of transversely straight; the gnathos distal process medially narrow and concave and the apex narrowly transverse; the vincular processes with a narrowly U-shaped median incision; and a broad, short saccus about one-third as wide as the distance between the antero-lateral angles of the vinculum and broadly rounded lateral margins; *S. polemoniella* differs mostly in the more triangular vincular processes separated by a V-shaped median incision, and straighter lateral margins of the vinculum.

In female genitalia, *Scrobipalpula* have the antrum funnel-like and extended to half or nearly the length of the anterior apophyses with the surface laterally covered with mesh-like microsculpture and medially with dense, fine microtrichiae, the corpus bursae is proportionally large and elongate (as long or longer than the 8th segment and extended ovipositor combined) with a slender, thorn-like signum with a slender base situated slightly posterad of the middle of the bursa. The mesh-like microsculpture is also present in several species of *Scrobipalpa* but differently distributed, and the antrum is not extended into an elongate funnel.

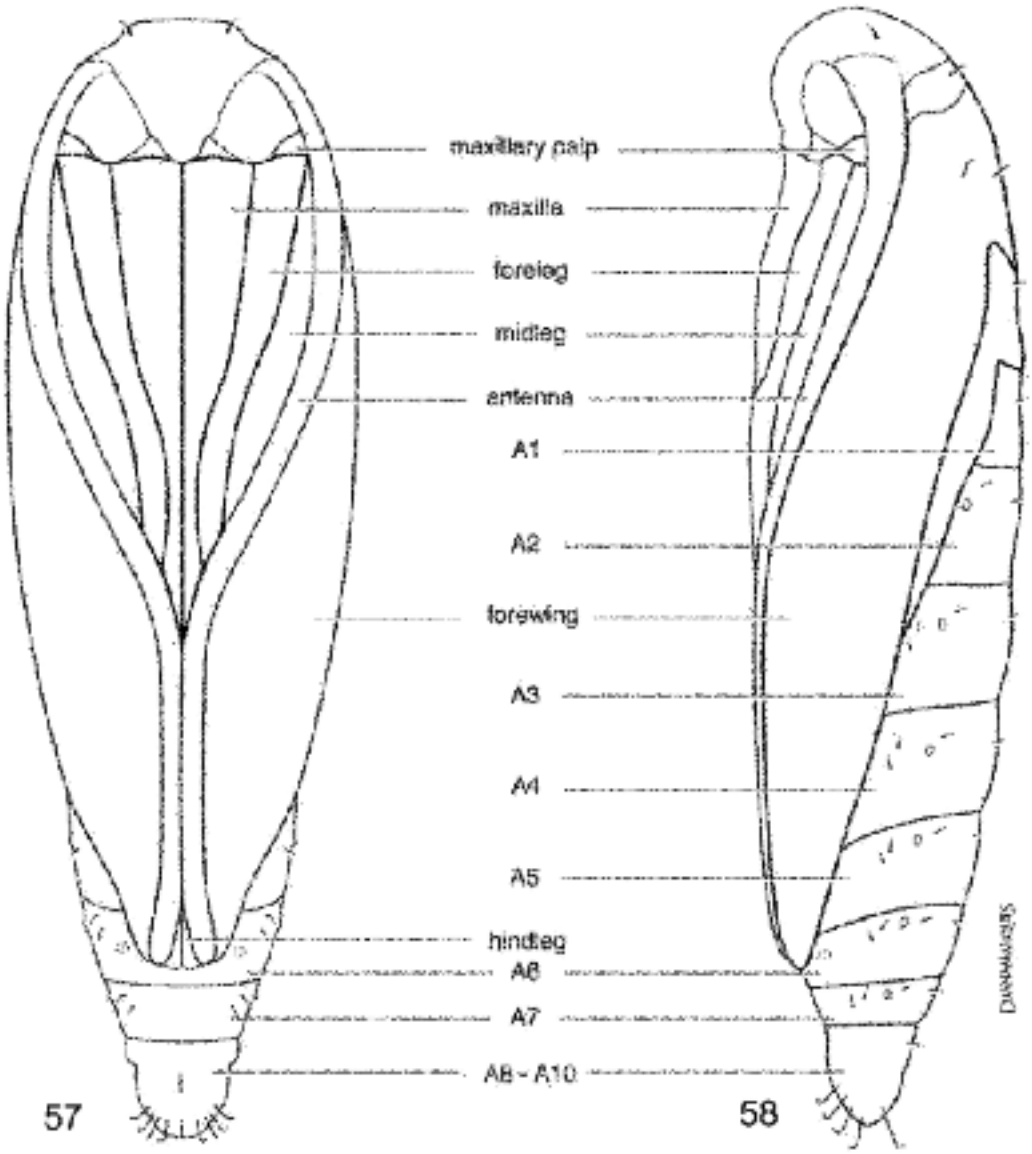


FIGS. 51–56. *Scrobipalpula manierreorum*, scanning electron micrographs of larva. **51.** Head chaetotaxy, frontal view. **52.** Head chaetotaxy, ventral view. **53.** Left tarsus on T3. **54.** SD1 and SD2 on A4, left side. **55.** Left proleg on A3. **56.** Anal plate chaetotaxy

Scrobipalpula manierreorum females have the antrum large and longer than S8 with anterior end somewhat rounded and only slightly narrowed; the corpus bursae very large, oblong, longer than the combined length of S8 and the extended ovipositor; a very short, slightly dilated colliculum; and divergent anterior apophyses. In *S. polemoniella* the antrum is triangular in outline and pronouncedly narrowed anteriorly and about the length of S8, the colliculum is more elongate, and the corpus bursae is narrowly oblong and subequal to the combined 8th segment + ovipositor.

Adult description. *Head*: Fronto-clypeus white. Vertex with agouti-patterned scales, with basal 2/3 white, tipped with brown with a narrow white distal margin. Scape of antenna with brown scales tipped with white, flagellomeres of flagellum dark brown basally, pale brown apically. Ocellus behind antennal base along margin of compound eye. Outer surface of labial palpus with segment 2 white intermixed with brown scales tipped with brown; terminal segment brown basally and apically with a broad white band between; inner surface as above but paler. Proboscis white.

Thorax: Mesonotum and tegula with agouti-patterned scales. Legs calico patterned. Foreleg: femur brown; tibia with a suffuse white band slightly beyond base, a suffuse white band near middle, and a white tuft along apical margin; tarsomeres with a narrow white band along apical margin. Midleg with femur brown intermixed with few white scales brown scales; tibia with a suffuse white band slightly



FIGS. 57–58. *Scrobipalpula manierreorum*, pupa. **57.** Ventral view. **58.** Lateral view.

beyond base, a suffuse white band near middle, and a white band on apical end adjacent to paired spurs; tarsomeres as above. Hindleg with femur white; tibia with a suffuse white band slightly beyond base, a white band adjacent to middle pair of spurs, and a white band adjacent to apical pair of spurs; tarsomeres as above. Forewing (Fig. 3), length 3.7–6.5 mm (n = 39) with white scales tipped with dark brown intermixed with brown, white, and grayish-orange scales; cell with two short, dark-brown streak, one near middle, one near distal end; a broad, suffuse, grayish-orange streak extending from base to apex. Fringe agouti. Underside brown except, fringe pale brown. Hindwing translucent pale brown.

Abdomen: Pale brown on upper surface, white on undersurface.

Male abdomen (Figs. 43–44). Tergum 8 transversely semicircular, wider than long, antero-lateral angles prolonged into short, thin, tapered extensions, without coremata (removed by dissection?). Sternum 8 transversely subtrapezoidal, posterior margin evenly convex, anterior margin shallowly, roundly emarginate.

Male genitalia (Figs. 41–42). Tegumen with pedunculi slightly longer than half length of dorso-medial portion, depth of anterior notch about 0.5 length of dorso-medial portion, its width slightly longer than length of dorso-medial portion. Uncus transversely subquadrate, posterior margin straight, anterior margin concave, lateral angles rounded, ventrally with paired patches of short setae. Gnathos with distal process hatchet-like, narrow, medial stem elongate and constricted, basal arms short, articulated to apical margin of tegumen. Vinculum transversely broad, about 2.5× wider than long (exclusive of vincular processes). Saccus tongue-shaped, short, broadly rounded, about one-third as wide as distance between antero-lateral angles of vinculum and broadly rounded lateral margins. Vincular processes about as long as vinculum, extended to about half length of valvae, with narrow, U-shaped median incision (gap), apex outwardly mucronate, distal upper surface with several short, sparse setae. Cucullus of valva extended slightly beyond apex of uncus, basal third incurved, distal two-thirds moderately dilated, setose; sacculus of valva

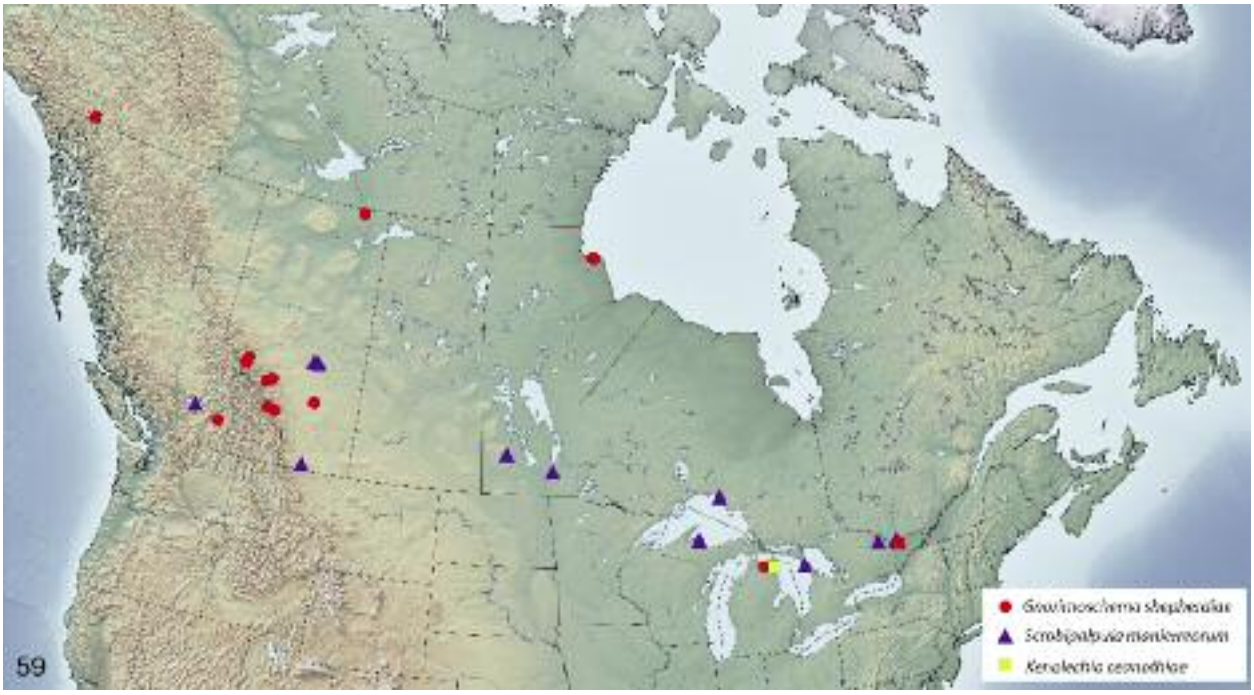


FIG. 59. Distribution map showing known localities of the three new species. The type locality of both *G. shepherdiae* and *X. ceanothiae* is the same in northern Michigan but the symbols were slightly offset so that both are visible.

very short, stubby, apically setose. Phallus with moderately dilated basal third, distal two-thirds very slightly arched, junction between swollen base and narrower distal part angulate, apex split into pair of downcurved hooks.

Female genitalia (Figs. 45–46). Ovipositor nearly 6× length of S8 (exclusive of antrum). Apophyses anteriores slightly curved, divergent, with slightly widened base. Apophysis posterioris about 3.4× length of apophysis anterioris, very thin, straight. Segment 8 slightly transverse, 1.5× wider than long. S8 laterally sclerotized with surface longitudinally wrinkled, medially membranous with dense, fine microtrichiae extended onto antrum surface. Antrum prominently developed, elongate-conical, extended nearly to apex of anterior apophyses, anterior end slightly roundly narrowed, lateral surface bulged into ridges covered with mesh-like microsculpture, medial area through-like and covered with dense, posteriorly directly microtrichiae. Ostium bursae situated at anterior end of antrum. Ductus bursae very short, < 1/2 length of antrum, internal wall with sclerotization (colliculum). Corpus bursae very large, oblong, slightly longer than combined length of S8 and extended ovipositor, inner surface covered with very fine, sparse spicules except in anterior 1/4. Signum slender, thorn-like, slightly curved, with slender, sharply curved base, and situated slightly posterad of middle of corpus bursae.

Larva description (Figs. 47–56). Length 5.5–8.2 mm (n = 7). Body pale gray; head golden yellow except, clypeus, labrum, ecdysial line, genal and stemmatal, and dorso-posterior and latero-posterior margins brown; thoracic legs and all pinacula brownish orange; prothoracic shield with a wide unpigmented area demarcating dorso-longitudinal axis, bisecting two pale golden-yellow halves, posterior and postero-lateral margins brown gradually becoming pallid anteriorly; anal shield pale golden yellow; spiracle on T1 slightly larger than spiracles on A2–A7; spiracle on A8 about twice diameter of spiracles on A2–A7.

Head (Figs. 47, 51–52): Epicranium slightly flattened dorso-ventrally; mouthparts semi-prognathous; an elongate, triangular frons demarcated by afrontal sclerites; sclerited widened distally, forming a broadly rounded ecdysial line; ecdysial suture short, bisecting adfrontal sclerites distomedially; epicranial notch deep forming two large hemispheres; AF2 at least 4× longer than AF1, distance between AF2 and AF1 slightly greater than distance between AF1 and P1; P1 about 3× and slightly above P2; distance from F1 to AF1 twice distance of distance from F1 and C2; C2 and C1 about equal in lengths; A3 above stemma 1, about 5–6× A2 and about 1/3 longer than A1; six stemmata in a C-shaped pattern, with stemma 1–5 approximate; S3 anterior, in vertical line with, or posterior S2; S2 approximate below area between stemmata 1–2; S1 below area between stemmata 2–3; L1 posterodorsal to stemma 1; SS1 beneath area between antenna and condyle of mandible; mandible broadly curved dorsally, with three apical dentitions, one subapical dentition, and two subequal setae at base near condyle (Fig. 49); labrum with six pairs of setae, two equal median pairs, two equal fronto-marginal pairs, and two subequal latero-marginal pairs; SS2 and SS3 approximate, both beneath area between stemmata 5–6.

Thorax (Figs. 47, 53): Prothoracic shield with SD1 about 1/3× longer than XD2 and XD1; XD2 and XD1 equal in lengths; XD2 and XD1 in straight line, slightly anterior to SD1; distance between XD2 and XD1 about 3× distance between XD2 and SD1; D2 about 4× longer than SD2; D1 slightly shorter than SD2, posterior to SD2 and D2; distance between D2 and D1 slightly shorter than distance between D2 and SD2; D1 closer to median longitudinal axis than XD1; L-group with L2 and L3 flanking L1, with L1 equidistant and ventral to both setae; pinaculum anterior and slightly ventral to spiracle; L1 at least 2× longer than L2, with L3 slightly shorter than L2; SV-group bisetose, with SV2 1/3–1/2 as long as SV1; V1s along a transverse line across posterior margins of coxae, separated about 1/4× less than distance of V1s on T2–T3 (not shown); tarsus (Fig. 53) with two pairs of setae ventroposterior and dorsoposterior to claw; ventroposterior setae equal in lengths, dorsoposterior pair subequal, with a broaden seta with an inwardly-curved, slightly flattened apical half.

T2–T3 (Fig. 47): D2 about 4–5× length of D1, each seta on separate pinaculum, with D2 pinaculum slightly larger than D1 pinaculum; SD1 3× length of SD2, each seta on same pinaculum, on

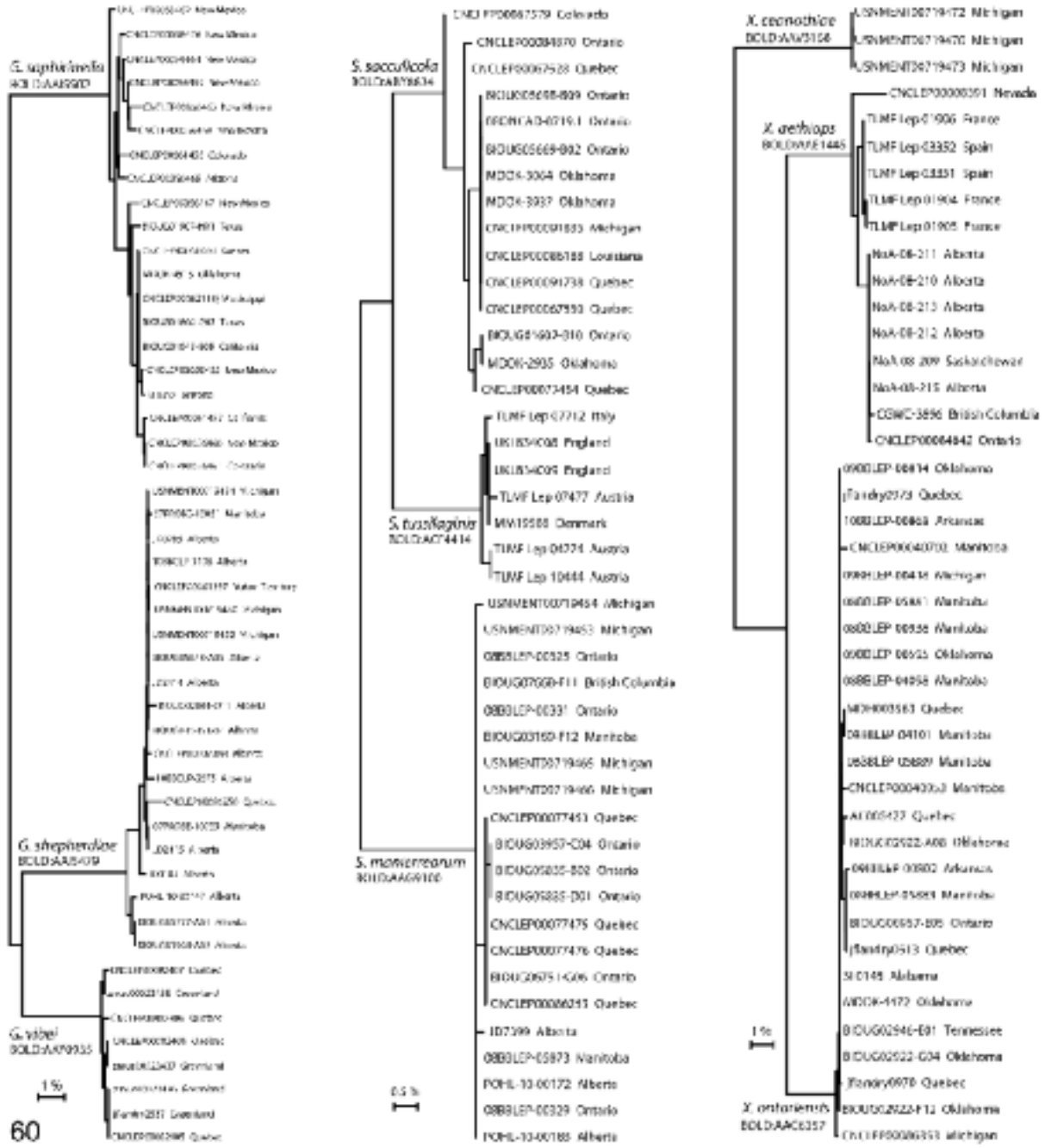


FIG. 60. Neighbor-joining tree based on K2P distances for the barcode region of the cytochrome c oxidase I gene for the three new species of leaf-mining Gelechiidae, each compared to two congeners. Alphanumeric characters at the end of branches refer to specimen numbers (Sample IDs); alphanumeric characters under the species names at the roots refer to Barcode Index Numbers (BINs) (see Methods for more details).

TABLE 1. Mean sequence divergence (K2P) for the barcode region of the COI gene for the three new species described herein and three pairs of closely allied species. Shaded diagonal cells indicate mean intraspecific divergence.

Xenolechia	*ceanothiae*	*aethiops*	*ontariensis*
ceanothiae (n=3)	0	-	-
aethiops (n=14)	12,52	0,52	-
ontariensis (n=26)	11,02	6,85	0,26
Gnorimoschema	*saphirinella*	*vibei*	*shepherdiae*
saphirinella (n=20)	0,91	-	-
vibei (n=8)	9,15	0,28	-
shepherdiae (n=20)	10,9	8,72	0,45
Scrobipalpula	*tussilaginis*	*sacculicola*	*manierreorum*
tussilaginis (n=7)	0,17	-	-
sacculicola (n=15)	3,69	0,23	-
manierreorum (n=21)	5,03	4,76	0,14

slight diagonal, anterior to D2 pinaculum; L2 2–2 1/2× longer than L1, each seta on same pinaculum, on acute diagonal, anterior to SD-group pinaculum; L3 slightly shorter than L1, on pinaculum posterior to area between SD-group pinaculum and L-group pinaculum, and slightly anterior to or in straight line with SV1; V1s between coxae near middle. (not shown).

Abdomen: A1-A2 (Figs. 48, 50, 54–56): D2 2–2 1/2 times longer than D1; SD1 on pinaculum dorso-posterior to spiracle on A1, dorso-anterior to spiracle on A2, with distance between SD1 and spiracle at least 2× on A1 than on A2; SD2 minute, on same pinaculum as SD1 (Figs. 48, 50, 54); SD1 at least twice distance farther from spiracle on A2 than on A1; L1 about 4× longer than L2, each seta on same pinaculum, with L2 posterior to spiracle on A1 and in vertical line to spiracle on A2; L3 about equal in length to L2, in straight line with or slightly anterior to D2, posterior and slightly dorsal to SV-group; SV-group on A1 diagonally oriented, bisetose, SV1 about 2× length of SV2, each seta on same pinaculum, posterior to L-group pinaculum (L1–L2); SV-group trisetose on A2, SV1 and SV2 diagonally orientated on same pinaculum; SV3 on separate pinaculum; distance betweenV1s as in T2 and T3 (not shown). A3-A6 (Figs. 50, 55): as above except, SV-group on a sclerotized band at base of proleg; crochets uniserial, uniordinal, in a circle, decreasing in size laterally. A7-A10 (Figs. 50, 56): as above except, SV-group bisetose, and V1s slightly closer; A8 as above except, SV-group unisetose; A9 with all setae in near straight line except, L2 lies anterior to L1and L3 on same pinaculum; D2 about 2× D1; SD1 hairlike, slightly shorter than D2; SV1 about as long as L2; V1s as above (not shown); A10 (Figs. 50, 56): anal plate with SD2 and SD1 about 2× distance apart than distance between SD1 and D2; SD2 and SD1 of equal lengths, about 2× length of D2; D2s parallel; D1 anterior to space between D2 and SD1, and in near transverse line with SD2; crochets uniordinal.

Pupa description (Figs. 57–58). Length 5.5–6.3 mm (n = 7): smooth; golden yellow, with thin brown lines demarcating sclerites; vertex rounded; frontoclypeus bilobed; clypeus U-shaped; labial palpi hidden; antennae broadly rounded encircling sclerites of maxillae, forelegs and midlegs, meeting medially slightly beyond midlength, extending distally in parallel, diverging distally slightly exposing mesothoracic legs; mesothoracic legs shorter or extending to lengths of antennae and forewings; maxillary palpi extending beyond foreleg; midleg abruptly narrowed distally, extending to area between apices of maxillary palpi and apices of forelegs; a pair of prolegs scars present on A6; abdominal spiracles slightly raised; segments A5, A6, and A7–10 movable; cremaster with several pairs of hooked setae present on dorsal and ventral surfaces of A9–10.

Type material. Holotype ♂, "MICHIGAN: Marquette Co[unty] ne/nw, T51N-R28W, S 09 [= 46.837°N, 87.854°W], Em[er]g[e]d. 17 Feb. 2006, Surv[eyor] [= Collector]: R.J. Priest", "Reared Ex *Eurybia* (*Aster*) *macrophylla*, Rec[o]v[red] [= date collected]: 13 Sept. 2005, Lot: RJP1654.30", [specimen #] "USNMENT 00719453", "DNA 2001" [blue label], "♂ Genitalia Slide by D. Adamski, USNM 83546" [green label]. [pupal exuvium in gelatin capsule beneath specimen] (USNM).

Paratypes: 12 ♂, 12 ♀. MICHIGAN: 5 ♂, 2 ♀; same data as holotype except: 1 ♂, em. 15 Feb 2006, larva 13 Sept. 2005, lot RJP1654.3, [pupal exuvium attached to minuten beneath specimen] (MSUC); 1 ♂, em. 12 Feb 2006, Surv: RJ Priest, lot RJP1654.6 (MSUC); 1 ♂, em. wintered, larva 28 Aug 2007, lot RJP1835.6, [pupal exuvium attached to minuten beneath specimen] (MSUC); 1 ♂, em. wintered, larva 28 Aug 2007, lot RJP1835.9, specimen # USNMENT 00719454, DNA barcoded, genitalia slide by D. Adamski, USNM 83547 [pupal exuvium attached to minuten beneath specimen] (USNM); 1 ♀, em. wintered, larva 28 Aug 2007, lot RJP1835.2, specimen # USNMENT 00719465, DNA barcoded, genitalia slide by D. Adamski, USNM 83548, [pupal exuvium attached to minuten beneath specimen] (USNM); 1 ♂, T51N-R28W, S 10 [= 46.83°N, 87.844°W], Emgd: wintered, larva 17 Sept. 2006, lot RJP1768.2, [pupal exuvium attached to minuten beneath specimen] (MSUC); 1 ♀, T51N-R28W, S 01 [= 46.844°N, 87.81°W], Emgd: wintered, larva 28 Aug 2007, lot RJP1834.9, specimen # USNMENT 00719466, DNA barcoded [right forewing missing] (USNM). ALBERTA: 1♂, Edmonton, 01 Jun 2010, J. J. Dombroskie, specimen # JD7399 (CNC); 1♀, Milk River Ridge, 10km north jct. Rte 820 & Rte. 501, at light, 24 Aug 1998, G.R. Pohl, specimen # POHL-10-00183, genitalia slide MIC 5723 (CNC); 1♂, Strathcona County, 8km SE Sherwood Park, 16 Jun 2008, G. R. Pohl, aspen forest, MVL, specimen # POHL-10-00172, genitalia slide MIC 5722 (CNC). MANITOBA: 1♂, near Winnipeg, Bird Hill Prov. Pk, Meadow, 4 Jul 2008, J. Sones, S. McCubbin, J. Straka, N. Jeffery & J. Cossey, UVL, specimen # 08BBLEP-05873 (CNC); 1♀, Riding Mountain Nat. Pk, mixed wood, medium stage aspen stand, 19–26 Jun 2012, BIObus 2012, specimen # BIOUG03169-F12 (CNC). ONTARIO: 1♀, Algonquin Park, Shaw Woods, South JK, 9 Jun 2012, Alex Smith, Uncut Forest, specimen # BIOUG06751-G06, genitalia slide MIC7183 (CNC); 1♀, Bruce Peninsula Nat. Pk, off trail nr visitors centre, 7–14 Jun 2012, Alina Mcmillan, Cedar stand – boreal forest, specimen # BIOUG05835-B02 (CNC); 1♀, Bruce Peninsula Nat. Pk, off trail nr visitors centre, 14–21 Jun 2012, Alina Mcmillan, Cedar stand–boreal forest, specimen # BIOUG03957-C04 (CNC); 1♀, Bruce Peninsula Nat. Pk, off trail nr visitors centre, 21–28 Jun 2012, Scott Parker, Cedar stand– boreal forest, specimen # BIOUG05835-D01 (CNC); 2♂, Pukaskwa Nat Pk, Park road entrance, 30 Jun 2008, BIObus 2008, UVL, specimens # 08BBLEP-00329, 08BBLEP-00331 (CNC); 1♀, Pukaskwa Nat. Pk, Park road entrance, 30 Jun 2008, BIObus 2008, UVL, specimen # 08BBLEP-00325, genitalia slide MIC5784 (CNC). QUEBEC: 1♂ 2♀, Gatineau, Aylmer, chemin

Boucher, 15 May 1998, B. Landry, MVL, specimens # CNCLEP00077453, CNCLEP00077475, CNCLEP00077476 (CNC); 1♀, Gatineau Park, chute de Luskville, 14 Jun 1990, J.-F. Landry, MVL, specimen # CNCLEP00086253, genitalia slide MIC5778 (CNC).

Other material excluded from the type series because the specimen was ground up for other DNA analysis:

BRITISH COLUMBIA: 1♂, 10 km W Kamloops, New Afton Mine, 6–13 Jun 2013, Chrystal Simon, Wetland Protected Area (control side) – Site 3, specimen # BIOUG07668-E11 (BIOUG).

Molecular data (Table 1, Fig. 60). BIN = BOLD:AAG9100. Full barcodes from 21 specimens, including the holotype and two paratypes of *S. manierreorum* were obtained which were compared to those of *S. sacculicola* (Braun) (BOLD:ABY8834) and *S. tussilaginis* (Stainton) (BOLD:ACF4414). We analyzed barcodes of 15 specimens of *S. sacculicola* from Alberta, Colorado, Louisiana, Manitoba, Michigan, Oklahoma, Ontario, Quebec. For the Palearctic *S. tussilaginis*, we analyzed barcodes of 7 specimens from Austria, Denmark, England, and Italy. *Scrobipalpula manierreorum* differs by 4.8% (31 base pairs) from *S. sacculicola* and 5% (33 base pairs) from *S. tussilaginis*. The two 'outgroup' species differ from each other by 3.7%, or about 24 base pairs). Intraspecific haplotype divergence is ≤ 0.25% in all three species.

Etymology. The species epithet, *manierreorum*, is named in honor of William and Anne Manierre, both recently deceased, who supported this research.

Biology. Host: *Scrobipalpula manierreorum* is a leaf-miner of *Eurybia* (*Aster*) *macrophylla* (L.) Cassini (Asteraceae).

Mine and larval behavior (Figs. 7–8). Larval mines are usually initiated at the midvein although some were observed to begin along a secondary vein of the leaf. There is only one larva per mine but as many as 14 mines were observed initiated on a single leaf. Frass is initially suspended externally by webbing, forming a small clump at the base of the mine on the lower surface of the leaf. Additional frass extends from the basal clump and forms a curved tube (Fig. 7), which serves as a retreat when the larva is not feeding or when it is disturbed. The mine is full depth, with all chlorophyll eaten between upper and lower epidermal layers and develops into a branching track. As the mine extends subsequent frass is formed into a double row along the main mine axis (Fig. 8) (rearing lot RJP1989.2a). This double frass row serves to guide the larva directly into its retreat when disturbed. Unlike larvae *G. shepherdiae* and *X. ceanothiae*, the larva of *S. manierreorum* feeds with its dorsal surface facing upwards.

When feeding is complete, the larva exits its mine via the frass tube and presumably pupates in the leaf litter or soil. Five cocoons were observed in rearing bags. When sand or frass was available this substrate was used to ring the cocoon exterior. Cocoons are oval and tannish-grey to white. They measure from 3.5–6.0 × 1.4–3.0 mm [mean = 4.8 ×1.9 mm].

Seasonal occurrence. *S. manierreorum* was first reared in August 2004 as part of an ongoing survey of leaf miners of dicotyledonous plants by RJP that began at the type locality in 2000. Since then an additional 13 visits, at irregular times between early June and early October, were made. Active mines were recovered between mid-August to early September. Adults appear after overwintering. This species was observed to have one generation per year in Marquette County of Upper Michigan and likely also in Lower northeastern Michigan. This is the only site that *S. manierreorum* has been repeatedly collected. The type locality of *X. ceanothiae* in northeastern lower Michigan is also believed to harbor this species, but no adults of have been reared for confirmation. No adults were collected or observed under field conditions in Michigan. Observations of larval mines in Michigan together with Canadian collection records indicate that *S. manierreorum* may be bivoltine.

Parasitoids. *Schoenlandella minuta* (Cresson) (Braconidae) and *Campoplex* sp. (Ichneumonidae).

Distribution (Fig. 59)**.** The species is here recorded from Alberta, British Columbia, Manitoba, Michigan, Ontario, and Quebec. Its host plant is distributed in the eastern half of North America west to Manitoba. The occurrence of *S. manierreorum* in Alberta and British Columbia suggests that it may be using other species of aster as larval host.

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LITERATURE CITED

CLARKE, J.F.G. 1941. The preparation of slides of the genitalia of Lepidoptera. Bull.Brooklyn Entomol. Soc. 36: 149–161.

DEWAARD. J.R., IVANOVA, N.V., HAJIBABAEI, M., AND HEBERT, P.D.N. 2008. Assembling DNA barcodes: analytical methods. Pp 275-293. *In* Cristofre M ed. Methods in Molecular Biology: Environmental Genetics. Humana Press Inc, Totowa, USA. 364pp.

FISHER, E.M. 2012. Dome light update. Fly Times 48: 2–9.

HEBERT, P.D.N., DEWAARD, J.R., ZAKHAROV, E.V., PROSSER, S.W.J., SONES, J.E., MCKEOWN J.T.A., MANTLE, B., AND LA SALLE, J. 2013. A DNA 'barcode blitz': Rapid digitization and sequencing of a natural history collection. PLoS ONE 8: e68535.

HUEMER, P. AND KARSHOLT, O. 1999. Gelechiidae I (Gelechiinae: Teleiodini, Gelechiini). *In* Huemer, P., Karsholt, O. & Lyneborg, L. (Eds), Microlepidoptera of Europe, 3, pp. 1–356. Apollo Books, Stenstrup.

HUEMER, P. AND KARSHOLT, O. 2010. Gelechiidae II (Gelechiinae: Gnorimoschemini). *In* Huemer, P., Karsholt, O. & Nuss, M. (Eds), Microlepidoptera of Europe, 6, pp. 1–586. Apollo Books, Stenstrup.

KARSHOLT, O., KRISTENSEN, N.P., AHOLA, M. AND SIMONSEN, T. In press. Lepidoptera. *In* Böcher, J. & Kristensen, N.P. (eds), The Greenland Entomofauna. An identification manual of insects and their allies. Stenstrup.

KIMURA, M. 1980. A simple method for estimating evolutionary rates of base substitutions through comparative studies of nucleotide sequences. J. Mol. Evol. 16: 111–120.

KNAPP, B.D. 1993. U.S. Department of Agriculture, Soil Conservation Service. Soil Survey of Presque Isle County, Michigan. Government Printing Office, Washington, D.C.

KORNERUP, A., AND J.H. WANSCHER. 1978. Methuen Handbook of Colour. 2nd ed., Methuen and Co., Ltd., London. 243 pp.

LANDRY, J.-F. 2007. Taxonomic review of the Leek Moth genus *Acrolepiopsis* (Lepidoptera: Acrolepiidae) in North America. Canad. Entomol. 139: 319–353.

LANDRY, J-F. AND B. LANDRY. 1994. A technique for setting and mounting Microlepidotpera. J. Lepid. Soc. 48: 205–227.

LEE, S.M. AND BROWN, R.L. 2008a. Revision of Holarctic Teleiodini (Lepidoptera: Gelechiidae). Zootaxa 1818: 1–55.

LEE, S.M. AND BROWN, R.L. 2008b. Phylogenetic relationships of Holarctic Teleiodini (Lepidoptera: Gelechiidae) based on analysis of morphological and molecular data. System. Entomol. 33: 595–612.

MOSHER, E. 1916. A classification of the Lepidoptera based on characters of the pupa. Bull. Ill. State Lab. Nat. Hist. 12: 159 pp.

NAZARI, V. AND LANDRY, J.-F. 2012. Gnorimoschemini fauna of Alberta (Lepidoptera: Gelechiidae). The Alberta Lepidopterists' Guild. 129 pp. PDF available at http://www.biology.ualberta.ca/uasm/alg/downloads/ALG%20Bursary%202012%20Final%20Report%20Nazari_Landry_2012.pdf (accessed 4 Dec 2013).

POVOLNÝ, D. 1991. Zur Bionomie und ökonomischen Bedeutung der Tribus Gnorimoschemini (Lepidoptera, Gelechiidae). Acta Univer. Agricul. Brno, Facul. Agron. 39: 275–291.

POWELL, J.A. 1980. Evolution of larval food preferences in Microlepidoptera. Ann. Rev. Entomol 25: 133–159.

POWELL, J.A. AND POVOLNÝ, D. 2001. Gnorimoscheminae moths of coastal dune and scrub habitats in California (Lepidoptera, Gelechiidae). Hol. Lepid. 8 (Supplement 1): 1–53.

POWELL, J.A. AND OPLER, P.A. 2009. Moths of Western North America. University of California Press, Berkeley and Los Angeles, xiii + 369 pp.

PRIEST, R.J. 2007. Photographing Leaf Mining Larvae and Adults. News. Michigan Entomol. Soc. 52: 27–28.

RATNASINGHAM, S. AND HEBERT, P.D.N. 2007. BOLD: The Barcode of Life Data System. (http://www.barcodinglife.org). Mol. Ecol. Notes 7: 355–364.

RATNASINGHAM, S. AND HEBERT, P.D.N. 2013. A DNA-based registry for all animal species: The Barcode Index Number (BIN) System. PLOS ONE 8: e66213. doi:10.1371/journal.pone.0066213

SIMPSON, T.B., P.E. STUART, AND B.V. BARNES. 1990. Occasional Papers of the Huron Mountain Wildlife Foundation, No. 4: Landscape Ecosystems and Cover Types of the Reserve Area and Adjacent Lands of the Huron Mountain Club. Huron Mountain Wildlife Foundation, Big Bay, Michigan.

STEHR, F.W. 1987. Immature Insects. Stehr, F.W. Editor. Kendall/Hunt Pub. Co., Dubuque, Iowa. xiv + 754 pp.

TAMURA, K., PETERSON, D., PETERSON, N., STECHRER, G., AND NEI, M. 2011. MEGA5: Molecular evolutionary genetics analysis using maximum likelihood, evolutionary distance and maximum parsimony methods. Mol. Biol. Evol. 28: 2731–2739.

VOSS, E.G., AND REZNICEK, A.A. 2012. Field manual of Michigan Flora. University of Michigan Press, Ann Arbor. 1008 pp.

WOLFF, N.L. 1964. The Lepidoptera of Greenland. Meddelelser Om Grønland 159: 1–74, plates I-XXI.

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