

New species and records of the Nearctic Epermeniidae (Lepidoptera)

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Two Nearctic Epermeniidae are described as new species: *Epermenia falcata* from USA (Washington), and *E. canadensis* from Canada (Alberta). The male of *E. infracta* Braun, 1926 is described for the first time, and this species is re-established as valid. *Epermenia strictelloides* Gaedike, 1977 is a new junior synonym of *E. infracta*. The variability of the valva in *Ochromolopis ramapoella* (Kearfott, 1903) is recognized and illustrated. For other species new North American localities are recorded. A key and checklist to the Nearctic Epermeniidae are given.

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Introduction

According to Dugdale et al. (1998), the Epermeniidae is the only family in the superfamily Epermenioidea. The phylogenetic relationships with other superfamilies within the Apoditrysia remain uncertain. Probable autapomorphies are: hind tibia with stiff bristles, forewing at dorsum with tufts of raised scales, larval submentum with posterior protuberance, prothoracic prespiracular L group bisetose, pupa without spines, abdominal segments I–IV immovable, segment IX with characteristic paired lateral pits. The family presently contains 119 described species in ten genera, and is known from all faunal regions (Gaedike 1996). Life histories indicate that the larvae live in leaf mines (sometimes only in the first instars), or that they skeletonize leaves and seeds, mainly of the Apiaceae (=Umbelliferae). There are a few host records from other plant families, including Araliaceae, Celastraceae, Epacridaceae, Fabaceae (=Leguminosae), Loranthaceae, Olacaceae, Pittosporaceae and Santalaceae. Some characters have been identified which define the presently known genera, but phylogenetic relationships between the genera remain uncertain. Autapomorphies are only known for some genera (e.g. the presence of abdominal pockets in the genus *Epermenia*, and the presence of a gnathos in the genus *Gnathifera*). The family is

divided into the subfamilies Epermeniinae and Ochromolopinae (autapomorphies for this are the presence of 11 veins in the forewing instead of 12 in the Epermeniinae, and the ventral branches of the apophyses anteriores being broadened).

From the Nearctics previously eleven species in three genera were known, revised by Gaedike (1977).

The examination of unidentified Nearctic Epermeniidae resulted in additional records for some previously known species, and the discovery of two unknown species, which are described below. The discovery of the previously unknown male of *Epermenia infracta*, and the examination of additional female specimens made it necessary to reinstate this taxon as species. Further the material made it possible to demonstrate the variability in the shape of the male genitalia of *Ochromolopis ramapoella*.

Material and methods

The specimens in this study were borrowed from the collections of the Canadian National Insect Collection in Ottawa (CNC), the National Museum of Natural History, Smithsonian Institution, Washington D.C. (USNM) and the Finnish Museum of Natural History in Helsinki (FMNH); some duplicates are retained in the Deutsches Entomologisches

Institut, Müncheberg (DEI).

Genitalia were dissected and mounted on microscopic slides in Euparal using standard preparation methods (Robinson 1976).

For light microscopic imaging stacks of digital source photos were taken with the KY-F75U camera (JVC) attached to a Leica Z6 macroscope. The final colour images with extended focus were computed using the software Auto-Montage 5.01. (Syncrosopy). Line drawings were made with a RME 5 compound microscope (Askania) at a magnification of 160× (ocular 16×, objective 10/0.25) with help of a graticule.

Taxonomy

Revised checklist of Nearctic Epermeniidae

Epermenia Hübner, [1825]

Subgenus *Calotripis* Hübner [1825]

E. imperialella Busck, 1906

Canada: Manitoba; Alberta (Pohl et al. 2005);

USA: Pennsylvania

E. falcata sp. n.

USA: Washington

E. canadensis sp. n.

Canada: Alberta

E. stolidota (Meyrick, 1917)

USA: Wyoming; Colorado; Utah; Arizona

E. californica Gaedike, 1977

USA: California

E. albapunctella Busck, 1908

Canada: Nova Scotia; Ontario; Northwest Territories; British Columbia; USA: New York; Delaware; Pennsylvania; North Carolina; Illinois Godfrey et. Al. 1987); Minnesota; Washington; Oregon; California

E. cicutella (Kearfott, 1903)

alameda Braun, 1923

Canada: Nova Scotia; New Brunswick; Quebec; USA: New York; New Jersey; New Hampshire; Delaware; Michigan; Wyoming; Oregon; California

E. pimpinella Murtfeldt, 1900

USA: South Carolina; Ohio; Illinois (Godfrey et al. 1987); Arkansas; Oklahoma

E. lomatii Gaedike, 1977

Canada: Alberta (Pohl et al. 2005); USA: Oregon; Washington; California

E. infracta Braun, 1926, stat. rev.

strictelloides Gaedike, 1977, **syn. n.**

Canada: Alberta; USA: Colorado; Oregon, California

Ochromolopis Hübner, [1825]

O. ramapoella (Kearfott, 1903)

metrothetis Meyrick, 1921

bidentata Braun, 1926

Canada: Quebec; Ontario; Manitoba; Saskatchewan; Alberta (Pohl et al. 2005); USA: New Jersey; Pennsylvania; Ohio; Illinois (Godfrey et al. 1987); Michigan; South Dakota; Wyoming; Colorado; Utah; Arizona

Parochromolopis Gaedike, 1977

P. floridana Gaedike, 1977

USA: Florida

P. mexicana Gaedike & Becker, 1989

Mexico: Chiapas

Key for the Epermeniidae of the Nearctic Region

Adults: external characters

1. Primary colour brown, yellowish-ochre or cream-coloured 2
 - Primary colour from dark grey to brown-grey 8
2. Forewing with tufts of raised scales 3
 - Forewing without tufts of raised scales *Epermenia imperialella*
3. Wingspan not more than 16 mm 4
 - Wingspan 18–22 mm 6
4. Wingspan 10–12 mm 5
 - Wingspan 16 mm, forewing cream-coloured, the oblique broad streak grey-brown *E. canadensis*
5. Forewing brown, with dark oblique streak, fringe black at termen *E. californica*
 - Forewing with oblique brown streak, scales on second segment of palpi stick out *Parochromolopis floridana*
6. Forewing with oblique dark-brown streaks *E. falcata*
 - Veins on forewings marked with light scales, without oblique dark streaks *E. stolidota*
7. Forewing with two tufts of raised scales, on discus with three black dots *Ochromolopis ramapoella*
 - Forewing with four tufts of raised scales, the fourth often very small 8
8. Wingspan 10–11 mm; forewing dark grey with dark brown pattern *E. pimpinella*
 - Wingspan more than 12 mm 9
9. Forewing dark grey brown, except the pale base and a pale area before apex, a small white dot at $\frac{2}{3}$ *E. albapunctella*
 - Forewing without small white dot 10
10. Forewing on discus with three very small black dots *E. cicutella*
 - Forewing with one or two black dots 11

11. Forewing with two small black dots on discus *P. mexicana*
 – Forewing with only one small black dot 12
 12. Forewing nearly white in basal quart, stark contrasting *E. infracta*
 – Forewing not rich in contrast *E. lomatii*

Male genitalia

1. Valva without ampulla, with processes on costal edge, or with separate costal arm 2
 – Valva with ampulla 4
 2. Valva with separate costal arm ... *O. ramapoella*
 – Valva with processes on costal edge 3
 3. Process on costal edge finger-shaped *P. mexicana*
 – Two hook-shaped pointed processes on costal edge *P. floridana*
 4. Tegumen edged on inner and outer margin ... 5
 – Tegumen hardly edged 7
 5. Costal edge of valva curved, ampulla strongly curved *E. infracta*
 – Costal edge of valva hardly curved, ampulla nearly straight 6
 6. Terminal edge of sacculus with distinct margin, ending in a blunt tooth *E. falcata*
 – Terminal end of sacculus narrow, strongly sclerotized, somewhat hook-shaped *E. canadensis*
 7. Cornutus small, less than ½ of the length of aedeagus *E. lomatii*
 – Cornutus longer 8
 8. Terminal edge of sacculus ending in pointed tooth 9
 – Terminal edge of sacculus ending in blunt tooth 10
 9. Cornutus nearly as long as aedeagus, slightly curved, basically with longitudinal sclerotizations *E. albapunctella*
 – Cornutus ¾ of the length of aedeagus, without longitudinal sclerotizations *E. imperialella*
 10. Costal edge of valva near transtilla curved *E. californica*
 – Costal edge of valva not curved 11
 11. Cornutus more than ½ of the length of aedeagus, apically cutted *E. cicutaella*
 – Cornutus ½ of the length of aedeagus, apically rounded *E. pimpinella*

Female genitalia

Female genitalia from *E. falcata* and *E. canadensis* unknown.

1. Ventral parts of the forked apophyses enlarged 2
 – Ventral parts of the forked apophyses not

- enlarged 4
 2. Bursa without signum, first half of ductus with rows of small thorns *O. ramapoella*
 – Bursa with one or more signa 3
 3. Bursa with one large elliptical signum *P. mexicana*
 – Bursa with two signa *P. floridana*
 4. Ductus bursae without any thorn-shaped sclerotizations 5
 – Ductus bursae with various thorn-shaped sclerotizations 6
 5. Ostium bursae with ring-shaped sclerotization *E. stolidota*
 – Ostium bursae with enlarged sclerotization, margin of VIII segment around ostium more stronger sclerotized *E. imperialella*
 6. Ductus bursae with many rows of very small, blunt thorns *E. infracta*
 – The thorns enlarged, with broad base, asymmetrically pointed *E. cicutaella*
 – The thorns small, irregular situated, pointed, outer margin of VIII segment more stronger sclerotized *E. californica*
 – The thorns medium-sized, irregular situated, pointed *E. pimpinella*

Epermenia (Calotripis) falcata sp. n.

Figs 1, 4–5

Type material. Holotype ♂, United States: “Dryden Wash.[ington state], 5–16–[19]42, E.C. Johnston”; “Gen.präp. [genitalia slide] Gaed.[ike] Nr. 5477”; “Holotypus ♂, *Epermenia falcata* sp. n. det. R. Gaedike 2006”; (CNC). **Paratype** 1 ♂, same dates, but genitalia slide Nr. 5266 (CNC).

Description

Male (Fig. 1). Wingspan 18–20 mm; head and palpi yellowish-ochre, the outside of the palpi with darker scales, the underside of the first segment of the antenna pale ochre, the dorsal part darker; thorax yellowish-ochre, tegulae at the base overlaid with brown scales; forewing yellowish-ochre, intermixed with yellowish-brown and brown scales; at dorsum dark brown tufts of raised scales at ¼, and before ½, and a diminutive tuft after ½; three very small dark brown tufts near the base of fringe from ¾ to the apex, a sickle-shaped dark brown streak on fringe from apex to dorsum; the first fourth of the costa dark brown and a large patch at ½, reaching the cell; above the first tuft a broad brown strip, oblique apically to cell; a pale brown streak from costa oblique to the second tuft, in the middle with a darker brown patch; some very small dark brown dots along costa from ¾ to apex, and on the base of cell a very small



Figs 1–3. *Epermenia* species. – 1, *E. falcata*, holotype ♂: USA, Washington, Dryden; 2, *E. canadensis*, holotype ♂: Canada, Alberta; 3, *E. infracta* ♀ USA, Colorado.

black dot; fringes white; hindwing white, shining, fringes white.

Female unknown.

Male genitalia (Figs 4–5). Uncus and tegumen typical for the genus, tegumen rounded with a more strongly sclerotized margin, fused medially; valva large, transtilla rectangular, ampulla slightly curved, pointed, border strongly sclerotized, terminal edge of sacculus with distinct margin, ending in a blunt tooth, from base oblique to the border of ampulla a more strongly sclerotized strip; aedeagus as long as valva, slightly curved, cornutus nearly half the length of aedeagus, basally pointed, ending bluntly.

Distribution

USA: Washington state.

Remarks

Distinguishable from the similarly yellowish *E. imperialella* Busck, 1906 by the narrower wings, the pattern of brown and dark brown scales, and by the dark brown tufts of raised scales on dorsum. In the male genitalia the tegumen of *imperialella* lacks a strongly sclerotized margin, and the length of the cornutus is more than half of the length of the aedeagus.

Etymology

The name refers to the shape of the dark streak near the apex of the forewing (Latin: falcatus, adjective = sickle-shaped).

Epermenia (Calotripis) canadensis sp. n.

Figs 2, 6–7

Type material. Holotype ♂, Canada, “Alberta, Cypress Hills Prov. Park, 7.viii.1982, J. F. Landry; at blacklight, spruce-fir forest”; “Gen.präp. [genitalia slide] Gaed.[ike] Nr.5258”; “Holotypus ♂, *Epermenia canadensis* sp. n. det. R. Gaedike 2006” (CNC).

Description

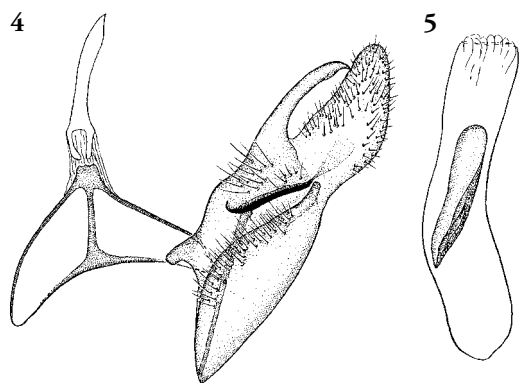
Male (Fig. 2). Wingspan 16 mm; head pale greyish-yellow, inner surface of palpi pale yellow, outer surface overlaid with greyish scales; thorax and tegulae with the same colouration as the head; forewing cream-coloured; at dorsum on $\frac{1}{3}$ and $\frac{1}{2}$ each a tuft of raised scales, costa overlaid with grey-brown scales; from the first tuft to the costa an oblique broad grey-brown streak, narrowest at dorsum; apically, on cell, and above dorsum, yellow-ochre; a yellow-ochre patch before apex; between it and the streak, at $\frac{2}{3}$, at end of cell, a very small black dot, a second black dot at $\frac{1}{3}$ near base of cell; fringes pale yellow, with a somewhat sickle-shaped dark line from apex to dorsum; hindwing pale grey.

Female unknown.

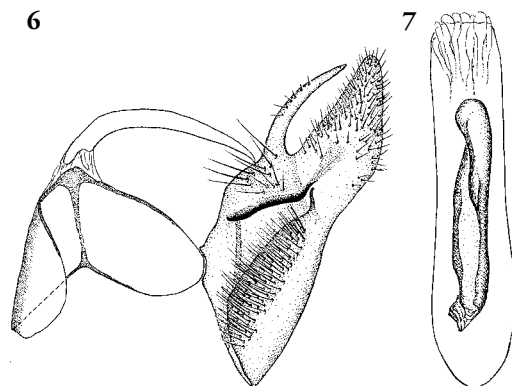
Male genitalia (Figs 6–7). Uncus long, pointed, tegumen medially strongly sclerotized, prolonged apically, and basally; valva long, narrow, transtilla very small; ampulla slightly bent, pointed, border of valva strongly sclerotized, confluent with cucullus; terminal end of sacculus narrow, strongly sclerotized, somewhat hook-shaped; aedeagus longer than valva, cornutus more than half length of the aedeagus, laterally more strongly sclerotized, with rounded tip.

Distribution

Canada: Alberta.



Figs 4–5. *Epermenia falcata*, male genitalia: holotype, slide Nr. 5477 (one valva removed, aedeagus (5) separate)



Figs 6–7. *Epermenia canadensis*, male genitalia: holotype, slide Nr. 5258 (one valva removed, aedeagus (7) separate).

Remarks

Distinguishable from the similarly coloured *E. imperialella* by the more greyish-yellow colouration, the two tufts of raised scales, and the two small black dots; it differs from *falcata* by its smaller size, the two small black dots, and the oblique broad streak. *Epermenia canadensis* differs from *imperialella* by having strongly sclerotized margins of the tegumen, and a narrower valva. *E. canadensis* differs from *falcata* by the longer cornutus.

Etymology

Named after the country in which the type was collected.

Epermenia (Calotripis) albapunctella Busck

Examined material. Canada: Nova Scotia: 1♂, Petite Riviere, 9.viii.1935, bred from *Aralia hispida*, leg. J. McDunnough (CNC); Ontario: 1♂, Ottawa, Pinhey Forest, 19.iv.1987, leg. P.T. Dang (CNC); 4♀, Ottawa, 5., 22., 30.v.1934, leg. C.H. Young (CNC; DEI); Northwest Territories: 9♂, 1♀, Aklavik, 10., 28.vi.1931, leg. Bryant (USNM; DEI); British Columbia: 1♀, Vernon, 27.vii.1927, leg. E.P. Venables (CNC). USA: Delaware: 1♀, Newark, 29.vii.1967, leg. D.F. Bray (USNM); Pennsylvania: 1♂, Dimock, 30.vii.1987, leg. D.F. Bray (USNM); North Carolina: 1♂, Jackson Co., 5 km SE Balsam, 1331 m, 9.-12.vii.1974, leg. D.R. & M. Davis (USNM); Oregon: 1♀, Baker, Spring Creek, 11.vi.1962, leg. J.H. Baker (USNM).

Distribution. First records for Canada: Nova Scotia, Ontario, Northwest Territories and USA: Pennsylvania and North Carolina.

Epermenia (Calotripis) cicutaella Kearfott

Examined material. Canada: Nova Scotia: 1♂, 1♀, Petite Riviere, 8.viii.1935, ex l. *Ligusticum scoticum* [*Recte: scoticum*], leg. J. McDunnough (CNC); 1♀, Parrsboro, 21.viii.1944, bred from Lovage [= *Ligusticum scoticum*], leg. J. McDunnough (CNC); New Brunswick: 1♂, Bathurst, 24.vii.1939, bred from *Ligusticum*, leg. J. McDunnough (CNC). USA: Delaware: 1♂, Newark, Glen Farms, 10.vii.1979, leg. D.F. Bray (USNM); Michigan: 2♂, 2♀, Chippewa Co., Tyen, 20.-24.vii.1946, leg. R. J. Priest (USNM; DEI); 2♂, 2♀, Isabella Co., 8., 9., 11., 12.vii.1979, leg. R. J. Priest (USNM; DEI); Oregon: 1♀, 5400', 28 mi SE Joseph, 20.vi.1970, leg. J. F. G. Clarke (USNM).

Distribution. First records for Canada: Nova Scotia and New Brunswick and USA: Delaware, Michigan and Oregon.

Epermenia (Calotripis) pimpinella Murtfeldt

Examined material. USA: Oklahoma: 1♂, Sequo. Co., Tenkiller Lake, 3 mi W Blackgum, 6.-9.vii.1979, leg. D. & M. Davis (USNM); Ohio: 2♂, 1♀, Cincinnati, O. B 594, 31.vii.1919, leg. Anette F. Braun (USNM; DEI).

Distribution. First record for USA: Oklahoma.

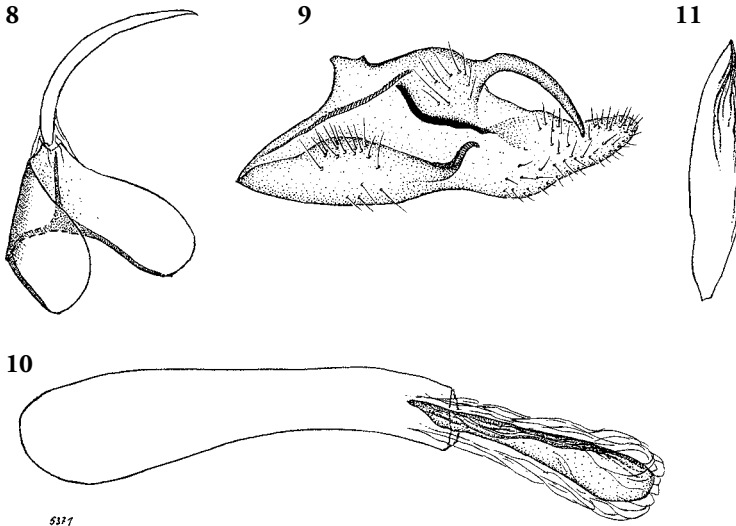
Epermenia (Calotripis) infracta Braun stat. rev.

Figs 3, 8–17

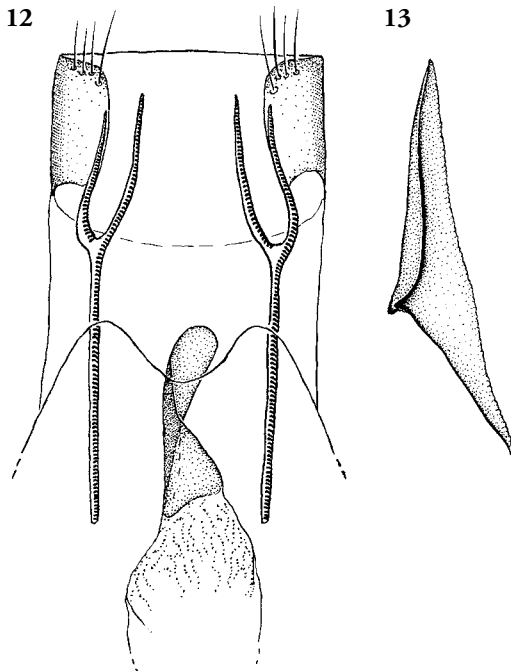
Epermenia (Calotripis) infracta Braun, 1926: 49, Canada: Alberta/Nordegg.

Epermenia strictelloides Gaedike, 1977: 305; USA: Oregon, syn. n.

Examined material: Canada: Alberta: 2♂, 2♀, Nordegg, 20., 23., 30.vi.1921, leg. J. McDunnough (CNC; DEI); 1♀,



Figs 8–11. *Epermenia infracta*, male genitalia: Canada, Alberta, slide Nr. 5371 (8, uncus and tegumen; 9, valva; 10, aedeagus); same locality, slide Nr. 5241 (11, cornutus (variability)).



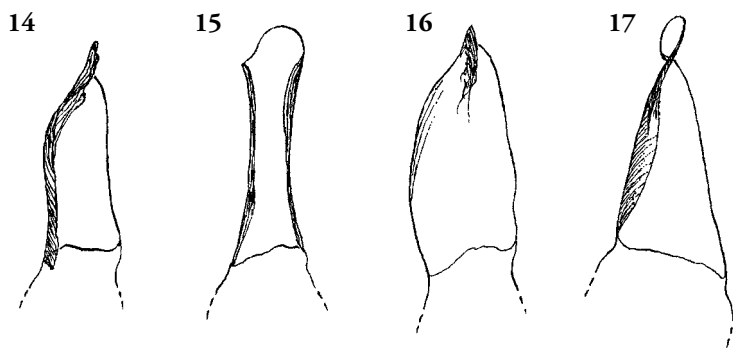
Figs 12–13. *Epermenia infracta*, female genitalia, Canada, Alberta, slide Nr. 5370, signum (Fig. 13) separate.

Waterton Lakes, 8.viii.1928, leg. J. McDunnough (CNC). USA: Colorado: 1♂, 4♀, Clear Creek Co., Arapaho Ntl For. West Chicago Creek Cmpgd, 2985 m, 14.viii.1993, leg. B. Landry (CNC; DEI); 1♂, Alamosa Co., Great Sand Dunes, Mosca Creek, 8200', 25 June 1982, leg. R.W. Hodges (USNM); 2♂, 4♀, California, Inyo Co., E. Sierra Nevada, Glacier Lodge, 15 km W Big Pine, 2600 m, 21.-27.vii. 1998, leg. L. Kaila & S. Timonen (FMNH).

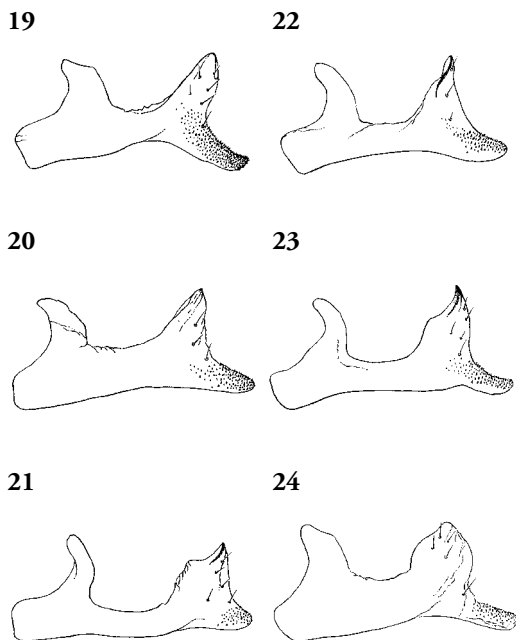
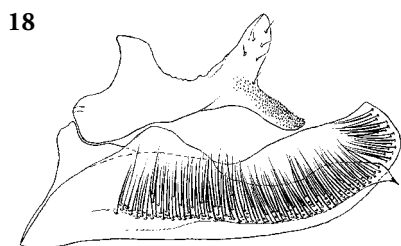
Redescription

Adult (Fig. 3). Wingspan 15–16 mm; head and palpi dark grey, mixed with whitish scales, inner surface of palpi and head below palpi lighter, thorax and tegulae dark grey, forewing dull white with dark grey drawing; costa with numerous short dark grey strigulae, an oblique transverse dark grey band from dorsum et $\frac{1}{2}$ to dorsum at $\frac{1}{3}$, a second oblique band from costa near apex to dorsum at $\frac{3}{4}$; basal area of forewing dark grey mixed with brownish; a small black spot on the disk at $\frac{3}{4}$; at dorsum tufts of raised scales before $\frac{1}{3}$ (the largest), before and after $\frac{1}{2}$, and at $\frac{3}{4}$ (the smallest); around apex with black scales; on fringe two parallel darker lines, beginning at apex; hindwing pale grey.

Male genitalia (Figs 8–11). Uncus long, narrow, with pointed tip, tegumen basally and medially with strongly sclerotized margin, valva with a short transtilla; valva with costa curved, ampulla hook-shaped, pointed, the border strongly sclerotized, confluent with cucullus; terminal end of sacculus, curved, narrow, pointed, with a narrow, oblique, strongly sclerotized strip from base of the valva to costa; aedeagus longer than valva, cornutus $\frac{1}{2}$ of length of aedeagus,



Figs 14–17. *Epermenia infracta*, female genitalia: variability in shape of ostium, depending on way of preparation. – 14, USA, Colorado, slide Nr. 5294; 15, USA, Colorado, slide Nr. 5243; 16, Canada, Alberta, slide Nr. 5240; 17, USA, Colorado, slide Nr. 5369.



Figs 18–24. *Ochromolopis ramapoella*, male genitalia. – 18, valva, USA, Illinois, slide Nr. 1472; 19–24, variability of the costal arm of valva. 19, USA, Illinois, slide Nr. 1472; 20, USA, New York, slide Nr. 1451; 21, Canada, Alberta, slide Nr. 5246; 22, same locality, slide Nr. 5239; 23, USA, Colorado, slide Nr. 5238; 24, USA, Colorado, slide Nr. 3576.

with pointed base, and rounded tip; lateral shape variable (see Fig. 11).

Female genitalia (Figs 12–17). Previously Gaedike (1977: Fig. 62) figures an image of female genitalia of the holotype. The examination of more specimens allows to illustrate some variability. Posterior margin of VIII. Sternit impressed, ostium and first part of ductus bursae strongly sclerotized (see Figs 14–17); with many rows of very small, blunt thorns; signum large, subtriangular, with one margin more strongly sclerotized.

Distribution

Canada: Alberta; USA: Colorado (new record); Oregon and California (new record).

Remarks

Examination of previously unknown males of this species shows that *Epermenia infracta* Braun is a valid taxon, whilst *E. strictelloides* Gaedike, 1977 is a junior synonym of this not of *E. strictella* Wocke, 1867 (correction to Gaedike 1993: 97–98).

Ochromolopis ramapoella (Kearfott)

Examined material: Canada: Quebec: 1♂, 1♀, Pontiac, chute de Luskville, 8.vi.1991 MVL, leg. J.-F. Landry (CNC); 1♀, d. r. Gatineau, Aylmer 48 Notre Dame, 13.vi.1990, MVL, leg. J.-F. Landry (CNC); Ontario: 1♂, Bobcaygeon, 31.v.'81, leg. J. McDunnough (CNC); Saskatchewan: 1♂, Killdeer, 26.v.1980, leg. R. Hooper (CNC); 1♂, Indian Head, 4.vii.1924, leg. J.J. DeGryse (CNC); Manitoba: 2♂, 1♀, Aweme, 4.vi.1921, leg. N. Criddle (Paratypes of *Epermenia bidenata* Braun) (CNC); 2♂, 2 mi. W. Stockton, 5.vi.1958, leg. C.D.F. Miller (CNC); 1♀, Grand Valley campgr., 8 km W Brandon, 25.vi.1983, leg. J.-F. Landry (CNC); Alberta: 2♂, 10 km W Drumheller, Red Deer River, badlands, 12.vi.1982, leg. J.-F. Landry (CNC, DEL); 1♂, Lost R. Valley, 10 km S. Onefour, 49°01' N, 110°27' W, 3.viii.1983, leg. J.-F. Landry (CNC). USA: Ohio: 1♀, Beaver Pond, Adams Co., 2.v. [19]30, leg. A.F. Braun

(USNM); Michigan: 2 ♂, Allegan Co., Allegan St. Game Area, 2.vii.1992, MVL, leg. B. & J.-F. Landry (CNC); 2 ♂, 1 ♀, Isle Royale, 3., 6.vii.1957, leg. R.W. Hodges (USNM); 1 ♂, Emmet Co., Wilderness State Pk., 30.vi.1992, leg. J.F. & B. Landry (CNC); Illinois: 1 ♂, Putnam Co., 16 May 1969, leg. M. O. Glean (USNM); Wyoming: 1 ♂, Mammoth, Yellowstone Pk., 19.v.1912, leg. D. Lindsley (CNC); Colorado: 8 ♂, Boulder, Silver Saddle Motel, 5500', 7., 10., 14., 16.vi.1961, leg. M. R. MacKay (CNC, DEI); 2 ♂, Alamosa Co., Zapata Ranch, 9500', 27 June 1982, leg. Ronald W. Hodges, USNM; Arizona: 1 ♂, Cochise Co., Chiricahua Mts, Whitetail Canyon creek, 1400 m, 22.iv.1996, leg. L. Kaila & J. Kullberg (FMNH).

Remarks. First records for Canada: Quebec, Ontario and Saskatchewan and USA: Michigan and Wyoming.

Examination of specimens mentioned above shows that the shape of the costal arm of valva is somewhat variable, illustrated in Figs 18–24.

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