Revision of the *Scopula cajanderi* (Lepidoptera: Geometridae, Sterrhinae) species group with description of a new species

Pasi Sihvonen[1]

Finnish Museum of Natural History, Division of Entomology, PO Box 17 (P Rautatiekatu 13), University of Helsinki, FIN-00014 Helsinki, Finland

The Canadian Entomologist **133**: 467–486 (2001)

Abstract—The Holarctic *Scopula cajanderi* (Herz) species group is revised on the basis of external and genitalic characters. The taxa included in the species group are *Scopula cajanderi* (Herz, 1903 [not 1904]) (= the Palaearctic *Scopula elwesi sajanensis* Prout, 1935 **syn.nov.**, = the Palaearctic *Scopula elwesi achlyoides* Prout, 1935 **syn.nov.**, = the Nearctic *Scopula septentrionicola* McDunnough, 1939 **syn.nov.**), thus making *S. cajanderi* Holarctic; *Scopula mustangensis* Yazaki, 1995; and *Scopula aegrefasciata* **sp.nov.** Lectotypes are designated for the following species which were described from more than one specimen without holotype designation: *S. cajanderi*, *Scopula anaitaria* (Herz, 1903), and *S. e. achlyoides*. The systematic position of *Scopula elwesi elwesi* Prout, 1922 within the genus *Scopula* is uncertain. A key to the species is presented with illustrations of the adults and genitalia, and a distribution map is presented for all taxa. An examination of the biogeography of *S. cajanderi* suggests that the Wisconsinan and Sartan glaciations may have played a part in the origin of the disjunct populations.

Sihvonen P. 2001. Révision du groupe d'espèces *Scopula cajanderi* (Lepidoptera : Geometridae, Sterrhinae) et descriptioin d'une nouvelle espèce. *The Canadian Entomologist* **133** : 467–486.

Résumé—La révision du groupe d'espèces *Scopula cajanderi* (Hertz), un ensemble holarctique, est basée sur des caractères externes et des caractères génitaux. Le groupe comprend d'abord *Scopula cajanderi* (Hertz 1903 [pas 1904]) (= le taxon paléarctique *Scopula elwesi sajanensis* Prout, 1935, **syn.nov.**, = le taxon paléarctique *Scopula elwesi achlyoides* Prout,1935 **syn.nov.**, = le taxon néarctique *Scopula septentrionicola* McDunnough, 1939 **syn.nov.**), qui devient donc une espèce holarctique; le groupe est formé aussi de *Scopula mustangensis* Yazaki, 1995 et de *Scopula aegrefasciata* **sp.nov.** Des lectotypes ont été désignés pour les espèces suivantes, décrites à partir de plusieurs spécimens et pour lesquelles il n'y a pas eu de choix d'holotype : *S. cajanderi*, *Scopula anaitaria* (Hertz) et *S. elwesi achlyoides*. La position systématique de *S. elwesi elwesi* Prout, 1922 au sein du genre *Scopula* demeure incertaine. On trouvera ici une clé d'identification des espèces, ainsi que des illustrations des adultes et des genitalia et la carte de répartition de chaque taxon. Un examen de la biogéographie de *S. cajanderi* permet de croire que les glaciations du Wisconsinien et du Sartan peuvent être en partir responsables de la discontinuité entre les populations de cette espèce.

[Traduit par la Rédaction]

Introduction

The species of the genus *Scopula* Schrank are moderate in size relative to other Sterrhinae (Lepidoptera: Geometridae). The distribution of the genus is cosmopolitan

[1] E-mail: pasi_sihvonen@hotmail.com.

and includes species of both forested and open habitats. The latter characteristic has led to its success at higher latitudes and altitudes (Holloway 1997). Some taxa of the genus *Scopula* in these habitats are poorly known in the Holarctic area. Their distributions are poorly known, as most studies treat exclusively either Palaearctic (Prout 1913) or Nearctic faunas (Prout 1938; McGuffin 1967; Covell 1970), with one exception (Viidalepp 1996).

Based on phenetic, rather than phylogenetic evidence, I have defined the *Scopula cajanderi* (Herz, 1903) species group to include species with a dentate, slightly concave postmedian line on the forewing, the male hind tibia with two apical spurs and without hair tuft, and the male 8th sternite widest at the cephalad margin, which is concave medially, and with cerata being short or absent. These species have similar ecological requirements, inhabiting tundra, northern boreal, and high-altitude montane areas.

Acidalia (*Scopula*) *cajanderi* Herz, 1903 and *Acidalia* (*Scopula*) *anaitaria* Herz, 1903 were described from specimens collected by a Finnish botanical expedition to Russian Yakutia in 1901 (Cajander 1903; Herz 1903). In 1922, *Scopula elwesi* Prout was described from a specimen collected from the Altai Mountains and Prout (1922, p 262) noted "There is a bare possibility that *anaitaria* Herz, described from the ♀ and unknown to me, may prove the same, but this is extremely unlikely both from the description and from the locality (Lena-Vilyui District)." Later, *A. anaitaria*, which had been described from the females from the type locality of *A. cajanderi*, became synonymized with *A. cajanderi* by Püngeler (reference unknown, cited in Prout 1913, p 57, and Prout 1935, p 35). Prout (1913, 1935) treated these taxa based on literature descriptions only. In 1935, two new subspecies were described for *Scopula elwesi*, namely *Scopula elwesi sajanensis* Prout and *Scopula elwesi achlyoides* Prout, on the basis of one and two individuals, respectively. In 1939, *Scopula septentrionicola* McDunnough was described from the Yukon Territory in North America and diagnosed as being related to the Holarctic *Scopula frigidaria* (Möschler). The distribution of *S. septentrionicola* in the Nearctic was later found to be boreo-montane (Covell 1970). In his checklist, Viidalepp (1996), without analysis, listed *S. cajanderi* as polytypic with five subspecies: *S. c. cajanderi*, *S. c. elwesi*, *S. c. sajanensis*, *S. c. achlyoides*, and *S. c. septentrionicola*.

In 1995, *Scopula mustangensis* Yazaki was described from male specimens collected from Nepal. Yazaki (1995) noted that the 8th sternite cerata, features typical of the genus *Scopula*, were lacking altogether and left the systematic position of the species within the genus *Scopula* uncertain. During my visit to the British Museum of Natural History in 1999, I found an undescribed taxon among the *Scopula praecanata* Staudinger, 1896 specimens which is related to the *S. cajanderi* species group.

The aim of this study is to present a systematic review of the above-defined boreal and boreo-montane Palaearctic and Nearctic taxa of the genus *Scopula*. In addition, effects of the Wisconsinan and Sartan glaciations on the biogeography of *S. cajanderi* are discussed to permit a better understanding of the present-day distribution of this taxon.

Material and methods

The bulk of studied material was collected from various places in Russia by Finnish–Russian expeditions during 1982–1997. A separate expedition to the Yukon Territory was conducted in 1985. Type material for the following species was studied: *S. cajanderi* Herz, *Scopula anaitaria* Herz, *Scopula elwesi elwesi* Prout, *S. e. sajanensis* Prout, *S. e. achlyoides* Prout, *S. septentrionicola* McDunnough, *S. mustangensis* Yazaki, *Scopula aegrefasciata* **sp.nov.**, and *S. praecanata* Staudinger.

Genitalia were prepared following methods described by Hardwick (1950), and male vesica were everted by injecting them with a hypodermic syringe through the caecum. The terminology for the genitalia follows Klots (1970) and Covell (1970). Most of the genitalia and abdominal skins are stored in glycerol tubes attached to the specimens, some of which are mounted in euparal. The negatives of adult and genitalia were scanned into a computer using a 35-mm scanner, processed with Adobe Photoshop™, and the final plates were compiled using CorelDraw™ software.

To delimit the studied taxa, I have used the phylogenetic species concept of Nixon and Wheeler (1990) which is more applicable than the biological species concept of Mayr (1942, 1963) when working with museum material.

Conventions

Localities and specimen data

Information regarding the holotypes, paratypes, lectotypes, and paralectotypes examined is provided in the Type material sections, and all non-type material examined is provided in the Non-type material sections. Specimen data are provided as they appear on labels. Localities are listed under country and province or territory. A forward slash with a space on each side separates lines, and a semicolon separates specimens.

Repository abbreviations

Specimens have been studied from the following institutions (acronyms after Arnett *et al.* 1993, except ZIN):

AMNH	American Museum of Natural History, New York, United States.
BMNH	Natural History Museum, London, United Kingdom.
CNCI	Canadian National Collection of Insects, Ottawa, Ontario, Canada.
IBPV	Institute of Biology and Pedology, Russian Academy of Sciences, Vladivostok, Russia.
MNHU	Museum für Naturkunde der Humboldt-Universität zu Berlin, Berlin, Germany.
NSMT	National Science Museum (Natural History), Tokyo, Japan.
ZIN	Zoological Institute, Russian Academy of Sciences, St. Petersburg, Russia.
ZMH	Zoological Museum, University of Helsinki, Helsinki, Finland.

Citation of information on primary type labels

Information from each label is enclosed within double quotes, a forward slash with a space on each side separates lines, a comma before double quotes indicates a separate label, information enclosed by square brackets provides further details about the specimen or the label, and a semicolon separates specimens.

Scopula cajanderi species group

Diagnosis

Medium-sized species; wingspan 17–28 mm. Postmedian fascia on forewing dentate, slightly concave. Male hind tibia unswollen, without hair tuft but with two apical spurs; 8th sternite wide basally, concave medially, cerata short or absent. Boreal or boreo-montane species in Northern Hemisphere. Species included: *S. cajanderi*, *S. mustangensis*, *S. aegrefasciata*.

Only males are included in the key because females of *S. mustangensis* and *S. aegrefasciata* are unknown and often sexual dimorphism is apparent in the genus *Scopula*.

Key to species of the *S. cajanderi* species group (external)

1. Only postmedian line of forewing well developed, wing colour almost uniform beige–brown . . . . . *S. aegrefasciata* **sp.nov.** (Figs. 2J–2K)
— All transverse lines of forewing well developed, wing colour different 2
2. Wings suffused with orange, light yellow spots on termen below . . . *S. mustangensis* (Figs. 2H–2I)
— Wings gray–brown (males), whitish (females), without spots on termen below . . . . . *S. cajanderi* (Figs. 2A–2G, 6)

Key to species of the *S. cajanderi* species group (male genitalia)

1. Aedeagus flattened dorsoventrally, grooved laterally . . . . . *S. cajanderi* (Figs. 5A–5D)
— Aedeagus round, without grooves laterally 2
2. Vesica without diverticulum distally, aedeagus almost straight . . . . . *S. mustangensis* (Fig. 5E)
— Vesica with diverticulum distally, aedeagus slightly curved ventrally . . . . . *S. aegrefasciata* **sp.nov.** (Fig. 5F)

Scopula cajanderi (Herz)

(Figs. 1, 2A–2G, 3A, 4A–4E, 4H–4L, 5A–5D, 6)

Acidalia cajanderi Herz 1903: 13; Prout 1913: 66. Type locality: Russia, Yakutia.
Acidalia anaitaria Herz 1903: 14; Prout 1913: 57.
Scopula cajanderi Prout 1934*b*: 192; Prout 1935: 35; Vojnits, 1977: 171; Müller 1996: 233; Scoble 1999: 843.
Scopula anaitaria Prout 1934*b*: 184 (*cajanderi* f.?); Prout 1935: 35 (♀, as synonym of *cajanderi* Herz); Scoble 1999: 843 (as synonym of *cajanderi*).
Scopula elwesi sajanensis Prout 1935: 35, Pl. 4, Fig. h; Scoble 1999: 847. **Syn.nov.**
Scopula elwesi achlyoides Prout 1935: 35; Scoble 1999: 847. **Syn.nov.**
Scopula septentrionicola McDunnough 1939: 189; McGuffin 1967: 19, Figs. 39–41, 90; Covell 1970: 174, Figs. 23, 44, 65, 93, 94; Hodges *et al.* 1983: 101; Poole 1996: 684; Scoble 1999: 863. **Syn.nov.**
Scopula cajanderi subsp. *cajanderi*: Viidalepp 1996: 55.
Scopula cajanderi subsp. *sajanensis*: Viidalepp 1996: 55.
Scopula cajanderi subsp. *achlyodes* [misspelling]: Viidalepp 1996: 55.
Scopula cajanderi subsp. *septentrionicola*: Viidalepp 1996: 55.

Material examined

Type material

***Acidalia cajanderi* Herz. Lectotype:** "Lectotype [red rectangle label]," "Ust Vilvi [Russia, Yakutia, Vilui River] 23. / 7.[19]01 B. Poppius / nedre [lower] reg. sub- / alpina," "Mus. Zool. H:fors / Spec. typ. No. 7194 / Acidalia ca- / janderi [not italics] Herz" male, present designation, the same specimen as in Herz 1903, judged by the posture of antennae and by the external appearance. **Paralectotypes:** "Paralectotype [red rectangle label]," "3242," "ORIG.," "Lena med. Ust / Vilvi. Mont. Ver. / hojansk 22.7. / 1901 reg. silvat. / B. Poppius," "Mus. Zool. H:fors / Spec. typ. No. 7190 / Acidalia ca- / janderi [not italics] Herz ♂," "Acidalia / kajanderi [not italics] / n.sp. Herz" male; "Paralectotype [red rectangle label]," "3314," "ORIG.," "Ust Vilvi 23.7. / 1901 B. Poppius / torr sluttn., nedre / regio subalp.," "Mus. Zool. H:fors / Spec. typ.

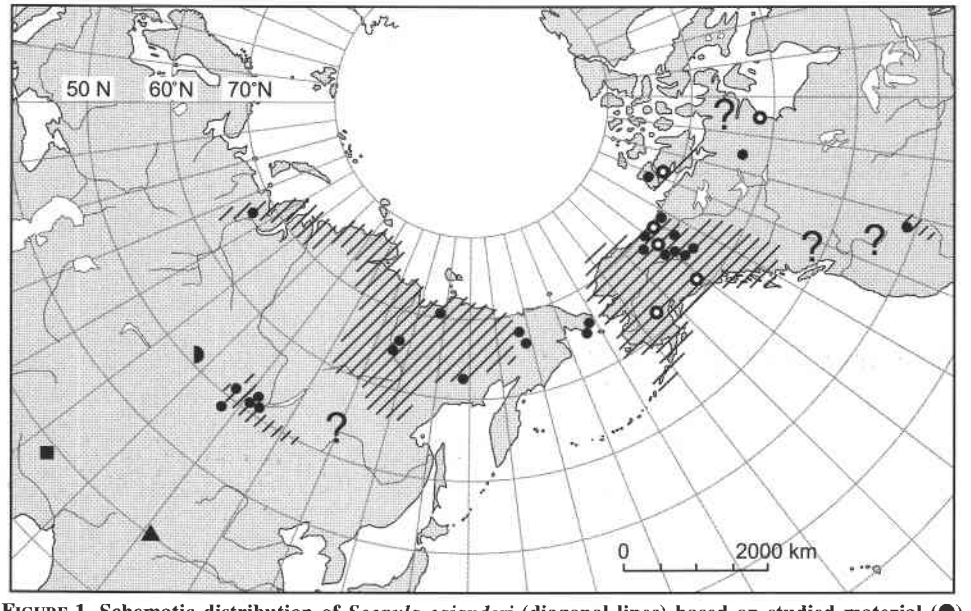


FIGURE 1. Schematic distribution of *Scopula cajanderi* (diagonal lines) based on studied material (●) and the literature (○); and the material examined of *Scopula mustangensis* (■), *Scopula aegrefasciata* (▲), and *Scopula elwesi elwesi* (◗). Question marks indicate possible suitable habitats of *S. cajanderi* but no records. Literature sources include McGuffin (1967), Covell (1970), Viidalepp (1996), and Vojnits (1977).

No. 7191 / Acidalia ca- / janderi [not italics] Herz ♂" male; "Paralectotype [red rectangle label]," "Ust Vilvi 23.7.[19]01 / nedre regio subalp. / B. Poppius," "ORIG.," "Toniwer [uncertain, handwritten]," "Mus. Zool. H:fors / Spec. typ. No. 7192 / Acidalia ca- / janderi [not italics] Herz" male; "Paralectotype [red rectangle label]," "ORIG.," "Ust Vilvi 23. / 7.1901. B. Poppius," "Mus. Zool. H:fors / Spec. typ. No. 7193 / Acidalia cajan- / deri [not italics] Herz" male; "Paralectotype [red rectangle label]," "Ust Vilvi 23.7.19[01]," "B. Poppius," "Genitalia prep. / No. 93 / Pasi Sihvonen" male (ZMH).

***Acidalia anaitaria* Herz. Lectotype:** "Lectotype [red rectangle label]," "Ust Vilvi [RUSSIA, Yakutia] 23.7. [19]01. / Torr. sluttn i nedre [dry slope on lower] / subalp. reg. / B. Poppius," "Mus. Zool. H:fors / Spec. typ. No. 7188 / Acidalia / anaitaria [not italics] ♀ Herz," "ORIG.," "acidalia / anaitaria [not italics] / Herz. n.sp. / abbilden" female, present designation, the same specimen as figured in Herz (1903), judged by the posture of one and lack of the other antenna and by the external appearance. **Paralectotype:** "Paralectotype [red rectangle label]," "3315," "ORIG.," "Ust Vilvi 23.7.[19]01 / torrsluttn. i nedre / subalp. reg. / B. Poppius," "Mus. Zool. H:fors / Spec. typ. No. 7189 / Acidalia anai- / taria [not italics] Herz ♀," "Genitalia prep. / No. 118 / Pasi Sihvonen" female (ZMH).

***Scopula elwesi sajanensis* Prout. Holotype:** "Type [round label with red margin]," "Munko Sardyk / Sajan mont. [RUSSIA, Burjatia]," "146.," "91.21," "Joicey / Bequest. / Brit. Mus. / 1934–120," "Scopula / elwesi / sajanensis [not italics] / ♂ Prout.," "BMNH / Geometridae / genitalia slide / No. 20096" male (BMNH). **Lectotype:** "Lectotype [round label with blue margin]," "Schawyr / Tannuola or. [MONGOLIA] / Juni 2500m," "91.21," "147.," "Joicey / Bequest. / Brit. Mus. / 1934–120," "Scopula / elwesi / achlyoides [not italics] / ♂ Prout," "BMNH / Geometridae / genitalia slide / No. 20095" male, present designation (BMNH).

***Scopula septentrionicola* McDunnough. Holotype:** "HoloTYPE / Scopula / septentrionicola [not italics] McD / No. 4478 [red rectangle label]," "Nation Riv / Yukon Terr. [CANADA] / Lat. 65°30′ / Long. 141° / D. D. Cairnes / July 29, 1912," "C. N. C. / Genitalia slide ♂ / GEO 3370," " SLIDE / Sc No. 12a." male (CNCI).

Non-type material

***Scopula cajanderi* Herz.** Ninety-five males (23 genitalia) and 29 females (13 genitalia). **RUSSIA.** Polar Urals, 66°55′N, 65°10′E / Krasnyi Kamen 500–1000 m / mt. tundra 8.vii.1994 / Jalava, Kullberg, and Koponen, 33 males, 2 females (ZMH). **Yakutia:** Mont. Verhojansk / 22–24.vii.1901 / B. Poppius, 4 males (ZMH); Jana: Adista do / Iktizhaja 12.vii / Bunge & Tol [19]85, 1 male (ZMAS). **Burjatia:** Irkut [Irkutsk], 1 male (ZMH); Irkut [Irkutsk], 2 males; Tunka [Tunkinskie Belki, East Sajan], 1 male (ZMAS); 10 km NW Mondy / Khulugaisha Mtn., 2300 m / 51°80′N, 101°10′E / 8.vii.1984 / Y. Tschistjakov, 2 males (IBPV). **Magadan:** 62°50′N, 148°15′E / nr. Susuman 750 m / steppe slope/larix 15.vii.1997 / Jalava and Tammaru, 12 males. **Chukchi:** 64°55′N, 172°30′W / 45 km Provideniya / Skalistyi Kryaz 200 m and Pestsovaya River valley, 12–15.vii.1991 / K. Mikkola, 15 males, 13 females; 64°55′N, 172°30′W / 55 km NNE Provideniya / Mt. Nirvinei, 270–500 m, 21.vii.1991 / K. Mikkola, 1 female; 65°30′N, 168°50′E / Upper Anadyr River / 700 m, 20–23.vii.1989 / K. Mikkola, 4 females (ZMH); Chukotka / Bilibino, 68°8′N, 166°33′E, 200–1000 m / 19.vii.1960 / A. Kurentzov, 2 males, 2 females (IBPV). **CANADA. Yukon Territory:** 64°45′N, 138°15′W / Ogilvie Mtns., 1200 m, 6.vii.1985 / K. Mikkola, 13 males; 65°06′N, 138°15′W / Ogilvie Mtns., 1000 m, 8.vii.1985 / Dempster Hwy. km 155, bog / K. Mikkola, 1 male; 65°35′N, 139°35′W / Ogilvie Mtns., 1500 m / Nahoni Range, 8.vii.1985 / K. Mikkola, 1 female (ZMH); Dempster Hwy. km 155 / 6.vii.1985, 1350 m / J.D. Lafontaine, 1 male; 66°06′N, 136°37′W, 2000 ft (1 ft = 0.3048 m) / Richardson Mtns. / 13.vii.[19]82 / M. Wood, 1 male; British Mts., Firth River / 24–25.vii.1956 / E.F. Cashman, 1 male, 1 female. **Northwest Territories:** Masik River, Banks Island / 4–18.vii [19]68 / W.R.M. Mason, 2 males, 3 females; Kidluit Bay, Richards Island / 30.vii.1948 / W.J. Brown, 1 female; Ford Lake, 63°11′N, 107°19′W / 3.vii.1966 / G.E. Shewell / M.T.S. Gravity Survey Camp, 1 male (CNCI). **UNITED STATES. Alaska:** Arctic Village, 15.vii.1964 / W.C. Hanson, 1 male. **Utah:** Timberline, Leidy Peak / Daggett–Uintah Counties / 10 700 – 11 200 ft / 22.vii.1963. / F.P. and M. Rindge, 3 males (AMNH).

Diagnosis

Scopula cajanderi is medium-sized with marked sexual dimorphism and variable appearance. The postmedian line of *S. cajanderi* is dentate (almost smooth in *S. aegrefasciata*), and wings are not suffused with orange and are without light spots in the termen below (with orange suffusion and beige spots in the termen below in *S. mustangensis*) (Figs. 2, 6). The length of the antennal cilia of *S. cajanderi* is about 0.15 mm (about 0.25 mm in *S. mustangensis* and *S. aegrefasciata*) (Fig. 3). The 8th sternite of *S. cajanderi* is with short cerata (absent in *S. mustangensis* and *S. aegrefasciata*) (Fig. 4), and the aedeagus is about 1.4 mm long (about 1.0 mm in *S. mustangensis* and about 1.1 mm in *S. aegrefasciata*), flattened dorsoventrally, and grooved laterally (round with a smooth surface in *S. mustangensis* and *S. aegrefasciata*). The vesica of *S. cajanderi* possesses a large distal diverticulum (absent in *S. mustangensis*) and dentate sclerotization at the point of origin of the ductus ejaculatorius (weak, irregular sclerotization in *S. mustangensis* and *S. aegrefasciata*) (Fig. 5).

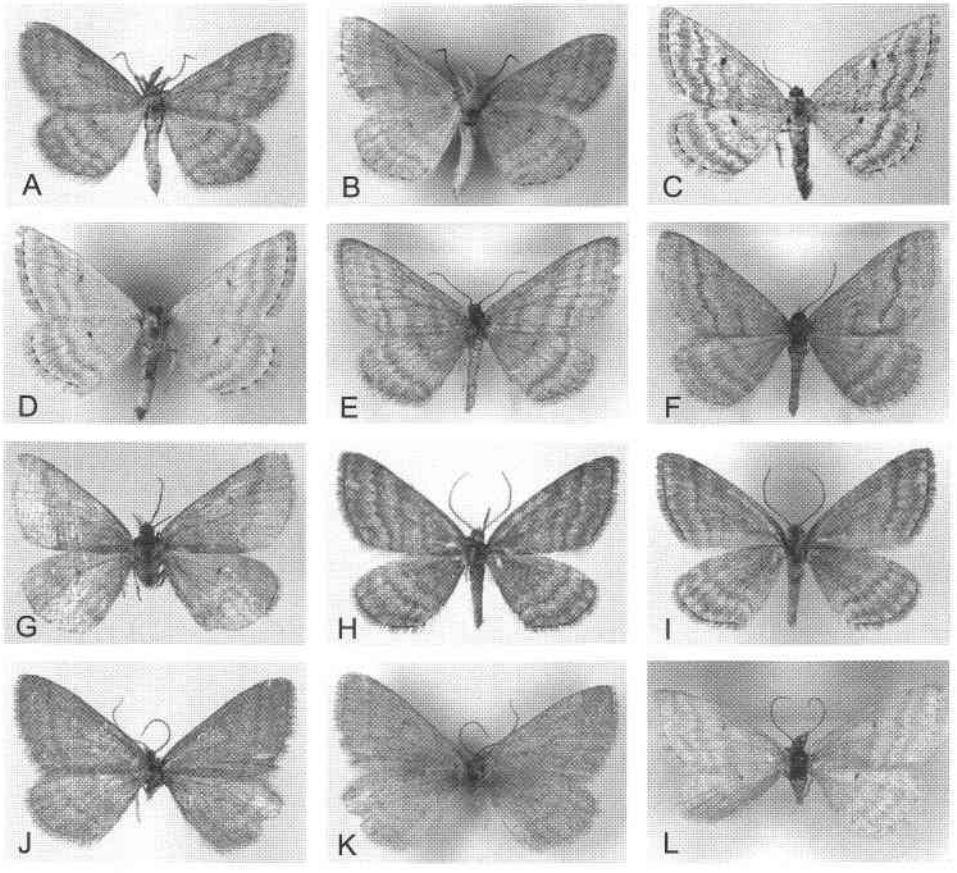


FIGURE 2. **External appearance of *Scopula cajanderi* and synonymized taxa (A–G), *Scopula mustangensis* (H, I), *Scopula aegrefasciata* sp.nov. (J, K), and *Scopula elwesi elwesi* (L): (A) Lectotype male of *S. cajanderi*; (B) lectotype male of *S. cajanderi* below; (C) lectotype female of *Scopula anaitaria*; (D) lectotype female of *S. anaitaria* below; (E) holotype male of *Scopula elwesi sajanensis*; (F) lectotype male of *Scopula elwesi achlyoides*; (G) holotype male of *Scopula septentrionicola*; (H) paratype male of *S. mustangensis*; (I) paratype male of *S. mustangensis* below; (J) holotype male of *S. aegrefasciata* sp.nov.; (K) holotype male of *S. aegrefasciata* sp.nov. below; (L) holotype of *S. e. elwesi*. Figures 2E, 2F, and 2L courtesy of BMNH.**

Dark, gray–brown males of *S. cajanderi* may resemble *S. frigidaria*. In *S. cajanderi*, the postmedian line is dentate on both wings (smooth in *S. frigidaria*), and the male hind tibia is not swollen and possesses two apical spurs (hind tibia swollen, spurs absent in *S. frigidaria*). The sacculus of the male genitalia tapers gradually towards the tip (distinct inner shoulder about one third from the distal end in *S. frigidaria*), and the anterior margin of the 8th sternite is concave (convex in *S. frigidaria*). The corpus bursae of the female genitalia is without a signum (with signa in *S. frigidaria*).

Description

Body and wings. Wing expanse: male 21.2–27.8 mm; female 18.5–23.6 mm. Sexual dimorphism apparent, females with lighter ground colour on wings, body, and legs. Labial palpi erect, with three segments, length about 1.0 mm, long hair-scales mixed with rough, appressed scales. Proboscis about 2.0–2.6 mm long. Front smoothly

scaled. Interantennal ridge, scape, and collar rough-scaled, gray, light-brown, brown, brown–black, or orange, or a mixture of these; white suffusion on few females. Ratio of frons diameter to eye diameter variable, usually frons wider. Male antennae coloured above as head, fasciculate, length of cilia about 0.1 mm, female antennae filiform, length of cilia about 0.04 mm. Thorax with appressed scales, together with hair-scales in patagia, thorax brown to brown–black, mixed with light brown or gray (males) or with white (females), thorax below with long hair-scales; patagia J-shaped. Legs light tan, with gray, brown-gray, brown, brown-black or orange (males) or with whitish scales (females), femur with hair and appressed scales; male hind tibia not compressed, with a pair of terminal spurs, female hind tibia with 2 + 2 spurs. Abdomen coloured as thorax, usually posterior margin of sternites with lighter scales. Wings of males gray–brown, scattered with black–brown scales; whitish in females, lightly scattered with black–brown scales; transverse lines of forewing straight, slightly darker than ground colour (males) or contrasting sharply (females); postmedian line slightly concave medially, dentate; antemedian line and median fascia often obscure; subterminal line not always seen, expressed in concentrations of brown–black scales; terminal line complete or broken at vein endings, brown–black; fringe with mixed brown and black–brown (males) or whitish and black–brown (females); discal spots usually vertically elongated, sometimes large, vestigial or absent in some specimens; lines continued on hind wing except antemedian line; wings coloured below as above, with lines and discal spots, but more diffuse than above. Tympanal organs strongly sclerotized; ansa narrowest at base, widens first, tapers again before wide hammer-shaped apex; male with paired accessory tympana ventrally, divided more or less medially, width variable in relation to tympanal organs, lacking in female. Tergites and sternites variably sclerotized.

Male genitalia. About 1.5 mm long, 0.8 mm wide, ovoid; socii pointing caudally, about length of posterior margin of tegumen between them, fused or separate at base, few setae at distal end. Posterior margin of tegumen between socii medially elongate, tegumen sclerotized. Valvula bent ventrally at about half length, distal end covered with setae, blunt ending; sacculus narrow at base, widens above it, tapering evenly inwards, terminally pointed, strongly sclerotized at distal end, ventral area of base covered with incurved seta. Juxta elongate, laterally bent inward, posterior margin concave, sclerotized; lateral arms of juxta rather narrow at base, with lobes on ventral side at about half length, medially forming a shallow U- or V-shaped trough; transtilla U-shaped, bent cephalad laterally; on ventral side of vinculum pocket that opens caudally, in few specimens almost absent; anterior margin narrow, V- or U-shaped. Aedeagus about 1.4 mm long, dorsoventrally flattened, slightly bent ventrally, longitudinally grooved on lateral and ventral sides between ductus ejaculatorius and apex, caecum round, apex on dorsal side medially pointed. Vesica opens ventrally, grooved, with two dorsolateral diverticula on proximal end, medially concave, wider at base, narrowing towards distal part; small sclerotization at distal end of vesica, sheet-like, apex with three to eight teeth on both sides, divided about halfway; ductus ejaculatorius opens from the distal end of dentate sclerotization. Sternite eight with anterior margin of base sharply angled medially and concave, base widest at anterior end, cerata short, symmetrical or asymmetrical, sometimes rudimentary, mappa membranous, posterior margin evenly round, with medial apex or concave.

Female genitalia. About 2.3 mm long (1.9–2.6 mm). Papillae anales rounded, fused dorsally, line of fusion visible, covered with distally projected setae, longest in distal part, arranged in irregular manner, surface with longitudinal grooves. Apophyses anteriores about 0.4 mm long, basally wider; apophyses posteriores about 0.7 mm long, usually about twice as long as apophyses anteriores, angled ventrally near base. Sterigma concave, lamella antevaginalis with two concentric, variably sclerotized,

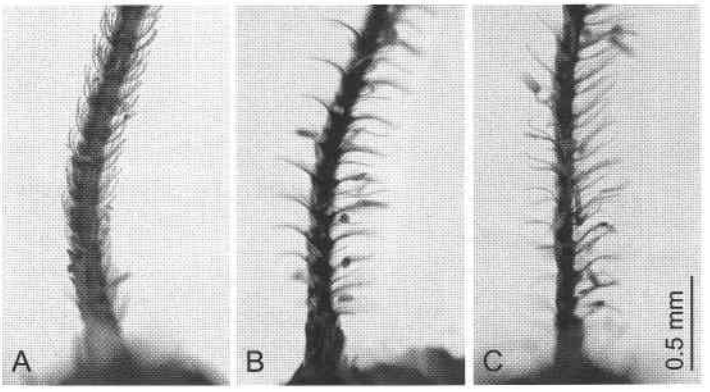


FIGURE 3. Male antennae of *Scopula cajanderi* species group: (A) paralectotype of *S. cajanderi*; (B) paratype of *Scopula mustangensis*; (C) holotype of *Scopula aegrefasciata*. Scale bar = 0.5 mm for all figures.

separate lunular plates, posterior one with two circular extensions on both lateral ends, cephalocaudally flattened medially; ostium bursae in 7th sternite, oval, about 0.1 mm in diameter; colliculum concave, cephalad of ostium bursae; forming sharp-ending projections on dorsolateral sides, dorsally membraneous, distal part of ductus bursae wider and ventrolaterally near juncture with corpus bursae slightly angled to left; ductus seminalis opens from left ventrolateral side at about 45° angle, approximately one-third length of ductus bursae. Corpus bursae membraneous, variable in shape and size, usually ovoid, may have small sacs (diverticula) on ventral or lateral sides, without signum.

Variation

The sharpness, thickness, and colour of the transverse lines and the amount of black scales varies on the wings. The ground colour varies between and within populations, and even ground colour of an individual specimen may vary between wings. As a result, specimens from a single population are similar to each other, but there are no clear geographic trends.

In the Palaearctic, the ground colour of the specimens ranges from gray–black (Polar Urals, Fig. 6C; East-Sajan, Fig. 2F) to gray–brown (Lena area, Fig. 6A; Irkutsk; East Sajan; Magadan, Fig. 6B) to gray to gray–black or yellow–brown (Chukchi Peninsula, Figs. 6E, 6I). In the Nearctic, the ground colour varies from light gray to yellow–brown (Ogilvie Mountains, Yukon Territory, Fig. 6D) to dark gray (Northwest Territories, Figs. 4F, 4H) to dark brown with orange suffusion (Utah, Fig. 6G).

Specimens from Magadan, Russia (Fig. 6B), are similar to the type of *S. e. sajanensis* from the Sajan Mountains (Fig. 2E) with orange suffusion in the head and collar and wide median fascia and postmedian line. I have not found diagnostic differences in the male genitalia from the type of *S. cajanderi*, but this may constitute a separate taxon. No females were available for study.

A few specimens from the Beringia and the British Mountains, Yukon Territory, have shiny wings, unlike the others (Figs. 6D, 6E). The smallest specimens are from the Polar Urals, Russia, and the Northwest Territories, Canada, and the largest are from the Lena area and Magadan, Russia. There is little variation in the male and female genitalia.

Biology

Flight period is from late June until early August (n = 133). Most records are from the first half of July. Immature stages are unknown. Species inhabit polar areas and high-altitude areas on mountains farther south. In Russia, it is found on the steppe slopes of Magadan, on rocky mountain slopes in the Polar Urals (J Jalava, personal communication), and on lowlands near the Lena River in the Lena district.

Distribution

Holarctic (Fig. 1). In the Palaearctic, from the Polar Urals to the Taimyr Peninsula, northeast Siberia, Magadan, Burjatia, Chukchi Peninsula, and northern Mongolia. In the Nearctic, from Alaska to western and northern Yukon Territory, northern British Columbia, and high-elevation areas in Utah. It might also be found in suitable habitats in the Stanovoi Mountains, Burjatia; northern Northwest Territories; the Canadian Arctic Archipelago; and high-elevation areas in the Rocky Mountains south to Utah.

Remarks

The date of publication of *A. cajanderi* Herz is 1903, not 1904 as cited elsewhere (Herz 1903, p 13; Prout 1934*b*; Müller 1996; International Commission on Zoological Nomenclature (ICZN) 1999, Article 21). This confusion is caused by an erroneous citation in the *Zoological Record* (Sharp 1904, pp 39, 271), where the year of the original publication is not mentioned and therefore it has been assumed to be 1904. The publication year is cited correctly in other literature sources (Field 1906, p 366; International Catalogue of Scientific Literature 1906*a*, p 234; International Catalogue of Scientific Literature 1906*b*, p 669).

The external appearance of *S. cajanderi* has a tendency to vary with the collection site. Because there are specimens that make intrapopulational and interpopulational differences inconsistent, I prefer not to recognize subspecies, whereas Viidalepp (1996) does. In my opinion, the similar traits in external appearance result from adaptation to local environmental factors, as seen in northern and high-altitude specimens which tend to be hairier and darker (Figs. 2F, 6F, 6G). The structures of internal genitalia exhibit no such variation in concordance with collection locality. The distributions of *S. e. achlyoides* and *S. e. sajanensis* are not allopatric on the basis of additional available material, and by definition of subspecies they cannot be recognized as such (Wilson and Brown 1953).

Biogeography

The geographic distribution of *S. cajanderi* appears disjunctive with many allopatric populations. Below are a few comments on the biogeography of *S. cajanderi*.

The extent of the Sartan glaciers in Siberia remain contentious, but many researchers agree that there were discontinuous and unglaciated areas across Asia (*e.g.*, Grosswald and Hughes 1995; Rutter 1995). According to the reconstructed vegetation maps, these discontinuous, unglaciated areas were mainly tundras (Grichuk 1984). It is possible, therefore, that populations of *S. cajanderi* in the Palaearctic were already isolated from one another at the time of the Sartan glaciation. For instance, specimens from northern Russia, namely from the Polar Urals (Fig. 6C) and the Lena area (Fig. 6A), tend to be different in size and colour, possibly as a result of their different origins. The biogeographical connections of the Sajan Mountains (Russia) and Magadan (Russia) populations of *S. cajanderi* are unknown, but these geographically isolated populations are similar (Figs. 2E, 6B).

Specimens from both sides of the Beringia are similar to each other but different from the other northern material. This may be explained by the contiguous Bering land bridge that connected eastern Siberia to the unglaciated parts of Alaska and Yukon Territory. According to pollen samples, the land-bridge vegetation was tundra with a mosaic of vegetation types (Colinvaux 1981; Young 1982). If the habitat was suitable for *S. cajanderi*, the Beringia may have acted as a glacial refugium.

The only known southern population of *S. cajanderi* in the Nearctic is in Utah, in an area that was cut off from the Beringia during the Wisconsinan glaciation by the Laurentide and Cordilleran ice sheets (Dyke and Prest 1987). Whether the Utah population is of preglacial origin and a glacial relict or of postglacial origin is uncertain. If the species is eventually found elsewhere in the Rocky Mountains, this may give clues about the dispersal and origin of this seemingly disjunct population. Populations of the blackfly *Simulium baffinense* Twinn (Diptera: Simuliidae) in Utah and Colorado have been considered as relict (Schwert and Ashworth 1988).

***Scopula mustangensis* Yazaki**

(Figs. 1, 2H, 2I, 3B, 4F, 4M, 5E)

Scopula mustangensis Yazaki, 1995: 3, Pl. 97, Figs. 14 and 539; Scoble 1999: 856.
Type locality: Nepal, Mustang.

Material examined

Type material

***Scopula mustangensis*. Paratypes:** "PARATYPE / *Scopula mustangensis* / Yazaki, 1995 [yellow rectangle label]," "NEPAL / Inner Himal / Dhaulagiri, Mustang / Dhung 3,300 m / 24.vi.1994 / M. S. Limbu leg.," "♂ Genitalia Slide No. KY-1948" male; "PARATYPE / *Scopula mustangensis* / Yazaki, 1995 [yellow rectangle label]," "NEPAL / Inner Himal / Dhaulagiri, Mustang / Dhung 3,300 m / 24.vi.1994 / M. S. Limbu leg.," "Genitalia prep. / No. 283 / P. Sihvonen" male (NSMT).

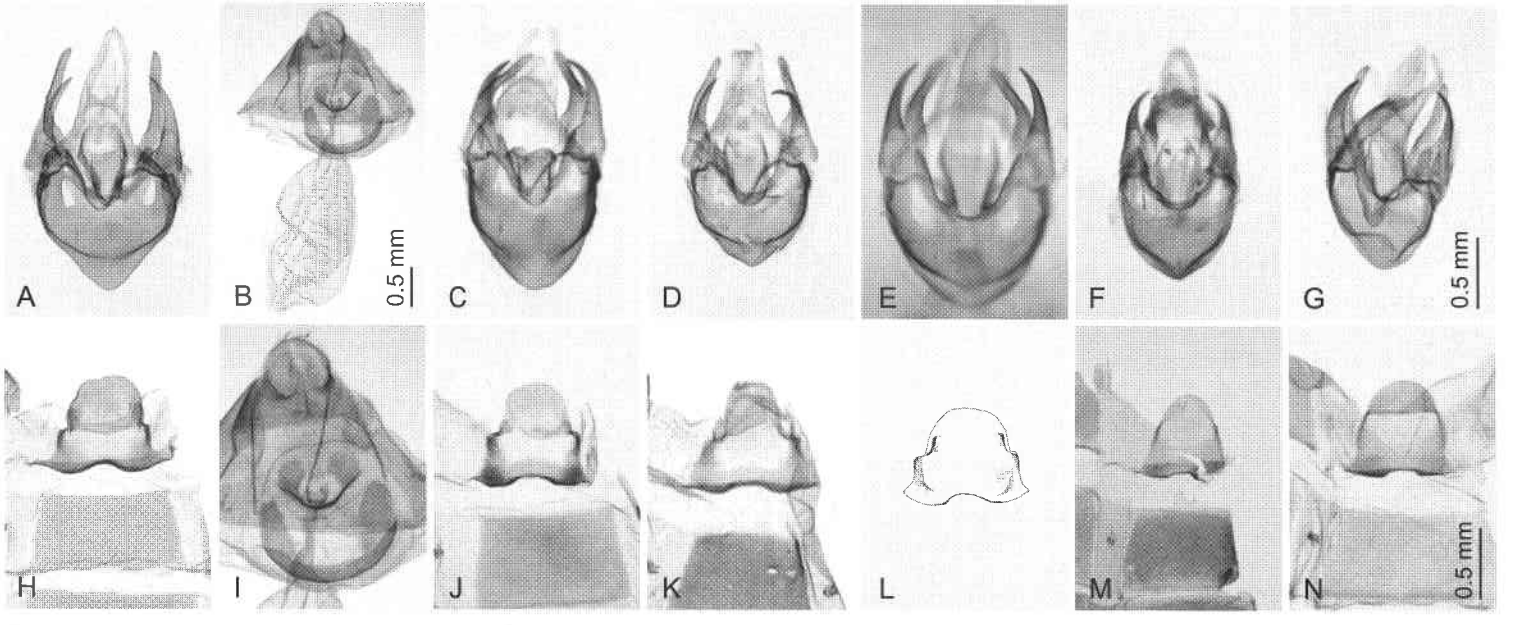
Diagnosis

Wings of *S. mustangensis* are heavily suffused with orange and dark brown (almost uniform dark brown in *S. aegrefasciata*), the terminal area of forewing is almost uniformly coloured orange brown and with beige spots on the termen below (termen without spots in *S. cajanderi*) (Fig. 2), and the length of the antennal cilia is about 0.3 mm (about 0.15 mm in *S. cajanderi*) (Fig. 3). The male genitalia of *S. mustangensis* is about 1.0 mm long, 0.6 mm wide (about 1.5 mm long and 0.8 mm wide in *S. cajanderi*), and the 8th sternite is without cerata (short cerata in *S. cajanderi*) (Fig. 4). The aedeagus is without grooves, about 1.0 mm long (with grooves, about 1.4 mm in *S. cajanderi*), and it is almost straight (slightly turned ventrally in *S. aegrefasciata*). The vesica of *S. mustangensis* is without a distal diverticulum (with distal diverticulum in *S. aegrefasciata*) (Fig. 5).

Description

Body and wings. Wing expanse: 17–22 mm. Frons and head above mixed with brown, black, and orange appressed scales; labial palpi with long beige, dark brown, and orange hair-scales, only few appressed scales on dorsal surface; antenna of male fasciculate, dark brown and beige dorsally, black ventrally, proximal row of cilia basally fused, length of cilia about 0.22 mm. Collar beige and dark brown; dorsally between

FIGURE 4. Male and female genitalia (without male aedeagus) of *Scopula cajanderi* and synonymized taxa (A–E, H–L), *Scopula mustangensis* (F, M), and *Scopula aegrefasciata* sp.nov. (G, N): (A) paralectotype male of *S. cajanderi* (genitalia prep. PS 93); (B) paralectotype female of *Scopula anaitaria* (genitalia prep. PS 118); (C) holotype male of *Scopula elwesi sajanensis* (genitalia prep. BMNH 20096); (D) lectotype male of *Scopula elwesi achlyoides* (genitalia prep. BMNH 20095); (E) holotype male of *Scopula septentrionicola* (genitalia prep. C.N.C. 3370); (F) paratype male of *S. mustangensis* (genitalia prep. PS 283); (G) holotype male of *S. aegrefasciata* sp.nov. (genitalia prep. BMNH 20099); (H) paralectotype male of *S. cajanderi* (genitalia prep. PS 93); (I) paralectotype female of *S. anaitaria* (genitalia prep. PS 118); (J) holotype male of *S. e. sajanensis* (genitalia prep. BMNH 20096); (K) lectotype male of *S. e. achlyoides* (genitalia prep. BMNH 20095); (L) holotype male of *S. septentrionicola* (genitalia prep. C.N.C. 3370); (M) paratype male of *S. mustangensis* (genitalia prep. PS 283); (N) holotype male of *S. aegrefasciata* sp.nov. (genitalia prep. BMNH 20099). Scale bar = 0.5 mm for all figures.



collar and thorax few creamy white, wide, appressed scales; patagia with beige and dark brown appressed scales, few long, beige, dark brown, and orange hair-scales distally; thorax and abdomen coloured as patagia, slightly tinted towards orange. Legs beige, mixed with dark brown or orange, proximally with long hair-scales, mesothoracic and metathoracic tibia with two apical spurs, not swollen, without hair tuft. Forewing grayish brown above, strongly suffused with orange, giving brownish appearance on base of wing, median fascia and postmedian lines and on terminal area; costa of forewing brownish. Antemedian line and median fascia weakly developed, expressed as concentrations of brown and orange scales, almost straight, postmedian line dentate, concave medially, subterminal line grayish, diffuse; terminal line complete, brown; fringes mixed with orange, brown, and beige; discal dots weak or absent, brown, elongated. Hind wing pale yellowish to beige with brown suffusion, orange scales lighter than on forewing; lines as on forewing, except antemedian line absent, brownish; basal third suffused with brown with long light yellowish hair-scales; terminal line brown; fringe lighter than on forewing. Wings below light yellowish to orange, strongly suffused with brown, only postmedian line strong, others diffused; in terminal area between vein endings lighter areas on both forewings and hind wings; terminal line more prominent on underside; fringe as above. Tympanal organs rather large, not meeting ventrally, ansa narrow at base, widest at basal third above base, narrow between widened apex and basal third, accessory tympanum roundish. Tergites 2–8 sclerotized, caudal margin slightly differentiated; sternites 3–8 undifferentiated.

Male genitalia. About 1.0 mm long, 0.6 mm wide; socii slightly curving dorsally, dorsoventrally widened basally, distal two thirds covered with short setae; tegumen weakly sclerotized, caudal margin round; transtilla U-shaped. Valva with valvula slightly bent ventrally at quarter from base, weakly setose; sacculus evenly tapering, narrow, turned inwards distally, apex sharp, few long setae laterally, at base group of setae ventrally. Juxta shallow; lateral arms of juxta wide at base, round, with two lobes, dorsal larger, ventral pointing ventrolaterally; superjuxta weakly sclerotized; vinculum unevenly round. Aedeagus about 1.0 mm long, 0.1 mm. wide; slightly bent ventrally, smooth, round, with lobe on left lateral side near apex, apex acute dorsomedially, caecum round; vesica opens ventrolaterally to right, simple, roundish sac; sclerotization at distal end with longitudinal grooves, proximal half divided in two parts longitudinally, distal half slightly narrowing, rough edged; ductus ejaculatorius opens from distal end of vesica.

Female. Unknown.

Biology and distribution

The biology of *S. mustangensis* is unknown. The species is known only from the type locality, Mustang, Nepal, at 3300 m (Fig. 1).

Remarks

Yazaki (1995, p 3) has written the following on the original description of *S. mustangensis*: "sacculus asymmetrical, left one long, smoothly curved dorsally, tapering towards pointed apex, right one shorter, acutely bent dorsally at apical one-third." I have examined the slide upon which the description is based and it is obvious that the genitalia were damaged during preparation. It has been further distorted by having a cover slip placed on it without support at the sides. Thus the sacculi of the valvae are symmetrical and they point slightly ventromedially.

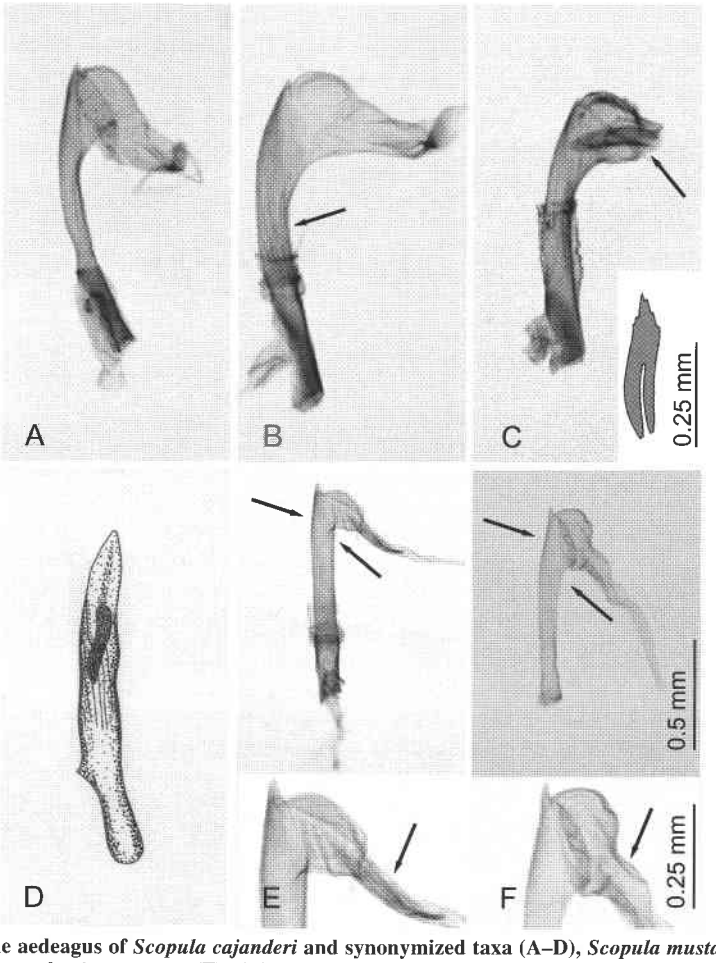


FIGURE 5. Male aedeagus of *Scopula cajanderi* and synonymized taxa (A–D), *Scopula mustangensis* (E), and *Scopula aegrefasciata* sp.nov. (F): (A) paralectotype male of *S. cajanderi* (genitalia prep. PS93); (B) holotype male of *Scopula elwesi sajanensis* (genitalia prep. BMNH 20096); (C) lectotype male of *Scopula elwesi achlyoides* (genitalia prep. BMNH 20095); (D) holotype male of *Scopula septentrionicola* (genitalia prep. C.N.C. 3370); (E) paratype male of *S. mustangensis* (genitalia prep. PS 283); (F) holotype male of *S. aegrefasciata* sp.nov. (genitalia prep. BMNH 20099). Arrows indicate diagnostic features. See text and key for details. Scale bar = 0.5 mm for all figures, except 0.25 mm for insets to C, E, and F.

Scopula aegrefasciata sp.nov.

(Figs. 1, 2J, 2K, 3C, 4G, 4N, 5F)

Material examined

Type material

Scopula aegrefasciata. **Holotype:** "Holotype [red rectangle label]," "Chasseurs Indigenes / des Missionnaires / de Ta-tsien-Lou [= Kangding] / 1906," "BMNH / Geometridae / genitalia slide / No. 20099 male (BMNH)." Type locality: China: Sichuan, about 30°N, 102°E. **Paratype:** "Paratype [red rectangle label]," "Thibet [Tibet] / Ta-Ho /

Chasseurs Indigenes / Printemps 1895," "BMNH / Geometridae / genitalia slide / No. 20098" male (BMNH).

Non-type material

"Ta-Tsien-Lou [China, Sichuan] / 1899 / Chasseurs Indigenes," "Ex. Oberthür Coll. / Brit. Mus. 1927–3" male, without caudal part of abdomen (BMNH).

Etymology

The specific name is Latin and refers to suffused, barely visible postmedian line of the forewing.

Diagnosis

The wings of *S. aegrefasciata* are dark, almost uniform beige–brown (not uniformly coloured, all transverse lines are visible in *S. cajanderi*, suffused with orange in *S. mustangensis*) (Fig. 2). The length of the antennal cilia of *S. aegrefasciata* is about 0.25 mm (about 0.15 in *S. cajanderi*) (Fig. 3). The 8th sternite of *S. aegrefasciata* lacks cerata (short in *S. cajanderi*) (Fig. 4). The aedeagus of *S. aegrefasciata* is about 1.1 mm long, without grooves (about 1.4 mm long, with grooves in *S. cajanderi*), slightly turned ventrally (almost straight in *S. mustangensis*). The vesica is with a distal diverticulum (without distal diverticulum in *S. mustangensis*) (Fig. 5).

Description

Body and wings. Wing expanse: 24.2–25.8 mm. Frons mixed black, dark brown, and beige with hair and appressed scales; labial palpi with erect hair-scales; antenna of male fasciculate, dark brown and beige dorsally, cilia about 0.24 mm long; head above and collar with dark brown and beige scales, darker brown than basic colour of wings. Patagia dark brown and beige with hair and appressed scales; thorax and abdomen light brown and beige. Legs mixed brown and beige, tibia of prothoracic leg with epiphysis, mesothoracic and metathoracic tibias with two apical spurs, not swollen, without hair tuft; abdomen with dark brown and beige scales. Forewing beige above, densely scattered with brown scales giving gray–brown appearance, costa with dark brown scales; median fascia barely distinguishable at dorsal end; only postmedian line clearly visible, brownish, straight, not dentate, starting at costa of forewing at about one-quarter distance from apex; subterminal line lighter than basic colour, hardly visible; adterminal line hardly visible, fused with terminal area of wing; terminal line brown, continuous; fringe beige brownish; margin slightly round; discal spot barely visible, brownish; hind wing of basic colour, with postmedian, subterminal and adterminal lines, margin evenly rounded. Wings below as above, slightly lighter, especially at forewing base; postmedian and subterminal lines faintly expressed as lighter concentrations of brown scales; terminal line and fringe as above. Tympanal organs rather large, not meeting ventrally; ansa narrow basally, widest at basal third, narrow between widened apex and basal third. Tergites 2–8 more strongly sclerotized at anterior and posterior margins, posterior margin weakly sclerotized medially; sternites 3–7 undifferentiated.

Male genitalia. About 1.25 mm long, 0.75 mm wide. Socius almost straight, dorsoventrally widened at base, with few weakly developed setae distally; tegumen sclerotized laterally and at caudal margin; transtilla V-shaped. Valva with valvula bent ventrally at about one half, weakly setose; sacculus evenly tapering, apex sharp, sclerotized, few setae laterally, ventrally group of setae at base. Juxta shallow, ventral margin flat, superjuxta weakly sclerotized; lateral arms of juxta wide at base, with two lobes, dorsal larger and wider with round margin; vinculum unevenly round. Aedeagus

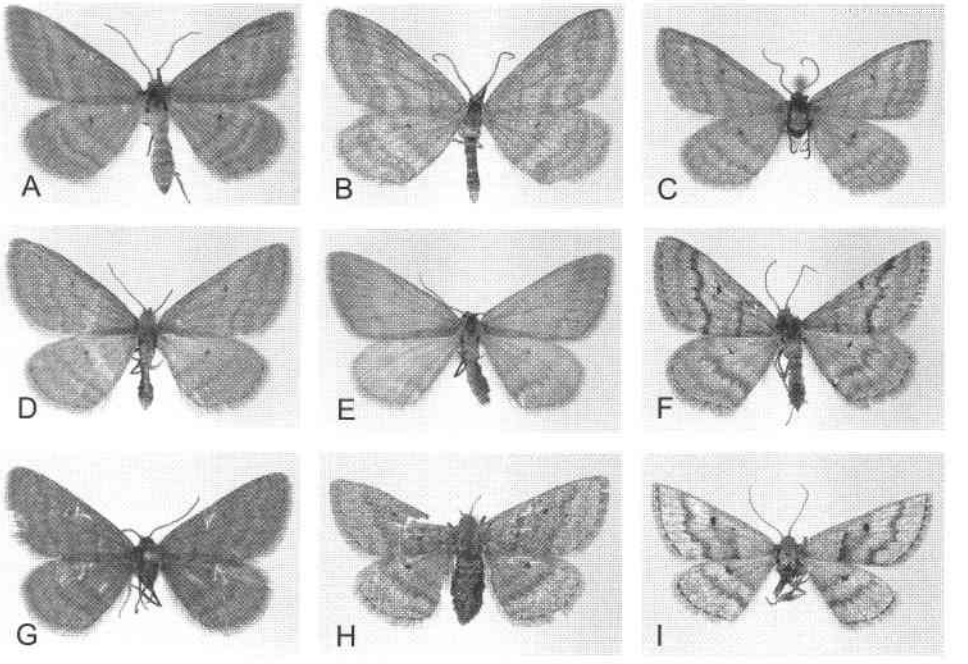


FIGURE 6. Variation of external appearance of *Scopula cajanderi* males (A–G) and females (H–I): (A) Ust Vilvi, Russia; (B) Magadan, Russia; (C) Polar Urals, Russia; (D) Yukon Territory, Canada; (E) British Mountains, Yukon Territory, Canada; (F) Ford Lake, Northwest Territories, Canada; (G) Utah, United States; (H) Banks Island, Northwest Territories, Canada; (I) Chukchi Peninsula, Russia.

about 1.1 mm long, not fused with genitalia, almost straight, slightly bent ventrally at one fifth from apex, surface smooth, caecum round, apex sharp. Vesica opens ventrally, sac-like at base, distal part elongate, almost straight; slightly sclerotized irregular plate at the distal end of vesica; 8th sternite weakly sclerotized, anterior margin of base medially concave; cerata absent; mappa small, posterior margin round.

Female. Unknown.

Variation

Only three male specimens of *S. aegrefasciata* are known. The beige–brown colour of wings is about the same in all the specimens. I have not seen this kind of wing colour in *S. cajanderi* or *S. mustangensis*.

Biology and distribution

The immature stages and habitat of *S. aegrefasciata* are unknown. The species is known only from the type locality, China, Sichuan (Fig. 1).

Remarks

Scopula aegrefasciata was discovered under the label *S. praecanata* (Staudinger 1896) in the BMNH collections. I have studied the type of *S. praecanata* (MNHU) (genitalia prep. PS 258, male) and, based on phenetics (overall similarity), *S. praecanata* is not closely related to *S. aegrefasciata* nor does it belong to the *S. cajanderi* species group.

Scopula aegrefasciata seems to be more closely related to *S. mustangensis* than to *S. cajanderi*. *Scopula aegrefasciata* and *S. mustangensis* have the following characters in common, but different from *S. cajanderi*: male antennal cilia about 0.25 mm (about 0.15 mm in *S. cajanderi*) (Fig. 3); lack of 8th sternite cerata (short in *S. cajanderi*) (Fig. 4); and small, round aedeagus without lateral grooves (large, dorsoventrally flattened aedeagus with lateral grooves in *S. cajanderi*) (Fig. 5).

Species of uncertain systematic position

Scopula elwesi elwesi Prout

(Figs. 1, 2L)

Scopula elwesi Prout, 1922: 261, Pl. 25, Fig. 10; Prout 1934*a*: 175; Prout 1935: 35. Type locality: Russia, Altai.
Scopula cajanderi subsp. *elwesi*: Viidalepp 1996: 55.
Scopula elwesi elwesi Scoble 1999: 847.

The abdomen for the holotype of *S. e. elwesi* Prout is missing, so the systematic position of this taxon within the genus *Scopula* is uncertain. It is described because *S. e. sajanensis* and *S. e. achlyoides* belong to this species group. In *Lepidopterorum catalogus*, Prout (1934*a*) treated *S. elwesi* as a close relative of *Scopula luteolata* Hulst and *Scopula ansulata* Lederer, but in *Palaerctic Geometridae*, Prout (1935) considered it to be closely related to *S. cajanderi*.

Material examined

Type material

Scopula elwesi Prout: **Holotype:** "Type [round label with red margin]," "Altai / Bashkars [RUSSIA] / 26.7.[18]98 / H. J. Elwes," "Joicey / Bequest. / Brit. Mus. / 1934–120," "Bull. Hill Mus. / 1(2) 261 / (1922)" male, without abdomen (BMNH).

Diagnosis

Easily distinguished from species of the *S. cajanderi* species group by the whitish cream ground colour of the forewing, with tawny, ochreous markings (gray–brown in *S. cajanderi*, suffused with orange in *S. mustangensis*, and beige–brown in *S. aegrefasciata*). Subterminal and adterminal lines are diffuse but distinct, and the terminal area of the forewing is creamy. The costa of the forewing is more strongly curved, so the wing differs in shape from that of *S. cajanderi* (Fig. 2). The species is known only by the holotype, which is without abdomen. The genitalia are unknown.

Description

Body and wings. Wing expanse: 25 mm. Frons yellow–brown with appressed scales, few dark brown scales; labial palpi ochreous, slightly mixed with dark brown, mainly appressed scales, interantennal ridge ochreous, with few dark brown scales; collar ochreous, mixed with blackish scales; antenna of male fasciculate, proximal row of setae not fused at base, coloured above cream and straw; dorsum of thorax devoid of scales (rubbed off), distal part of abdomen is missing, according to Prout (1922, p 261): "Thorax and abdomen above pale, with very heavy black irroration, only the abdominal incisions and anal end freer therefrom; abdomen with a lateral stripe of ochreous, the venter pale, with sparse irroration." Proximal part of abdomen is dark ochreous with

black scales; legs ochreous, with some black scales; hind legs are missing, according to Prout (1922, p 261): "hind tibia not dilated, with a pair of well-developed terminal spurs." Wings creamy, costa grayish with brown irroration, denser at base, markings ochreous, darker at base, lighter towards terminal area and on hind wing; costa of forewing bent at about three fifths from base, giving narrow appearance; antemedian line barely seen, median fascia passing through discal spot, postmedian line slightly dentate, medially concave, parallel with almost straight, wide, subterminal line; these lines run from about four-fifths costa to about four-fifths hind margin; areas between median fascia, postmedian and subterminal line and terminal area of wing cream; terminal line broken at vein endings, brown; fringes ochreous with some brown scales; discal dots distinct, elongated, brown; lines continued on hind wing, basal area more densely scattered with ochreous and brown scales; margin of hind wing evenly round. Wing below as above, markings more diffuse; base of wing less ochreous as above; discal spots weaker; terminal line light brown.

Male genitalia. Unknown. The abdomen of the holotype of *S. e. elwesi* is missing without any indication on the specimen that a genitalia preparation has been made.

Female. Unknown.

Biology and distribution

Only the holotype is known from Altai, Russia (Fig. 1). Immature stages and habitat are unknown.

Discussion

Examination of the relationships between the Nearctic and Palaearctic geometrid faunas is long overdue, especially when compared to Noctuidae (*e.g.*, Lafontaine *et al.* 1987; Mikkola *et al.* 1991). According to the studied material, the external appearance of the *S. cajanderi* is variable, but based on consistent diagnostic characters of the genitalia, including the internal genitalia, the Nearctic *S. septentrionicola*, the Palaearctic *S. e. sajanensis*, and the Palaearctic *S. e. achlyoides* are conspecific with *S. cajanderi*, making it Holarctic. These could have been treated as subspecies of *S. cajanderi*, but the external variation between and within populations was inconsistent. If I had recognized these taxa as subspecies, I should have used the same lines of reasoning throughout the geographic distribution of *S. cajanderi*. For instance, specimens from the Polar Urals (Russia) and Utah (United States) would have deserved the subspecies status as well. Without causing the nomenclature to become inflated, formal trinominals may be replaced by informal locality names, as proposed by Wilson and Brown (1953).

The systematic position of *S. elwesi* within the genus *Scopula* is uncertain because the holotype abdomen is missing. Additional specimens are needed to resolve its systematic position or its inclusion in the *S. cajanderi* species group.

On the species level, the male antenna, the aedeagus, and the internal genitalia offered most of the diagnostic characters to separate the species of the *S. cajanderi* species group: *S. cajanderi*, *S. mustangensis*, and *S. aegrefasciata*. The vesicae contained diagnostic features unlike the rather uniform male genitalia. Vesicae structures have been useful for species-level studies in other Lepidoptera groups also (Callahan and Chapin 1960), especially allopatric populations (Lafontaine *et al.* 1987). Based on this study, I recommend that vesicae be everted in the genus *Scopula* where possible. The shape of the male 8th sternite correlated with other diagnostic characters but, as this structure is known to vary within species in the genus *Scopula* (Hausmann 1999), I did not base species decisions on this character alone.

No sound phylogenetic study exists on the genus *Scopula*. Thus, the similarity-based definition of the *S. cajanderi* species group which was used in this study may turn out to be artificial. The defining characters of the *S. cajanderi* species group are by no means unique in the genus *Scopula*. For instance, the character state "cerata absent" is found in *Scopula subgastonaria* Wiltshire from Saudi Arabia and Yemen, but based on other characters it is not closely related. I have studied the literature and Lepidoptera collections to find more species that would fit the definition of the *S. cajanderi* species group but without success. Expeditions to mountainous regions of the Himalayas could result in more species, in addition to the unknown females of *S. mustangensis* and *S. aegrefasciata*.

The systematic position of the *S. cajanderi* species group within the genus *Scopula* remains uncertain. Following Covell (1970), I would place species of the *S. cajanderi* species group with boreal species of the genus, such as the Holarctic *S. frigidaria* and the Palaearctic *Scopula ternata* Schrank.

Acknowledgements

I thank L Kaila for advising me to study this subject, and VA Mironov (St. Petersburg), EA Beljaev (Vladivostok), J-F Landry (Ottawa), W Mey (Berlin), E Quinter (New York), and K Yazaki (Tokyo) for providing material for this study. K Mikkola kindly commented on earlier drafts of the manuscript, and M Parsons (London) provided photographs of many taxa. I also thank CV Covell and an anonymous referee for their critical and helpful comments on an earlier draft. I am grateful to S Venn for revising my English. This study was financially supported by the Finnish Cultural Foundation.

References

Arnett R, Samuelson G, Nishida G. 1993. *The insect and spider collections of the world*. 2nd edition. Flora and Fauna Handbook 11. Gainesville: Sandhill Crane Press, Inc

Cajander A. 1903. Beiträge zur Kenntniss der Vegetation der Alluvionen des nördlichen Eurasiens I. Die Alluvionen des Unteren Lena-Thales. *Acta Societatis Scientiarum Fennicae* **32**: 1–182

Callahan P, Chapin J. 1960. Morphology of the reproductive system and mating in two representative members of the family Noctuidae, *Pseudaletia unipuncta* and *Peridroma margaritosa*, with comparison to *Heliothis zea*. *Annals of the Entomological Society of America* **53**: 763–82

Colinvaux P. 1981. Historical ecology in Beringia: The south land bridge coast at St. Paul Island. *Quaternary Research* **16**: 18–36

Covell C. 1970. A revision of the North American species of the genus *Scopula* (Lepidoptera, Geometridae). *Transactions of the American Entomological Society* **96**: 101–221

Dyke A, Prest V. 1987. Late Wisconsinan and Holocene history of the Laurentide ice sheet. *Géographie Physique et Quaternaire* **41**: 237–63

Field H. 1906. Lepidoptera. pp 346–95 *in* H Field (Ed), *Bibliographia zoologica* 1905, volume 11. Lipsiae, Germany: W Engelmann

Grichuk V. 1984. Late Pleistocene vegetation history. pp 155–78 *in* H Wright, C Barnosky (Eds), *Late Quaternary environments of the Soviet Union*. London: Longman

Grosswald M, Hughes T. 1995. Paleoglaciology's grand resolved problem. *Journal of Glaciology* **41**: 313–32

Hardwick D. 1950. Preparation of slide mounts of Lepidopterous genitalia. *The Canadian Entomologist* **82**: 231–5

Hausmann A. 1999. Falsification of an entomological rule: polymorphic genitalia in Geometrid moths. *Spixiana* **22**: 83–90

Herz O. 1903. Lepidopteren-Ausbeute der Lena-Expedition von B. Poppius im Jahre 1901. *Öfversigt af Finska Vetenskaps-Societetens Förhandlingar* XLV 1902–1903 **15**: 1–20

Hodges R, Dominick T, Davis D, Ferguson D, Franclemont J, Munroe E, Powell J. 1983. *Checklist of the Lepidoptera of America north of Mexico including Greenland*. London: EW Classey Ltd and Wedge Entomological Research Foundation

Holloway J. 1997. The moths of Borneo, part 10: family Geometridae, subfamilies Sterrhinae and Larentiinae, addenda to other subfamilies. *Malayan Nature Journal* **51**: 1–242

International Catalogue of Scientific Literature. 1906*a*. N, Zoology, Part I, author catalogue. Volume 3. London: Harrison and Sons

——— 1906*b*. N, Zoology, Part II, subject catalogue. Volume 3. London: Harrison and Sons

International Commission on Zoological Nomenclature (ICZN). 1999. *International code of zoological nomenclature*. 4th edition. London: International Trust for Zoological Nomenclature, The Natural History Museum

Klots A. 1970. Lepidoptera. pp 115–30 *in* S Tuxen (Ed), *Taxonomist's glossary of genitalia in insects*. Copenhagen: Munksgaard

Lafontaine J, Mikkola K, Kononenko V. 1987. *Anarta cordigera* (Lepidoptera: Noctuidae: Hadeninae), a species complex. *The Canadian Entomologist* **119**: 931–40

Mayr E. 1942. *Systematics and the origin of species*. New York: Columbia University Press

——— 1963. *Animal species and evolution*. Cambridge: Harvard University Press

McDunnough J. 1939. New North American Geometridae with notes, I (Lepid.). *The Canadian Entomologist* **71**: 187–92

McGuffin WC. 1967. Guide to the Geometridae of Canada (Lepidoptera). I. Subfamily Sterrhinae. *Memoirs of the Entomological Society of Canada* **50**: 1–67

Mikkola K, Lafontaine J, Kononenko V. 1991. Zoogeography of the Holarctic species of the Noctuidae (Lepidoptera): importance of the Beringian refuge. *Entomologica Fennica* **2**: 157–73

Müller B. 1996. Geometridae. pp 231–49 *in* O Karsholt, J Razowski (Eds), *The Lepidoptera of Europe, a distributional checklist*. Stenstrup, Denmark: Apollo Books

Nixon K, Wheeler Q. 1990. An amplification of the phylogenetic species concept. *Cladistics* **6**: 211–23

Poole RW. 1996. Lepidoptera. pp 605–1122 *in* RW Poole, P Gentili (Eds), *Nomina Insecta Nearctica. A check list of the insects of North America III: Diptera, Lepidoptera, Siphonaptera*. Rockville, Maryland: Entomological Information Services

Prout L. 1913. 12. Gattung: *Acidalia*. pp 51–82 *in* A Seitz (Ed) [1912–1916], *Die Gross-Schmetterlinge der Erde IV: Geometridae Palearcticae*. Stuttgart: Verlag des Seitz'schen Werkes

——— 1922. Some new Geometridae and Dioptidae in the Joicey collection. *The Bulletin of the Hill Museum: a Magazine of Lepidopterology* **1**: 252–69 and 624

——— 1934*a*. Geometridae: Subfamilia Sterrhinae I. pp 1–176 *in* E Strand (Ed), *Lepidopterorum catalogus* 61. Berlin: W Junk

——— 1934*b*. Geometridae: Subfamilia Sterrhinae II. pp 177–432 *in* E Strand (Ed), *Lepidopterorum catalogus* 63. Berlin: W Junk

——— 1935. 16. Gattung: *Scopula*. pp 33–47 *in* A Seitz (Ed) [1934–1954], *Die Gross-Schmetterlinge der Erde, Supplement zu Band IV: Geometridae Palearcticae*. Stuttgart: Alfted Kernen Verlag

——— 1938. The American Geometridae. pp 1–144 *in* A Seitz (Ed), *Die Gross-Schmetterlinge der Erde* 8. Stuttgart: Alfted Kernen Verlag

Rutter N. 1995. Problematic ice sheets. *Quaternary International* **28**: 19–37

Schwert D, Ashworth A. 1988. Late Quaternary history of the northern beetle fauna of North America. pp 93–107 *in* JA Downes, DH Kavanaugh (Eds), Origins of the North American insect fauna. *Memoirs of the Entomological Society of Canada* **144**: 93–107

Scoble M (*Editor*). 1999. *Geometrid moths of the world, a catalogue (Lepidoptera, Geometridae)*. Victoria, Australia: CSIRO Publishing

Sharp D (*Editor*). 1904. Section XIII (Insecta), C (Lepidoptera): Geometridae, Epiblemidae, Uraniidae. pp 271–86 *in* D Sharp (Ed), *Zoological record* 41. Cambridge: John Clay

Staudinger O. 1896. Beschreibungen neuer Lepidopteren aus Tibet. *Deutsche Entomologische Zeitschrift, Iris* **8**: 300–43

Viidalepp J. 1996: *Checklist of the Geometridae (Lepidoptera) of the former U.S.S.R*. Stenstrup, Denmark: Apollo Books

Vojnits A. 1977. Archiearíinae, Rhodometrinae, Geometrinae II, Sterrhinae II and Ennominae III (Lepidoptera, Geometridae) from Mongolia. *Annales Historico-Naturales Musei Nationalis Hungarici* **69**: 165–75

Wilson E, Brown W. 1953. The subspecies concept and its taxonomic application. *Systematic Zoology* **2**: 97–111

Yazaki K. 1995. Geometridae. pp 2–27 *in* Haruta, T (Ed), *Moths of Nepal. Part IV*. Tinea 14, Supplement 2. Sendai, Japan: Sasaki Printing and Publishing Co

Young S. 1982. The vegetation of land-bridge Beringia. pp 179–94 *in* D Hopkins, J Matthews, C Schweger, S Young (Eds), *Paleoecology of Beringia*. New York: Academic Press

(Received: 29 August 2000; accepted: 28 March 2001)