





Revision of the genus *Prometopidia* Hampson, 1902, with description of the new species *P. joshimathensis* sp. nov. from West-Himalaya and its subspecies *P. j. yazakii* ssp. nov. from Nepal (Lepidoptera: Geometridae, Ennominae)

PRITHA DEY^{1,2,3*}, VIRENDRA PRASAD UNIYAL², AXEL HAUSMANN³ & DIETER STÜNING⁴



¹Centre for Ecological Sciences, Indian Institute of Science, CV Raman Rd, Bengaluru, Karnataka 560012 (present address).

 prithadey@iisc.ac.in;  <https://orcid.org/0000-0003-3586-9235>



²Wildlife Institute of India, Chandrabani, Dehradun-248001, Uttarakhand, India.

 uniyalvp@wii.gov.in;  <https://orcid.org/0000-0001-5757-6383>

³SNSB - Zoologische Staatssammlung München, Münchhausenstraße 21, 81247 Munich, Germany.

 hausmann.a@snsb.de;  <http://orcid.org/0000-0002-0358-9928>

⁴Zoologisches Forschungsmuseum Alexander Koenig, Adenauerallee 160, 53113 Bonn, Germany.

 D.Stuening@leibniz-zfmk.de;  <https://orcid.org/0000-0002-1748-4510>

*Corresponding author

Abstract

The genus *Prometopidia* Hampson, 1902 and its type-species *P. conisaria* Hampson, 1902 are redescribed and newly discovered morphological characters are explained. The female holotype of *Prometopidia arenosa* Wiltshire, 1961, was studied and the species redescribed, its correct position in *Prometopidia* is verified. The new species *P. joshimathensis* sp. nov. is described from Joshimath area in India, Uttarakhand province. Sympatric with *P. conisaria* at Joshimath, *P. joshimathensis* also occurs at Shimla, Punjab province, and in central and eastern Nepal. Morphological and genetic differences found in the specimens of Nepal are considered subspecific, justifying the new taxon *P. joshimathensis yazakii* ssp. nov. Types and specimens of *Prometopidia* across its whole range of distribution from Afghanistan to Nepal, habitats, genitalia, remarkable morphological characters and DNA barcoding-results are figured.

Key words: Afghanistan, CO1, India, Kashmir, morphology, Pakistan, *P. arenosa*, *P. conisaria*, taxonomy

Introduction

The present article is part of a larger study to understand the biodiversity and distribution of moths, based on faunistic monitoring and identification through DNA Barcoding (Dey, 2019; Dey *et al.* 2015, 2017, 2019; Sanyal *et al.* 2017; Dey & Sondhi 2019) in a fragmented and threatened landscape of the western Himalaya which was hitherto poorly explored. The area of Joshimath, a city in the Chamoli district of Uttarakhand, is a perfect example of how natural forest spaces amidst an anthropogenic landscape can harbour fascinating biodiversity. Joshimath forms a gateway to a famous religious shrine (Badrinath) and a Himalayan Ski resort (Auli) and other trekking activities.

The specimens assessed in this paper were collected at different forest types between 2000 and 2900 m asl with changing dominant vegetation: Blue Pine (*Pinus wallichiana* A. B. Jacks.) (location: Joshimath)—Banj Oak (*Quercus leucotrichophora* A. Camus), Moru Oak (*Quercus floribunda* Lindl. ex A. Camus) (location: Sunil)—Kharsu Oak (*Quercus semecarpifolia* Sm.) (location: Auli) from lower to higher elevation (Figs 1b–d). As the dominant vegetation and forest types change distinctly with elevation in the western Himalaya (Gairola *et al.* 2008) the moth material collected at Joshimath area reflects the distinctive faunal diversity there and the need for extensive modern research on their taxonomy and systematics.

Some of the fresh Geometridae (Ennominae) collected recently from the Joshimath area turned out to belong to *Prometopidia conisaria* Hampson, 1902 and to a new species close to it. *P. conisaria* is the type species of the genus *Prometopidia* Hampson (1902) which was originally described as monotypic. Meanwhile, Wiltshire (1961) had described another species in the genus, *P. arenosa* from Nuristan in north-eastern Afghanistan (Parsons *et al.*

1999: 784). The unique female holotype of *P. arenosa* is housed at the Staatliches Museum für Naturkunde Karlsruhe, Germany. The type-locality of *P. conisaria* is Narkundah in Kashmir but the species has also been known from Shimla in Punjab (NW India), from NW Pakistan and eastern Afghanistan, the recently collected specimens from Joshimath extending the range of distribution in India considerably eastwards.

Yazaki (1995) designated a lectotype for *P. conisaria* selecting a male from Narkundah of the H.McArthur coll. in the NHMUK and recorded *P. conisaria* from eastern Nepal, though stating that the specimens from Godavari are slightly different from the male lectotype of *P. conisaria* in being larger and having more prominent, often continuous transverse lines while agreeing in male genitalia. Yazaki found the female specimens from Godavari to have the genitalia almost identical with those of *conisaria* specimens from Shimla. On the basis of the morphological studies as well as the DNA-barcoding results presented here, those specimens from Nepal are treated as a new taxon described below (see *P. joshimathensis yazakii* **ssp. nov.**).

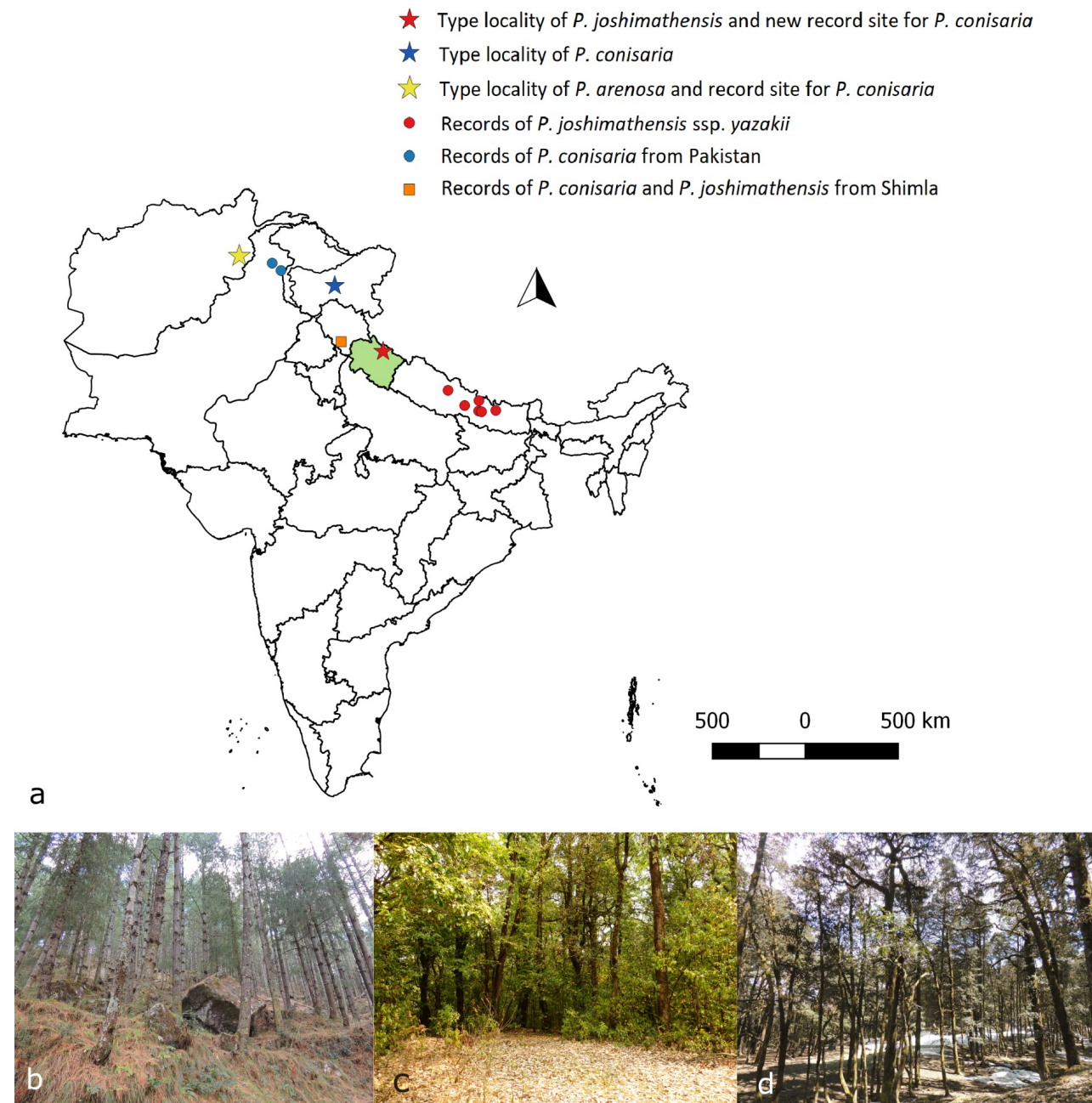


FIGURE 1. (a) Previous and new records and the type-localities of *Prometopidia conisaria*, *P. joshimathensis joshimathensis*, its subspecies *yazakii* and *P. arenosa* within Indian territory and the neighbouring countries Afghanistan, Pakistan and Nepal; (b–d) habitats of *P. joshimathensis* with dominant vegetation as b: Blue Pine (*Pinus wallichiana*), Joshimath, c: Banj Oak (*Quercus leucotrichophora*) and Moru Oak (*Quercus floribunda*), Sunil and d: Kharsu Oak (*Quercus semecarpifolia*), Auli.

Comparison of the morphology of specimens and types involved and the DNA-barcoding results suggested a revision of *Prometopidia* and its taxa and resulted in adding a number of newly found characters to the definition of the genus and its type species *P. conisaria*, in the description of a new species *P. joshimathensis*, revealed by integrative taxonomy, and a new subspecies *P. j. yzakii*, and in ascertaining the placement of *P. arenosa* in *Prometopidia*.

Material and methods

Collecting and collections studied

Samples were collected from Joshimath (also from Sunil and Auli, hamlets within the same region), Uttarakhand, India, using vertical-sheet method of light-trapping. The collected specimens were pinned, labelled, partly mounted and identified at ZSM. Specimens and genitalia slides from the following collection were compared: CMS: private collection of Manfred Sommerer, Munich; NCBS: Museum Facility of the National Centre for Biological Sciences, Bangalore, India; NHMUK: Natural History Museum London, U.K.; SMNK: Staatliches Museum für Naturkunde Karlsruhe (State Museum of Natural History, Karlsruhe); ZFMK: Zoologisches Forschungsmuseum Alexander Koenig (Zoological Research Museum Alexander Koenig), Bonn, Germany; ZSM: SNSB - Zoologische Staatssammlung München, Germany (Bavarian State Collection of Zoology, Munich).

Genitalia dissection and documentation

The genitalia and the abdomens were prepared following methods described by Robinson (1976). Morphological analyses were performed with a Wild 308700 microscope, measurements were taken with a calibrated measuring eyepiece, slide photographs were taken with multilayer automontage technique (Helicon software) at a Leica DM2700M microscope. Resulting images were edited and assembled to plates with Adobe Photoshop software.

DNA sequencing

One dry leg was removed from each individual and used for DNA extraction and sequencing, which was performed at the CCDB, University of Guelph, following standardized high-throughput protocols for DNA barcode (mitochondrial cytochrome c oxidase I, COI 5'; 658 base pairs) amplification and sequencing (Ivanova *et al.* 2006; deWaard *et al.* 2008, accessible at <http://ccdb.ca/resources/>). All information regarding the voucher specimens, genetic sequence, images, taxonomic classification, collection data and other relevant information is available in the public dataset DS-EPITHERI on Barcode of Life Datasystems (BOLD; Ratnasingham & Hebert 2007; doi: <https://dx.doi.org/10.5883/DS-EPITHERI>). The details of collection localities and Barcode sample IDs are provided in Table 1.

Abbreviations: CCDB: Canadian Centre for DNA Barcoding, Guelph, Canada; CBG: Centre for Biodiversity Genomics, Guelph, Canada.

DNA sequence analysis

Sequence divergences for the barcode region were calculated using the analytical tools on BOLD (Kimura-2-Parameter model: Kimura 1980; neighbour-joining algorithm: Saitou & Nei 1987). Distances between species are presented as minimum pairwise distances, while intraspecific variation refers to the maximum pairwise distance within that species. Genetic data were used for species delimitation based on the system of Barcode Index Numbers as implemented on BOLD (cf. Ratnasingham & Hebert 2013). A maximum likelihood tree using the Kimura-2-Parameter model was created, including all available sequences of *Prometopidia*, with *Lomographa* as the closest related genus (Fig. 7).

TABLE 1. Selected data of the specimens of *Prometopidia* collected at Joshimath (Uttarakhand).

Specimens of <i>Prometopidia</i> , types, sex	Barcode sample ID Genitalia slide Nos.	Collecting sites at or nr. Joshimath	Elevation (m)	Latitude (N)	Longitude (E)
<i>P. joshimathensis</i> , PT, male	BC ZSM Lep 103735	Auli	2893	30.52292	79.56681
<i>P. joshimathensis</i> HOLOTYPE, male	BC ZSM Lep 103734	Sunil	2424	30.54589	79.55369
<i>P. joshimathensis</i> , PT, male	ZSM G 20802	Sunil	2418	30.54592	79.55397
<i>P. joshimathensis</i> , PT, female	ZSM G 20803	Sunil	2609	30.54022	79.56525
<i>P. joshimathensis</i> , PT, female	BC ZSM Lep 94424 WII-G-1	Joshimath	2210	30.55325	79.54503
<i>P. joshimathensis</i> , PT, male	Not dissected Not barcoded	Auli	2893	30.52292	79.56681
<i>P. joshimathensis</i> , PT, female	ZSM G 21265	Joshimath	2210	30.55325	79.54503
<i>P. conisaria</i> , female	BC ZSM Lep 94421	Sunil	2414	30.546	79.55411
<i>P. conisaria</i> , female	BC ZSM Lep 94423 ZSM G 21263	Joshimath	2210	30.55325	79.54503
<i>P. conisaria</i> , male	BC ZSM Lep 94422	Sunil	2424	30.54589	79.55369
<i>P. conisaria</i> , male	Not dissected Not barcoded	Sunil	2414	30.54589	79.55369
<i>P. conisaria</i> , male	Dto.	Joshimath	2238	30.55303	79.54528
<i>P. conisaria</i> , male	Dto.	Joshimath	2210	30.55325	79.54503
<i>P. conisaria</i> , male	Dto.	Sunil	2414	30.546	79.55411
<i>P. conisaria</i> , male	Dto.	Sunil	2414	30.546	79.55411
<i>P. conisaria</i> , male	Dto.	Sunil	2414	30.546	79.55411
<i>P. conisaria</i> , male	Dto.	Joshimath	2053	30.55567	79.54756
<i>P. conisaria</i> , male	Dto.	Sunil	2422	30.54558	79.55436
<i>P. conisaria</i> , male	Dto.	Sunil	2424	30.54589	79.55369

Taxonomic account

***Prometopidia* Hampson, 1902, J. Bombay nat. Hist. Soc., 14: 509.**

Type-species: *P. conisaria* Hampson, 1902, type-locality: Narkundah, Kashmir.

Original generic description: “Genus PROMETOPIDIA, nov. Proboscis fully developed; palpi porrect, slender,

hardly reaching as far as the large conical frontal prominence; antennae of male laminate; legs slender; wings slender; forewing with the termen oblique; vein 3 from close to angle of cell; 5 from middle of discocellulars; 7, 8, 9, 10 stalked from before upper angle; 11 approximated to 12, then 10. Hindwing with vein 3 from before angle of cell; 5 obsolescent from middle of discocellulars; 7 from before upper angle; 8 approximated to cell to middle.”

[NOTE: forewing vein 3 = CuA1; 5 = M2; 7, 8, 9, 10 = R5, R4, R3, R2; 11 = R1; 12 = Sc; hindwing vein 3 = CuA1; 5 = M2; 7 = Rs; 8 = Sc + R1].

Additional characters revealed by present studies. *Head.* Palps covered with narrow, elongate lamellar scales, providing a broader appearance to them; frontal prominence distally rounded or acutely pointed (Figs 4a, b); antennae filiform, slightly flattened and serrated in lateral view, finely ciliate (pubescent) in males, cylindrical, less ciliate in females; chaetosemata small, near eye-margin.

Thorax. Wings with basal and medial transverse lines absent, fovea in male absent; base of veins Sc and R1 in hindwings swollen, frenulum present. Index of spurs 0-2-4, hindlegs not dilated.

Pregenital abdomen. Tympanal organs large, ovoid, flattened on tympanum side, basal half of ansa with a lateral curvature and a knob at middle, membranous extension on one side only, opposite to curvature, with straight outer margin; lacinia absent, but a transverse band of sclerotization present; supporting sclerites of phragma between 1st and 2nd segment strap-like, tapering in width towards ventral side (Fig. 4i); 1st and 2nd tergites and sternite 1+2 sclerotized in males, in females additionally posterior half of 7th tergite sclerotized and the distal margin lined with a dense row of two types of modified scales (type 1 stiff, elongate, slightly broadening towards forked apex; type 2 setous); in females only, the distal margin of the 7th sternite bears a sclerotized, spatulate process of varying shape, very densely covered with modified scales like those on 7th tergite, but smaller (Fig. 4g; Yazaki, 1995: 18, fig. 575).

Male genitalia with uncus long, narrow, stick-like, strongly bent ventrad near the broadly triangular base, remaining part slightly curved, decorated with a few long setae in the middle, tip a curved spine. Gnathos with long, very narrow lateral arms and a broader, moderately sclerotised, band-like medial part, subanal plate present. Valves elongate, tip rounded, medial surface setous on distal two thirds, setation very dense with longest setae towards costa. The latter broadly sclerotized up to two thirds, broadest in the middle. Sacculus not developed. Valves at base of outer surface with moderately developed coremata, bearing a brush of strong setae exceeding the valves in length. Hemi-transtillae band-like, tapering to a point towards middle, there touching each other, medial parts gently curved dorsad. Juxta of a complicated shape: broadly plate-like at base, then roundly incurved and fringed with long setae (“crista-hairs”), more distally broadening to arm-like processes, narrowed again, distally with a deep incision and finished by a roof-like plate. Saccus small, hardly extending beyond valve bases. Aedeagus narrow and rather short, vesica with a large field of numerous, small teeth.

Female genitalia (terminology following Skou & Sihvonen, 2015) with ostium bursae moderately funnel-shaped, membranous, ductus bursae partly sclerotized (“colliculum”) or without sclerotized part. Posterior part of corpus bursae narrow, weakly sclerotized, fluted, broadening abruptly or gradually towards anterior part or extended into it, the latter membranous, with a stellate signum. At the transition between anterior and posterior part of corpus bursae a broad, ring-like area present which is more strongly and irregularly fluted and scobinate. Abdominal segment A8 reduced to a heavily sclerotized ring, broader dorsally, ventrally consisting of narrow arms, tapering towards middle, covered partly with elongated scales, with a small, medio-ventral gap for the genital opening, the latter membranous, without any ornamentation. Apophyses anteriores relatively short and stout, with triangular bases and enlarged apices. Papillae anales strikingly modified, floricomous (Pierce, 1914), consisting of a collar of numerous, very long, incurved setae, arising from baso-lateral pad-like structures; in the centre between them an ovally cylindrical tube with a double line of specialized, strongly sclerotized setae, their bases straight and with distinct, sharply pointed hooks distally. Apophyses posteriores rather straight, narrower and longer compared to the apophyses anteriores.

Biology, phenology, habitats. Immature stages and hostplants are unknown, though, regarding the collecting sites at Joshimath, *Quercus* may be the most probable hostplant: more than 80% of the specimens collected come from localities where oak-trees are dominant (see Introduction and Fig. 1, b–d). Adults are on the wing in April and May (*conisaria*, *joshimathensis*) and in July (*joshimathensis* of Shimla, Punjab, perhaps a second generation).

Habitats are mainly situated at elevations between 1600m and 2500m, rarely lower or higher.

Systematic position. *Prometopidia* belongs to the tribe Baptini. Holloway [1994: 58] provided a detailed diagnosis of the tribe Baptini and he analysed for this purpose the morphological characters of a large number of East

Asian genera of potential Baptini, but also includes the typical genus *Lomographa* Hübner [1825]. He mainly refers to a number of characters of the male genitalia as potential synapomorphies for the tribe: a gnathos which is weak or absent; a broad, immaculate costal zone and a central zone of long setae on the valve; coremata which are present at the base of the valve; socii which are present in most genera; absence of two characters abundant in other Geometridae: a transverse group of setae (“setal comb”) on male third abdominal sternite and no fovea on male forewing. These characters are also shared by *Prometopidia*.

Skou & Sihvonen (2015) summarized the published knowledge about the classification of European Ennominae genera into tribes. For the tribe Baptini they noticed that the geographical extent and the number of included species is unclear and no convincing synapomorphies for this tribe have been identified, except potentially the swelling of the base of the vein Sc in the male hindwing and, as also mentioned by Holloway, [1994: 58] the weakly developed or absent gnathos in the male genitalia, both characters shared by *Prometopidia* Hampson, 1902 (gnathos weakly developed in *Prometopidia*).

Moreover, the very finely ciliate male antennae agree with those of *Lomographa* Hübner [1825], the genus which typifies the tribe Baptini. *Lomographa* also possesses a distinctive venational character which it has in common with *Prometopidia*: vein R_2 in the forewing arises from the common stalk of R_3 – R_5 . All those characters shared clearly confirm the systematic position of *Prometopidia* as a member of the tribe Baptini.

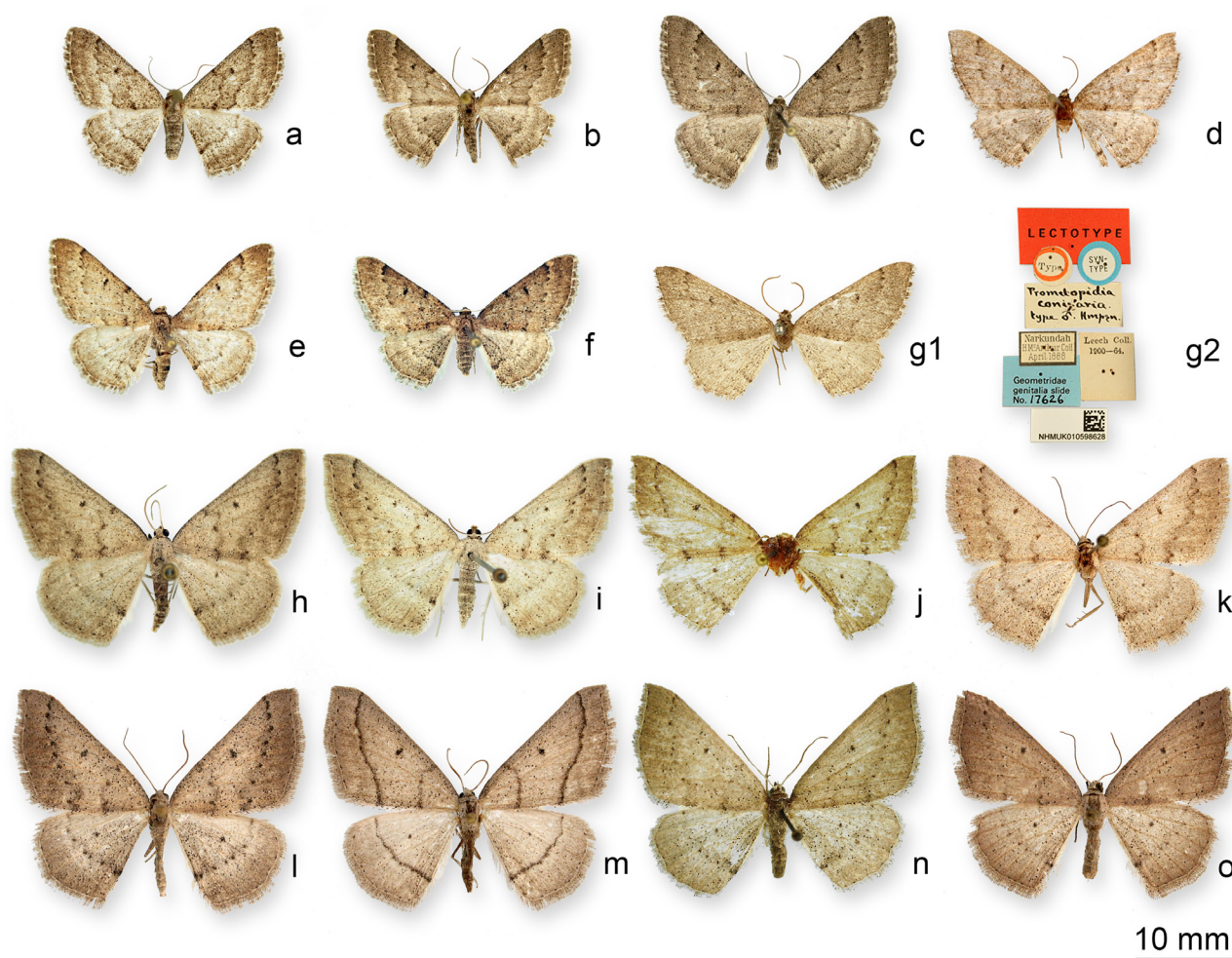


FIGURE 2. Adults (a–f), including lectotype (g1, g2) of *Prometopidia conisaria*, adults of *P. joshimathensis* (h–o). a: *P. conisaria*, female (Afghanistan, ZFMK); b: *P. conisaria*, male, (Pakistan, CMS); c: *P. conisaria*, female (Pakistan, CMS); d: *P. conisaria*, female (Pakistan, ZFMK); e: *P. conisaria*, male (India, Uttarakhand; NCBS); f: *P. conisaria*, female (India, Uttarakhand; NCBS); g1: *P. conisaria*, male lectotype (Narkundah, Kashmir); g2: *P. conisaria*, labels of male lectotype; h: *P. joshimathensis*, male holotype (Uttarakhand; NCBS); i: *P. joshimathensis*, male paratype (Uttarakhand; NCBS); j: *P. joshimathensis*, female paratype (Uttarakhand; NCBS); k: *P. joshimathensis*, female paratype (Punjab; ZFMK); l: *P. joshimathensis* ssp. *yazakii*, male holotype (E. Nepal; ZFMK); m: *P. j. yazakii*, male paratype (E. Nepal; ZFMK); n: *P. j. yazakii*, female paratype (E. Nepal; ZSM); o: *P. j. yazakii*, female paratype (E. Nepal; ZFMK).

On the other hand, *Prometopidia* exhibits a number of characters not shared with other genera of Baptini, as far as we know: the conical frons in males and females; the spatulate process on posterior margin of female 7th abdominal sternite, the strongly modified 8th abdominal segment and the special floricomous condition of the ovipositor in females, with short, strong, hook-like setae (see fig. 3f).

The function of a typical floricomus (Pierce, 1914) is still not satisfactorily clarified. It is assumed, however, that “females use the floricomous, scoop-shaped setae of the papillae anales to scratch particles from the surface of the bark to cover and camouflage eggs” (Skou & Sihvonen, 2015, referring to Rajaei, 2010 and Rajaei *et al.* 2012). The dense collar of elongated setae surrounding the scoop-shaped setae may support this function by brushing aside or distributing the particles. The special “*Prometopidia*-floricomus” with very strong, short, hooked setae instead of long, flexible, scoop-shaped ones may have a similar function, but is adapted for more resistant material. Both types of floricomus are building together with the similarly modified 8th abdominal segment (which is reduced to a heavily sclerotized, ring-like structure with short, strong apophyses anteriores) a functional unit. It is present in all species possessing a floricomus and most likely enables a free, powerful movement of the ovipositor.

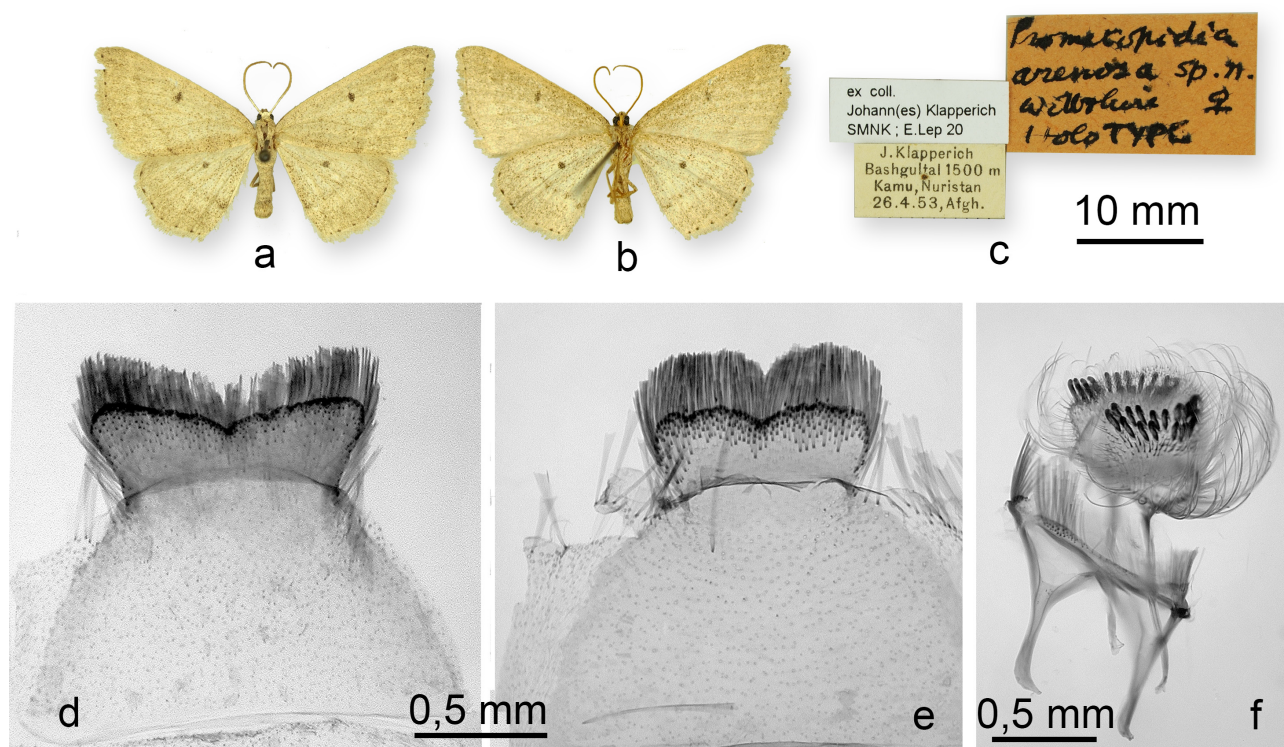


FIGURE 3. Adult, abdominal details, female genitalia of *Prometopidia arenosa* and *P. joshimathensis yazakii*. **a:** *P. arenosa*, female holotype, upperside, **b:** *P. arenosa*, underside (NE. Afghanistan; SMNK); **c:** *P. arenosa*, labels of holotype; **d:** *P. arenosa*, process on 7th sternite; **e:** *P. joshimathensis yazakii*, process on 7th sternite; **f:** *P. arenosa*, 8th segment and papillae anales (“*Prometopidia*-floricomus”).

Remarks. With exception of the spatulate process on female 7th abdominal sternite and the hooked setae of floricomus, all or some characters of *Prometopidia* mentioned above are found also in a group of genera which are characterised by possession of a typical floricomus, as known before since more than a century (Pierce, 1914) (but not well-known at all) and figured in detail by Skou & Sihvonen (2015: 364, Text-figures 118–121): with modified, flexible, scoop-shaped setae, arising from pads of different shape on the papillae anales. These genera are *Theria* Hübner, 1825 (mainly European), *Aleucis* Guenée, 1845 (Europe, Turkey, Levante, Caucasus, Turkmenistan), both placed in the Theriini recently (Skou & Sihvonen, 2015), *Ramitia* Viidalepp, 1988 (Tadzhikistan, Turkmenistan, N. Iraq, SE. Turkey), *Epitherina* Wehrli, 1938 (Iran), *Heterobapta* Wiltshire, 1943 (Iran, Tadzhikistan, Afghanistan), *Earoxyptera* Djakonov, 1936 (Mongolia). The last-mentioned four genera are generally similar to *Aleucis* in the structure of the male genitalia and may also belong to the Theriini. To decide this, more detailed studies are required, including also female genitalia and DNA sequence analyses which is beyond the scope of the present paper.

A very similar, typical floricomus has also been found in the two unrelated genera *Gnopharmia* Staudinger,

1892 and *Neognopharmia* Wehrli, 1951, which are members of the tribe Macariini. The question how such highly apomorphic structures could have developed independently is still unresolved and additional detailed studies are needed.

***Prometopidia conisaria* Hampson**

Figs 2a–g; 4a, d, g, i; 5a–d; 6a–c

Prometopidia conisaria Hampson, 1902, J. Bombay nat. Hist. Soc. 14: 509, fig. (India, Kashmir: Narkundah; McArthur [leg.]).
Lectotype male (NHMUK, photos of adult and genitalia examined).

Type-material examined. Lectotype ♂, “Narkundah, H. McArthur coll., April, 1888; Leech Coll. 1900–64”, lectotype designated, genitalia dissected (NHMUK Geometridae genitalia slide 17626) by Yazaki (1995: 18, 27, fig. 579; pl. 128, fig. 5; erroneously indicated as “*Calocalpe anestia* Prout”). Lectotype and genitalia are here figured again.

Additional material examined. 10♂, 2♀, North-western India, Uttarakhand, Joshimath: 1♂, 2424 m, 12.IV.2015, coll. NCBS (NRC-AA-1690); 1♂, 2238 m, 19.IV.2015, genitalia slide No. ZSM G 21262; 1♂, 2210 m, 09.IV.2015, coll. NCBS (NRC-AA-1701); 4♂, 2414 m, 12.IV.2015, coll. NCBS (NRC-AA-1696, 1697, 1698, 1702); 1♂, 2053 m, 14.IV.2015, coll. NCBS (NRC-AA-1699); 1♂ 2422 m, 23.IV.2015, coll. NCBS (NRC-AA-1700); 1♂, 2424m, 12.IV.2015, Barcode No.: BC ZSM Lep 94422, coll. NCBS (NRC-AA-1694). 1♀: 2414 m, 12.IV.2015, Barcode No.: BC ZSM Lep 94421, coll. NCBS (NRC-AA-1693); 1♀: 2210 m, 09.IV.2015, Barcode No.: BC ZSM Lep 94423, genitalia slide No.: ZSM G 21263.

Specimens examined from other regions are: 1♀, E. Afghanistan, Prov. Kunar, Nuristan, 1600m, 14.iv.71, leg. C. Naumann; 1♂, NW. Pakistan, 20 km W of Besham, Karaora, 1200m, 27.v.1992, leg. Hreblay & Csorba, genitalia slide No. 2186-DS; BC ZFMK Lep 00598 (failed); 1♀, Simla, Punjab, 2500m, Mai, genitalia slide No. KYS-1021 (ZFMK); 4♂, Pakistan, Prov. NW-Frontier, Kagan valley, 1750m, 6.iv., genitalia slide No. 2187-DS; BC ZFMK Lep 00599; 10.iv., 14.–15.iv.1999, leg. B. Benedek & A. Szabó; 2♀, Pakistan, Himalaya Mts., Kaghan valley, 2900m, 17.v.1998, leg. Gyula M. László & G. Ronkay, genitalia slide No. 2188-DS; BC ZFMK Lep 00600 (failed); 1♂, 1♀, dto., Kaghan valley, 2150 m, 16.iv.1999. (CMS).

Original description. “Brownish-grey irrorated with brown; frontal prominence black; wings irrorated with some large black scales. Forewing with waved blackish antemedial line; a small discoidal tuft of black scales; an oblique postmedial line slightly dentate at the veins and incurved between the veins 3 and 1; a terminal series of black points; the cilia intersected with white. Hindwing with black discoidal point; a slightly dentate postmedial line and traces of a subterminal line; a terminal series of black points; cilia whitish at base.

Habitat.—Kashmir, Narkundah (McArthur), Exp. 30 mill. *Type*—in B.M.”

Additional characters revealed by present studies. Small moths, wingspan 22–25 mm. Expanse of 30 mm in original description is probably due to a mistake of measurement.

Head. Scales on palps mixed white and dark grey or lighter grey and dark grey; frontal process stout, short, tip broadly rounded in females, longer and slightly narrower in males, covered with small, dark greyish-brown scales; vertex scales larger, white anteriorly, grey and white posteriorly.

Thorax. Patagia and tegulae of the latter colours, tegulae partly with elongated scales. Legs chequered with dark grey and whitish scales. Forewings almost triangular, termen only slightly oblique, smooth and evenly curved. Ground colour light grey, densely dusted with dark grey scales. Antemedial and postmedial fasciae present, distinct, a submarginal fascia vaguely visible. Antemedial fascia angled four times, postmedial dentate on the veins and incurved at posterior half. Hindwings with an evenly curved, also dentate postmedial fascia, a submarginal fascia also present, but the antemedial line absent. Discal dots present on both wings, weaker on hindwing. Termen slightly undulating, at margin with short, black streaks always opposite to white fringe sections; fringes long, shorter white and longer dark grey sections alternating. Underside lighter, less densely dusted with dark grey scales. Forewings with postmedial fascia only, but less distinct compared to upper side, postmedial fascia of hindwings indistinct, interrupted. Discal dots present, similar to upper side. Base of hindwings swollen between the basal parts of veins Sc+R1 and the upper vein of cell, more strongly so in males than in females.

Pregenital abdomen. Externally with almost white ground colour, but heavily dusted with dark grey scales. Otherwise as described in the generic description. The spatulate process of the distal margin of female 7th sternite semi-circular (Fig. 4g).

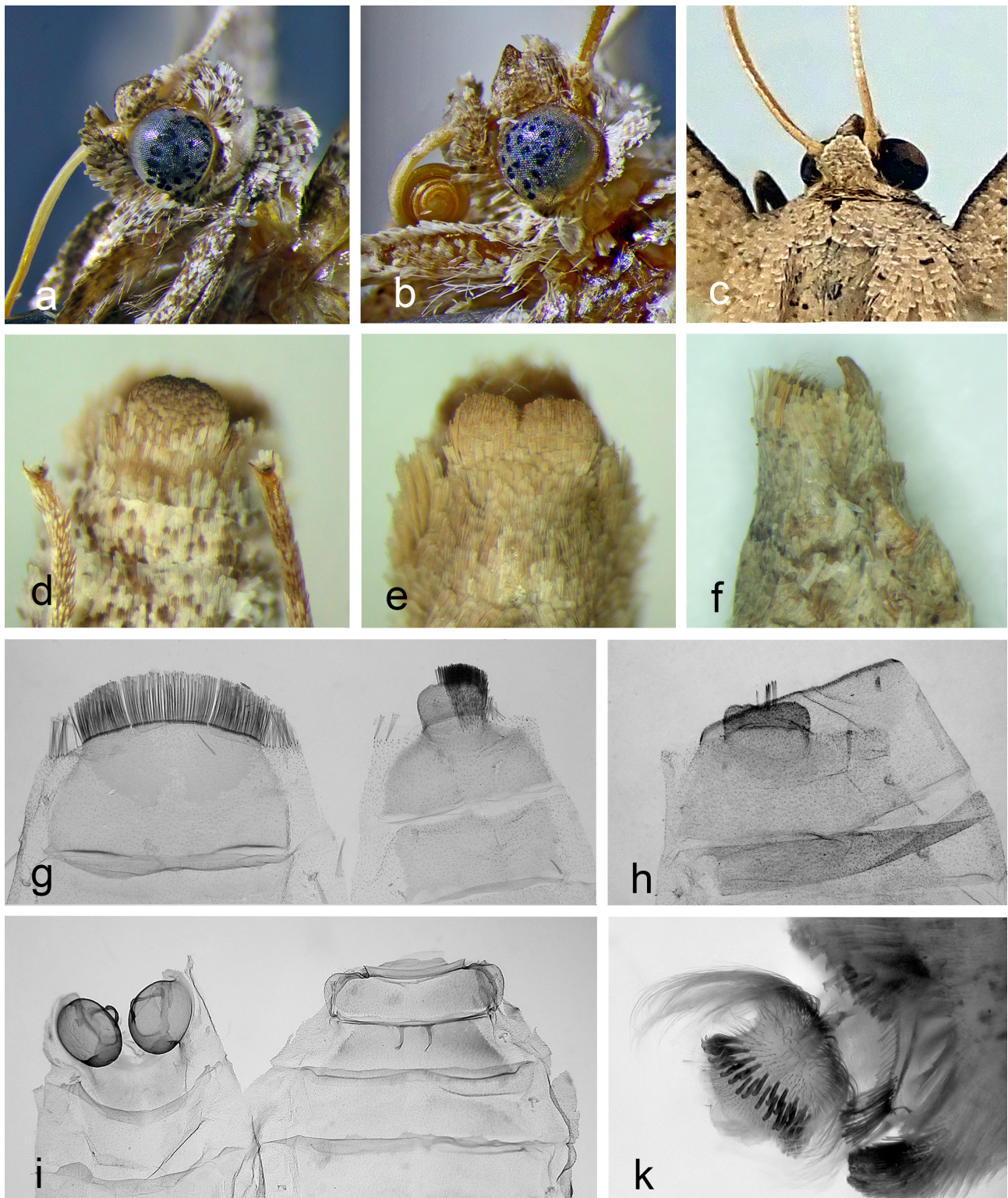


FIGURE 4. *Prometopidia* spp., morphological characters. **a:** *P. conisaria*, head, lateral view; **b:** *P. joshimathensis yazakii*, head, lateral view; **c:** *P. j. yazakii*, head, dorsal view; **d:** *P. conisaria*, process of 7th sternite, ventral view; **e:** *P. j. yazakii*, process of 7th sternite, ventral view; **f:** *P. j. yazakii*, process of 7th sternite, lateral view; **g:** *P. conisaria*, female, 7th tergite (left, showing rows of modified scales) and 7th sternite with distal process (left side descaled); **h:** *P. joshimathensis*, 7th sternite with distal process; **i:** *P. conisaria*, female, anterior abdominal segments (left side: sternites with tympanal organs; right side: sternites with supporting sclerites of first phragma); **k:** *P. j. yazakii*, abdomen in fluid, 7th segment with distal process (at bottom) and papillae anales with long, curved setae and rows of hooked setae (“*Prometopidia*-floricomus”).

Male genitalia as described in the generic description, not clearly distinguishable from *P. joshimathensis* sp.nov, only slight, gradual differences present in the genitalia capsule which is also a little smaller than the capsule of the next species. The narrower central part and the smaller baso-lateral incisions of the juxta may also be diagnostic. Aedeagus also a little narrower and shorter, but the group of teeth on vesica more numerous, teeth smaller and reaching widely towards base of vesica, getting gradually smaller.

Female genitalia. Largely as described in generic description, but ductus bursae without colliculum; the long, fluted posterior part of corpus bursae with a longitudinal sclerotized band and only moderately getting wider near anterior part of corpus bursae, there without a broad, more strongly and irregularly fluted area as present in the next species. Moreover, the membranous anterior part of bursa is small and globular or slightly oval. The signum is small, with large marginal teeth on distal half only, proximal half with tiny little teeth, the central opening rounded on proximal side, straight on distal side.

Modified 8th segment and papillae anales with floricomus as described above in additional characters of the genus.

Diagnosis. See *P. joshimathensis*.

Distribution. Afghanistan, Pakistan, NW. India: Kashmir, Punjab (now Himachal Pradesh), Uttarakhand

Genetic data. BIN: BOLD:ADF3039 (n=3 from India, Uttarakhand). Intraspecific variation 0.15%. Genetic distance to one barcoded specimen from Pakistan 4.4% (BC ZFMK Lep 00599), the latter, however, just sequenced to a 407 bp fragment, requiring confirmation by additional specimens and full DNA barcodes. At present, we do not consider this singleton as a member of a different taxon, but it is possible, as the female is unusually large and the distal sclerotized process of 7th sternite is shaped differently. A subspecific state may also be possible. Genetic distance to *P. joshimathensis* 6.8%.

***Prometopidia arenosa* Wiltshire**

Figs 3 a, b, c, d, f, 6f

Prometopidia arenosa Wiltshire, 1961, Beitr. Naturk. Forsch. SW-Dtl. 19 (3): 358, pl. 4, fig. 45; holotype ♀, Afghanistan, Nuristan, Bashgul-valley, 1500 m, 26.iv.1953, leg. Klapperich (in coll. Klapperich); coll. SMNK, examined. For type-locality compare Fig. 1 (a).

Original description. “Wingspan 27 mm. Frons a brown naked blunt cone. Vertex whitish. Antenna (female) minutely setose. Thorax with sandy-white and grey-brown scales mixed. Abdomen with concolorous (sandy-brown) floricomus (female), bifurcate ventrally, not black-scaled as in *P. conisaria*. Fore-wing pale sandy brown sparsely speckled with sooty scales. Basal and ante-median fasciae lacking. Cell-spot a distinct blackish oval. Post-median fascia darker, faint, denticulate, with a pale outer edging, beginning nearer the apex than its termination lies from the tornus. Termen marked with a series of black, inter-neural spots. Fringes concolorous. Hind-wing similar, but with cell-spot less conspicuous, post-median fascia less denticulate, straight, rather faint. Under-side duller, with cell-spots equally distinct on both wings, and post-median fascia clearer on hind-wing. *Remarks.* This new species is at once distinguishable from *P. conisaria* with which it flies in Nuristan, by its broader wings, fewer fainter fasciae, and pale sandy almost pink colouring.”

Additional characters revealed by present studies. *Head.* Frons with conus not naked, but covered with tight, small, brown scales.

Thorax. Venation of forewings agreeing with type-species, with slight differences only (e. g. common stem of veins R₂–R₅ arising from upper vein of cell at a wider distance from upper angle of cell). Underside of wings with only forewing duller, only traces of postmedial fascia visible; hindwing lighter, greyish-white, speckled with contrasting, dark grey scales and prominent marginal spots and streaks; cell-spots weaker, elongate in forewing, round and more distinct in hindwing; on hindwings base of vein Sc swollen, but not very conspicuous, as in females of the other species.

Pre genital abdomen. The “bifurcate ventral part of floricomus” is in fact the distal, sclerotized process on 7th sternite (see fig. 3d); it is the biggest process of this kind of all included species and subspecies. The process of *P. joshimathensis yazakii* is similar, but smaller and rather bilobed. Modified (strongly sclerotized, ring-shaped) 8th segment similar to other species of *Prometopidia*.

Female genitalia. Papillae anales a typical *Prometopidia*-floricomus, the hooked setae even stronger with

broadened (oval in lateral view) bases (Figs 3f, 6f). Ductus bursae with colliculum; posterior part of corpus bursae fluted, a narrow, longitudinal band more strongly sclerotized, transitional part not widened, but extended into the lumen of the anterior part of corpus bursae, these and surrounding parts strongly scobinate. Anterior part of corpus bursae membranous, small, oval; the signum rather small, oval, with strong teeth covering only three fourths of the sclerotized ring.

Although *P. arenosa* is only known by the unique female holotype, the so far unpublished morphological features mentioned here, especially the spatulate, abdominal process and the new type of floricornus in the female genitalia, described in the present paper, confirm the affiliation of *arenosa* to the genus *Prometopidia*.

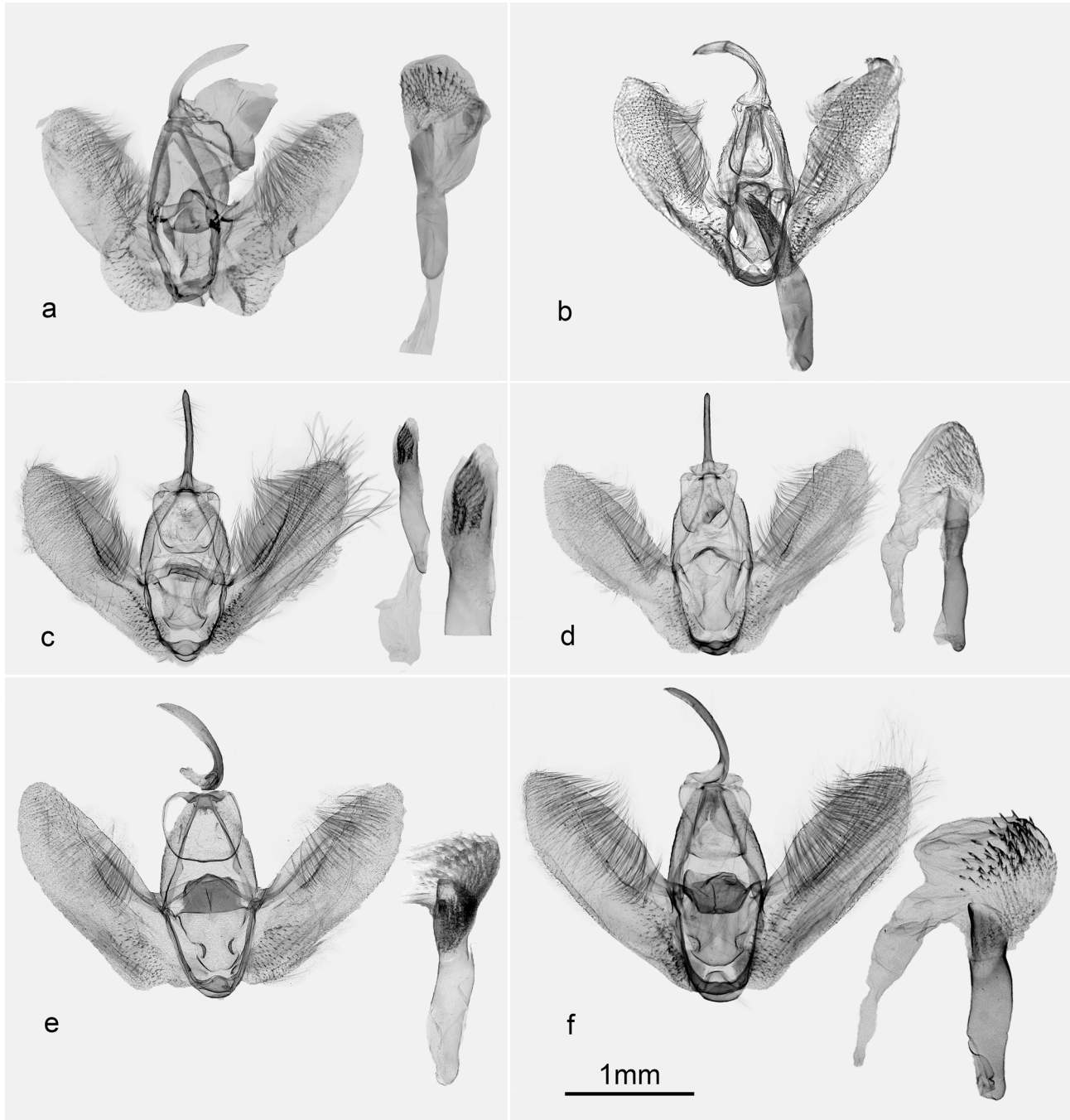


FIGURE 5. *Prometopidia* spp., male genitalia. **a:** *Prometopidia conisaria*, lectotype (Kashmir; vesica of aedeagus everted); **b:** *P. conisaria*, (Uttarakhand; vesica not everted); **c:** *P. conisaria*, (Pakistan; vesica not everted, apical region of aedeagus enlarged to show arrangement of cornuti); **d:** *P. conisaria*, (Pakistan; vesica everted); **e:** *P. joshimathensis* (Uttarakhand; vesica incompletely everted); **f:** *P. j. yazakii* (E.Nepal; vesica everted).

***Prometopidia joshimathensis joshimathensis* sp. nov.**

Figs 2h–k; 4h; 5e; 6d, e

Material examined. Types: Holotype ♂, NW. India, Uttarakhand, Joshimath, Sunil, 2424m, 12.IV.2015, leg. P. Dey; Barcode No.: BC ZSM Lep 103734; coll. NCBS (NRC-AA-1690).

Paratypes: 3♂, 3♀, Joshimath, north-western India, Uttarakhand. 1♂, Sunil, 2418m, 01.V.2014, genitalia slide No.: ZSM G 20802, coll. NCBS (NRS-AA-1688); 1♂, Auli, 2893m, 25.IV.2014, Barcode No.: BC ZSM Lep 103735, coll. ZSM; 1♂, Auli, 2893m, 25.IV.2012, coll. NCBS (NRC-AA-1689); 1♀, Sunil, 2609m, 09.V.2014, genitalia slide No.: ZSM G 20803, coll. NCBS (NRC-AA-1691); 1♀, Joshimath, 2210m, 09.IV.2015, Barcode No.: BC ZSM Lep 94424, genitalia slide No.: WII-G-1, coll. NCBS (NRC-AA-1692); 1♀, Joshimath, 2210m, 09.IV.2015, genitalia slide No.: ZSM G 21265, coll. ZSM. Paratypes in coll. NCBS, except one male and one female, donated to ZSM.

3♀, NW. India, Punjab: 2♀, “Simla, Punjab, 2500 m, Juli”, genitalia slide No. KYS-1056 ♀; 1♀, “Berg Kufri, Himalaya Gbg. Simla, Punjab, 2500 m”, ZFMK.

Description. Moths of moderate size, wingspan 28–29 mm.

Head. Palps slender, straight, not reaching tip of frons in length, broadened by elongate scales, becoming gradually smaller towards tip, mixed white and shades of grey, with white tips. Terminal segment very small, almost invisible. Proboscis well developed. Frontal process large, conical, tip acutely pointed, covered with small, dark greyish-brown scales on ventral side and lighter grey scales laterally; vertex scales larger, white, extending triangularly on dorsal part of frontal conus. Antennae filiform, finely pubescent in males. Chaetosemata small, near eye-margin.

Thorax. Patagia and tegulae of large, light greyish scales with white tips, tegulae with elongate lamellar scales and hair-scales mixed. Legs long, slender, chequered with dark grey and whitish scales. Forewings almost triangular, termen evenly rounded, only slightly oblique. Apex moderately falcate. Ground colour light greyish-white, densely dusted with darker grey scales at submarginal area, a few black scales scattered over the wing surface. Antemedial and postmedial fasciae present, distinct, a submarginal fascia indistinct. Antemedial fascia consisting of three black dots, connected by a thin, wavy line, postmedial evenly curved outwards at anterior half, then more strongly incurved towards hind margin, built of dots on the veins, stronger towards costa, connected by a vague broad line. Hindwings with a similar, but evenly curved or rather straight postmedial fascia, submarginal and antemedial lines absent. Margin smooth, marginal line of both wings with short, black streaks between the veins, discal dots present on both wings, weaker on hindwing. Fringes long, of the same colour as wing surface. Base of hindwings swollen (only three females from Shimla could be studied). Underside lighter, forewings with postmedial fascia only, but less distinct, dots almost absent. Wing surface homogeneously dusted with light grey scales. Postmedial fascia of hindwings similar, but wing surface almost white, irrorated with single dark grey or black scales. Discal dots present, similar to upperside.

Pregenital abdomen. Externally ground colour like wing surface, but heavily dusted with dark grey scales. Integument and tympanal organs as described in the generic description, the spatulate process posteriorly on 7th sternite of female transversely elongate, almost rectangular (Fig. 4h).

Male genitalia largely as described in the generic description, slightly larger than that of the type-species, but not clearly distinguishable, only slight, gradual differences present. The broader central part of juxta and the smaller, semicircular incisions more basally may be diagnostic, but this has to be studied on a larger number of specimens. Aedeagus a little longer and the shaft broader, but the group of teeth on vesica less numerous, teeth larger and base of vesica free of many small to minute teeth, as present in *P. conisaria*.

Female genitalia. Largely as described in generic description, colliculum of ductus bursae present. The long, fluted posterior part of corpus bursae gradually getting wider towards bursa and there with a broad, more strongly and irregularly fluted and scobinate area. The membranous anterior part of corpus bursae copulatrix is moderately large and oval, the signum rather large with a small opening and a broad sclerotized band with big, triangular marginal teeth. Modified 8th segment and floricomous papillae anales as described above.

Diagnosis. The present new species is distinguished from the type-species of *Prometopidia*, *P. conisaria*, by larger size and lighter grey ground colour. The apex of forewing is more strongly falcate, transverse fasciae are punctate rather than dentate. *P. joshimathensis* has a larger, conical frontal process with pointed tip (broader, shorter and rounded at tip in *P. conisaria*). The spatulate process on posterior margin of 7th sternite is broad but narrow and almost rectangular in *P. joshimathensis*, but longer and rather oval, spatulate in *P. conisaria*. In the male genitalia which are generally similar, the capsule is larger and the juxta broader at centre, with smaller incisions basally

(has to be confirmed). The group of teeth on vesica is less numerous (but the teeth are larger) in *P. joshimathensis* (smaller, more numerous teeth with many tiny teeth at basal part of vesica in *P. conisaria*). The female genitalia are distinguished by the length and shape of the corpus bursae and the presence or absence of a colliculum within the ductus bursae: long and narrow posterior part, colliculum absent in *P. conisaria*, broader and gradually widening posterior part, colliculum present in *P. joshimathensis*. Moreover, the signa are also different: round, with a complete set of marginal teeth in *P. joshimathensis*, smaller, more or less irregular, with large teeth only on distal margin in *P. conisaria*. In addition, the signum is situated close to the transitional zone between anterior and posterior part of corpus bursae in *P. conisaria*, more or less in the middle of the anterior part in *P. joshimathensis*.

Distribution. NW. India: Punjab (now Himachal Pradesh), Uttarakhand.

Etymology. The species is named after the type locality Joshimath, Uttarakhand, western Himalaya (compare Fig. 1(a)).

Genetic data. BIN: BOLD:ADF3537 (n=3 from India, Uttarakhand). Intraspecific variation 0.0%. Genetic distance to subsp. *yazakii* 3.3% (n=3). Genetic distance to *P. conisaria* 6.8%.

Prometopidia joshimathensis yazakii ssp. n.

Figs 2l–o; 3e; 4b, c, e, f, k; 5f; 6e

Prometopidia conisaria: Yazaki, 1995: 18 (specimens from Nepal only), text fig. 575 (female genitalia and 7th abdominal sternite), pl. 100, fig. 11 (♂ moth; Yazaki, pers. comm.) (nec Hampson, 1902).

Type-material examined. Holotype ♂, Nepal, Ganesh Himal, 1 km E of Gadrang, 2520 m, 9.iii.1996, 85°16'E 28°09'N, leg. László Bódi & György Makranczy; genitalia slide no. 2367-DS, Barcode No.: BC ZFMK Lep 00595. Coll. ZFMK.

Paratypes: 1♂, Nepal, Dhumre, Bimal Nagar, 500m, 29.–30.iii.1995, 84°26'E 27°55'N, leg. László Bódi & György Makranczy; genitalia slide No. 2368-DS, Barcode No.: BC ZFMK Lep 00597; 1♂, Nepal, Ganesh Himal, 1 km SW of Gadrang, 2900 m, 10.iii.1996, leg. László Bódi & György Makranczy; genitalia slide No. 2399-DS, Barcode No.: BC ZFMK Lep 00596; 1♀, Nepal, Dhaulagiri Himal, 2,5 km SE of Lebang, 2450 m, 24.iii.1996, leg. László Bódi & György Makranczy; genitalia slide No. 2400-DS, Barcode No.: BC ZFMK Lep 00594; Coll. ZFMK.

1♂, Nepal, Prov. Nr. 2 East, Jiri, 5.IV.1964, leg. W. Dierl; genitalia slide No. ZSM G 424; 1♀, same data, genitalia slide No. ZSM G 20364 (Pritha Dey fec.), coll. ZSM; 1♀, Nepal, Kathmandu valley, 5km SW of Kathmandu, Dhankinkali, 25.I.1996, leg. Chenga Sherpa; coll. CMS.

Nepal, Kathmandu valley, Godavari, 1600 m: 1♂, 10.i.1992; 1♂, 27.ii.1992; 2♂, 2.iii.1992; 1♀, 16.iii.1992; Godavari, Mt. Phulchouki, 2075–2275 m: 1♂, 2.iii.1992; 1♂, 17.iii.1992; 1♂, 19.iii.1992. Coll. K. Yazaki, Tokyo.

Description and diagnosis. Wingspan in males 29–31 mm, female 28 mm. Type-material from Joshimath of the same size as specimens of *yazakii* ssp.n. from E. Nepal. Pattern and coloration almost the same in both subspecies. There are lighter grey specimens which only have the area outside of the postmedial line darker grey, and completely darker grey specimens. Ante- and postmedial lines are punctate, with the dots on the veins. Females with very indistinct fasciae rarely occur. About half of the specimens of the subspecies *yazakii*, however, have continuous transverse fasciae (see fig. 2m): two of four in coll. ZFMK, four of eight in coll. Yazaki; the relation may change in larger samples. In both collections the single females have punctate fasciae. Among the nominotypical subspecies from Joshimath (n=7) and paratypes from Punjab (n=3) specimens with continuous fasciae do not occur.

The hindwing bases in males of ssp. *yazakii* are swollen and distinctly modified like a rectangular pouch, with a small, round, membranous section, similar to a tympanum, near the base of the frenulum. The basal part of vein Rs (upper vein of the hindwing cell) is also strongly angled, running adjacent to the distal border of the pouch. The function of this unusual structure is unknown and it should be paid more attention to it in future.

Further differences are seen in the shape of the distal process of the 7th sternite in females: a rather narrow, transverse, almost rectangular process in *P. joshimathensis joshimathensis* (Fig. 4h), a broader, distally double-curved process in ssp. *yazakii* (Fig. 3e). The male genitalia of both subspecies are without distinctive differences, but the female genitalia are slightly larger in subsp. *yazakii*, with the anterior part of corpus bursae larger in relation to the posterior part and a larger signum with wider opening, broader sclerotized ring with more numerous and longer spines. Morphologically, all these differences are considered to be of subspecific value, though the genetic distance is rather high.

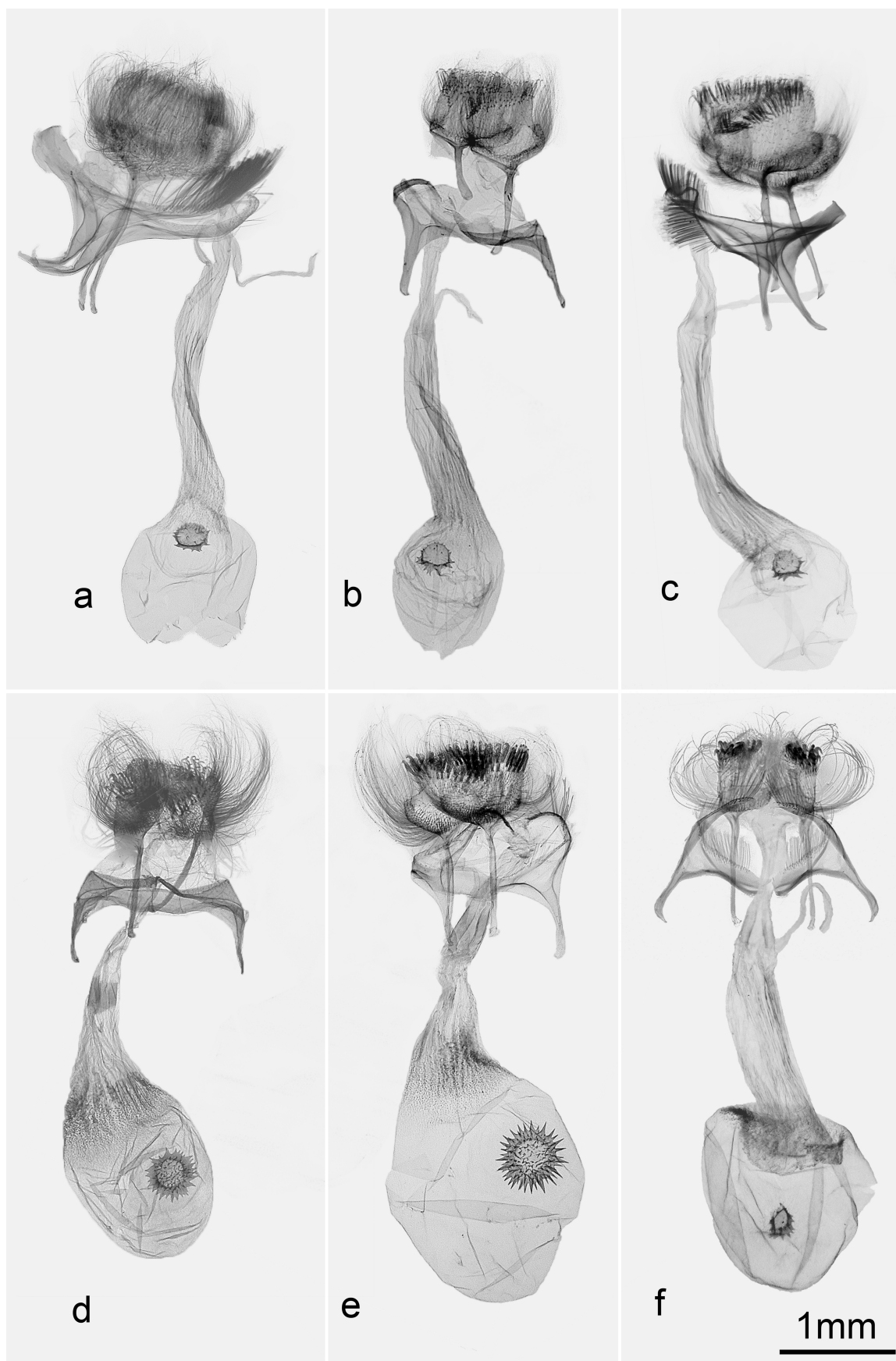


FIGURE 6. *Prometopidia* spp., female genitalia. **a:** *P. conisaria* (Pakistan); **b:** *P. conisaria* (Punjab); **c:** *P. conisaria* (Uttarakhand); **d:** *P. joshimathensis joshimathensis* (Punjab); **e:** *P. j. yazakii* (E.Nepal); **f:** *P. arenosa* (NE Afghanistan).

Distribution. Central and eastern Nepal (Fig. 1 (a))

Etymology. Dedicated to Katsumi Yazaki, Tokyo, one of the best-known experts of East Asian Geometridae, who as the first revising author studied specimens of *Prometopidia* intensively, designating and figuring also the lectotype of the type-species in the collection of the NHMUK. Moreover, he first recorded specimens of *Prometopidia* from Nepal.

Genetic data. BIN not yet assigned, data based on three sequences with fragment lengths of 407 bp, all from eastern Nepal. Maximum intraspecific variation 1.0%. Genetic distance to nominotypical subspecies 3.3%, requiring confirmation by additional specimens. Genetic distance to *P. conisaria* 6.7%.

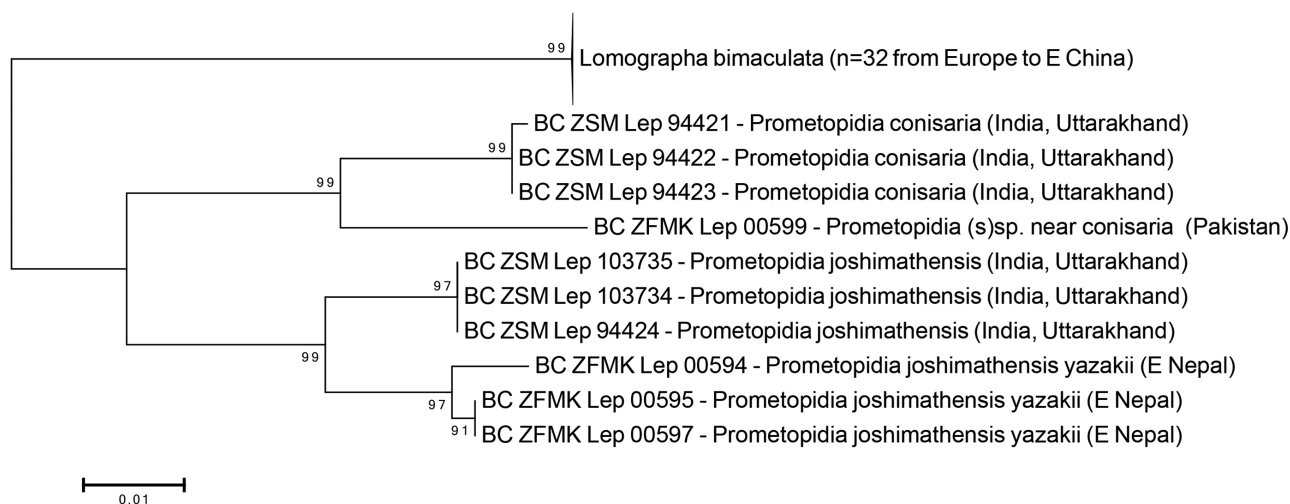


FIGURE 7: Maximum Likelihood Tree of COI data for the genus *Prometopidia*, 50 Bootstrap Replications, Tamura-Nei model, uniform rates, built with Mega 6 software (Tamura *et al.* 2013; scale bar = 1%), rooted with 32 specimens of the type-species of the genus *Lomographa* (data collapsed). Original data see <https://dx.doi.org/10.5883/DS-EPITHERI>.

Discussion

Our research has shown again, that an accurate, combined (integrative) investigation of morphology and molecular data is necessary for correctly assessing the taxonomy of geometrids (and all other creatures), backed up by a reference database of single gene barcodes from reliably identified museum vouchers. Nevertheless, the present study provides only a small step forward to understand the diversity and distributions of moths of that poorly explored area, the western Himalaya. Many questions are still remaining open for further research. Immature stages and hostplants of all three *Prometopidia*-species are still unknown and are subject of a forthcoming project, facilitated by the knowledge about habitats, prospective hostplants and flight-times acquired during recent investigations. Elucidating the biological function of newfound morphological characters (e. g. “floricomus”) will also be an important part of future research. New taxa revealed by modern genetic tools (DNA-barcoding) may point to the probability of finding even more biodiversity across the whole range of distribution of certain Geometridae if more adequate specimens become available and can be successfully processed by DNA-barcoding. For the time being, doubtful cases like the one related to a female of, or close to, *P. conisaria* from Pakistan cannot be cleared. The specimen is unusually large, with different wing-shape (see fig. 2c) to other females, and the distal sclerotized process of the 7th sternite is of another shape than those of true *P. conisaria*. The genetic distance on the basis of sequence of just 407 bp to barcoded specimens from Uttarakhand is 4.4% (BC ZFMK Lep 00599). Confirmation by additional specimens and full DNA barcodes is required.

Acknowledgements

The study was a part of a project funded by the Department of Science and Technology, Govt. of India, and German Academic Exchange Service (DAAD). We are thankful to the Director and the Dean, Wildlife Institute of India,

for providing the opportunity to carry out this study in India. We also wish to extend our gratitude to the National Biodiversity Authority (India) for giving the necessary permissions to export moth samples on loan to ZSM, Munich for our study. Thanks are also due to Geoff Martin and particularly to Alessandro Giusti, Natural History Museum London, U.K., for providing photographs of type-specimens and their genitalia and to Robert Trusch and Michael Falkenberg, State Museum of Natural History, Karlsruhe, Germany, who generously provided the possibility to study the holotype of *P. arenosa* Wiltshire. Katsumi Yazaki, Tokyo, kindly answered our questions about his specimens from Nepal and allowed to study and publish some of his original photos herein. The authors are grateful to CCDB and CBG, University of Guelph for their help in sequencing the specimens and to Mrs Ulla Kreutz, Meckenheim, Germany, for digitally improving and arranging most illustrations in this paper with great expertise. We are also very thankful to three referees (Evgeny Beljaev, Vladivostok; Claudio Flamigni, Bologna; Xue Dayong, Beijing) and especially to Manfred Sommerer, Munich, for their valuable comments on our manuscript.

References

- deWaard, J.R., Ivanova, N.V., Hajibabaei, M. & Hebert, P.D.N. (2008) Assembling DNA barcodes: analytical protocols. *In*: Martin, C. (Ed.), *Methods in Molecular Biology: Environmental Genetics*. Humana Press, Totowa, New Jersey, pp. 275–293.
https://doi.org/10.1007/978-1-59745-548-0_15
- Dey, P. (2019) *Diversity Assessment and Molecular Characterization of Geometridae moths (Lepidoptera: Heterocera) in Nanda Devi Biosphere Reserve, Uttarakhand*. PhD Thesis, Saurashtra University, Rajkot, Gujarat, India, 291 pp.
- Dey, P., Uniyal, V.P. & Sanyal, A.K. (2015) Moth assemblages (Lepidoptera: Heterocera) as a potential conservation tool for biodiversity monitoring—study in western Himalayan protected areas. *Indian Forester*, 141 (9), 985–992.
- Dey, P., Uniyal, V.P. & Chandra, K. (2017) A Prefatory Estimation of Diversity and Distribution of Moths in Nanda Devi Biosphere Reserve, Western Himalaya, India. *National Academy Science Letters*, 40 (3), 199–203.
<https://doi.org/10.1007/s40009-016-0534-1>
- Dey, P., Hausmann, A. & Uniyal, V.P. (2019) Towards creating a DNA barcode reference library of geometrid moths from western Himalaya, India. *Spixiana*, 42 (1), 47–59.
- Dey, P. & Sondhi, S. (2019) First records of *Agnidra vinacea* (Moore, 1879) (Lepidoptera: Drepanidae: Drepaninae) from the western Himalaya, extending its known range westwards. *Journal of Threatened Taxa*, 11 (5), 13622–13624.
<https://doi.org/10.11609/jott.4593.11.5.13622-13624>
- Gairola, S., Rawal, R.S. & Todaria, N.P. (2008) Forest vegetation patterns along an altitudinal gradient in sub-alpine zone of west Himalaya, India. *African Journal of Plant Science*, 2, 42–48.
- Hampson, G. (1902) The Moths of India. Supplementary paper to the volumes in The Fauna of British India, Series II, Part VII. *Journal of Bombay Natural History Society*, 14, 494–519.
- Holloway, J.D. [1994] The moths of Borneo, part 11: Family Geometridae, Subfamily Ennominae. 309 pp. *Malayan Nature Journal*, 47, 1–309.
- Ivanova, N.V., deWaard, J.R. & Hebert, P.D.N. (2006) An inexpensive, automation friendly protocol for recovering high-quality DNA. *Molecular Ecology Notes*, 6, 998–1002.
<https://doi.org/10.1111/j.1471-8286.2006.01428.x>
- Kimura, M. (1980) A simple method for estimating evolutionary rates of base substitutions through comparative studies of nucleotide sequences. *Journal of Molecular Evolution*, 16 (2), 111–120.
<https://doi.org/10.1007/BF01731581>
- Parsons, M.S., Scoble, M.J., Honey, M.R., Pitkin, L.M. & Pitkin, B.R. (1999) s.n. *In*: Scoble, M.J. (Ed.), *Geometrid Moths of the World: A Catalogue (Lepidoptera, Geometridae)*. CSIRO Publishing, Collingwood and Apollo Books, Stenstrup, pp. 1–1016, Index 129 pp.
- Pierce, F.N. (1914) *The Genitalia of The Group Geometridae of the Lepidoptera of the British Islands*. The Northern Publishing Company, LTD., xxix + 88 pp., pls I–XLVIII.
- Prout, L.B. (1912–1916) Die spannerartigen Nachtfalter. *In*: Seitz, A. (Ed.), *Die Gross-Schmetterlinge der Erde, Stuttgart*, 4, i–v + 1–479, pls. 1–25.
- Rajaei, H. (2010) Life-history of *Gnopharmia kasrunensis* Wehrli, 1939 and *G. colchidaria* Lederer, 1870 (Geometridae, Ennominae) and their distribution in Iran, with first host-plant records for the genus. *Bonn zoological Bulletin*, 57, 65–73.
- Rajaei, H., Stüning, D. & Trusch, R. (2012) Taxonomic revision and zoogeographical patterns of the species of *Gnopharmia* Staudinger, 1892 (Geometridae, Ennominae). *Zootaxa*, 3360 (1), 1–52.
<https://doi.org/10.11646/zootaxa.3360.1.1>
- Ratnasingham, S. & Hebert, P.D.N. (2007) BOLD: The Barcode of Life data systems. *Molecular Ecology Resources*, 7 (3), 355–364.
<https://doi.org/10.1111/j.1471-8286.2007.01678.x>
- Ratnasingham, S. & Hebert, P.D.N. (2013) A DNA-based registry for all animal species: the Barcode Index Number (BIN) system. *PLoS ONE*, 8 (7), e66213.

<https://doi.org/10.1371/journal.pone.0066213>

- Robinson, G.S. (1976) The preparation of slides of Lepidoptera genitalia with special reference to the Microlepidoptera. *Entomologist's Gazette*, 27, 127–132.
- Saitou, N. & Nei, M. (1987) The neighbour-joining method: a new method for reconstructing evolutionary trees. *Molecular Biology and Evolution*, 4, 406–425.
- Sanyal, A.K., Dey, P., Uniyal, V.P., Chandra, K. & Raha, A. (2017) Geometridae Stephens, 1829 from different altitudes in Western Himalayan Protected Areas of Uttarakhand, India (Lepidoptera: Geometridae). *SHILAP Revista de Lepidopterologia*, 45 (177), 143–163.
- Skou, P. & Sihvonen, P. (2015) Ennominae I. In: Hausmann, A. (Ed.), *The Geometrid Moths of Europe. Vol. 5*. Brill, Leiden, pp. 1–657.
<https://doi.org/10.1163/9789004265738>
- Tamura, K., Stecher, G., Filipski, A. & Kumar, S. (2013) MEGA6: Molecular Evolutionary Genetics Analysis Version 6.0., *Molecular Biology and Evolution*, 30, 2725–2729.
<https://doi.org/10.1093/molbev/mst197>
- Wehrli, E. (1939–1954) Geometrinae. In: Seitz, A. (Ed.), *Gross-Schmetterlinge der Erde, Stuttgart*, 4 (Supplement), pp. 254–722.
- Wiltshire, E.P. (1961) Ergebnisse der Deutschen Afghanistan Expedition 1956 der Landessammlungen für Naturkunde Karlsruhe. Middle East Lepidoptera XV. A second contribution to the Lepidoptera of Afghanistan. *Beiträge zur Naturkundlichen Forschung in Südwestdeutschland*, 191 (3), 337–371, pls. I–IV.
- Yazaki, K. (1995) Geometridae. In: Haruta, T. (Ed.), *Moths of Nepal. Part 4. Tinea 14. Supplement 2*. The Japan Heterocerists' Society, Tokyo, pp. 2–27, text-figs. 537–585, pls. 97–101.