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NEW SPECIES OF *THITARODES* VIETTE, 1968 GHOST MOTH FROM KUMAUN HIMALAYA, INDIA (LEPIDOPTERA: HEPIALIDAE)

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New species of *Thitarodes* Viette, 1968 ghost moth from Kumaun Himalaya, India (Lepidoptera: Hepialidae)

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Abstract

A new species of *Thitarodes* Viette is described from the montane habitat of Balmiya in the western Himalaya of Uttarakhand, India. Genitalia are described and illustrated for male and female specimens. The species is distinctive for its sinuate-shaped valva of the male genitalia and this feature distinguishes it from all other *Thitarodes* species where the male genitalia is described and illustrated. The male and female genitalia also distinguish this species from the other five *Thitarodes* species recorded from the Himalaya. Based on current records for the harvesting of the *Ophiocordyceps* fungus that parasitises *Thitarodes* in this region, the moth appears to be widespread in alpine habitats of at least the eastern regions of Uttarakhand, which currently represents the western-most geographic limit for the distribution of *Thitarodes*.

Keywords

Asia, Balmiya, conservation, morphology, taxonomy, Uttarakhand

Introduction

The genus *Thitarodes* Viette, 1968 may well have remained a relatively obscure and overlooked taxon within the Hepialidae if it were not for the larvae of so many species being host to the parasitic fungus *Ophiocordyceps sinensis* (Berk.) Sung, Sung, Hywel-Jones & Spatafora. The fungal-infected larvae, known in India as Yartsa Gunbu (see also Wang & Yao (2011) for other common names), are widely harvested in montane regions of Asia for their medicinal properties (Wang & Yao 2011, Negi *et al*. 2016, Wang *et al*. 2020). The geographic range of *Thitarodes* extends across eastern and southern Asia between the Himalaya, the Russian Far East, Japan, and Taiwan, although it is absent from much of northern China (other than the Altai region between China, Russia, and Kazakhstan), and eastern China (Grehan 2011). The distributional range of *Thitarodes* greatly exceeds that of the *O. sinensis* which is largely endemic to the Tibetan Plateau and nearby high elevation areas. In China, the fungus occurs in alpine and meadow habitats from about 3,000 m to the snowline in Gansu, Qinghai, Sichuan, Tibet, and Yunnan provinces (Wang & Yao 2011). In the western Himalaya, the sustainability of *Thitarodes* populations may be threatened

by the increasing harvesting intensity of Yartsa Gunbu resulting from rising demand and higher prices (Negi *et al*. 2014).

There are 78 described, valid species of *Thitarodes*, excluding the new species presented here. Most records are from the mountainous regions of the eastern Tibetan Plateau and nearby regions of Central Asia (Yang *et al*. 1996, Grehan 2011), a pattern of diversity that may be the result of geological vicariance (Quan *et al*. 2014, Dai *et al*. 2019). The known species diversity of *Thitarodes* in the Himalaya is relatively low, with eight recorded from Nepal: *T. danieli* Viette, 1968, *T. dierli* Viette, 1968, *T. eberti* Viette, 1968, *T. harutai* Ueda, 2000, *T. kishadai* Ueda, 2000, *T. limbui* Ueda, 2000, *T. kingdonwardi* Ueda, 2000, and *T. maculatum* Ueda, 2000 (Ueda 2000) and two from Bhutan: *T. caligophagus* Maczey, 2000 and *T. namnai* Maczey, 2000 (Maczey *et al*. 2010). This low diversity may well represent a lack of proper documentation. While we present the first species description for the Indian Himalaya, the presence of this genus was already indicated by harvesting of Yartsa Gunbu in Uttarakhand (Negi 2014, Negi *et al*. 2006, 2016), and the recent documentation of larvae and a pupa from Munsiyari, Uttarakhand that was attributed to a species of *Thitarodes* (Wang *et al*. 2020). The new species described here is from a mountain ridge very close to that of the larval population reported by Wang *et al*. (2020).

Materials & Methods

Moths were not found at light traps (solar lamps) and specimens were collected by hand at dusk when temperatures were 7-8º C between 27 July and 17 August in 2019 and 2020. Voucher specimens are deposited in the Research Collections of the National Centre for Biological Sciences, Bengaluru, Karnataka, India (http://collections.ncbs.res.in/), and Department of Zoology, M B Government Postgraduate College, Haldwani, Uttarakhand, India.

The abdomen was removed and treated in a cold solution of 5% KOH solution for more than 12 hours. The abdomen was opened by a right lateral cut from the tergosternal bar to the genitalia which was removed, stained with methylene blue, and preserved in glycerol along with the abdominal integument. Terminology follows Kristensen (2003) for wing venation and female genitalia, Mielke & Casagrande (2013) for the tegumen (= intermediate plate), saccus (= vinculum), and fultura inferior (= juxta), Grehan & Mielke (2017) for the fultura superior (= trulleum), Mielke & Grehan (2017) for the tergosternal connection, and Dumbleton (1966) for the hepialine wing pattern where Rs3 shares a common stalk with Rs2. Wing venation diagrams were drawn over photographic images using InkScape® software.

Abbreviations

FW (forewing), HW (hindwing)

NCBS (National Centre for Biological Sciences, Tata Institute of Fundamental Research, Bengaluru)

Taxonomic section

***Thitarodes balmiya* Grehan, Negi & Basu sp. n.**

Figs 1-7

Holotype: ♂, verbatim labels (separated by /): India, Uttrakhand, Balmiya, 1 August, 2020, 3,790 m /dissection BM773. Holotype deposited in the NCBS Research Collections.

Paratypes: 8♀, same site data as for holotype except for two at 4,000 m. Two paratypes (1 August, 2021 at 4,000 m [BM 774], & 8 August, 2021 [BM 775]) deposited in the NCBS Research Collections. Six paratypes (17 August, 2019, 27, 28, & 30, July 2021, 8 August 2021) deposited in the Department of Zoology, M B Government Postgraduate College, Haldwani.

Etymology

Named as a homonym of the type locality, Balmiya. Treated as noun in the nominative singular standing in apposition to the generic name.

Diagnosis

The sinuous shape of the valva of the male genitalia of *T. balmiya* sp. n. is distinct from all other *Thitarodes* species. The sinuous valva with the pointed apex in *T. balmiya* sp. n. contrasts with the slightly curved and lobate distal valve of the nine other Himalayan species where the male genitalia are described (Figs. 8.01-8.10). For the two Himalayan species known only by the female genitalia, *T. limbui* lacks distinct anal papillae (Fig. 8.9) while in *T. harutai* the U-shaped medial notch of the posterior margin is longer, the corners of the anal papillae are almost right-angled, and the lamella antevaginalis much wider (Fig. 8.10).

Description

♂ (Figs 1a-b). Wingspan ~44 mm, FW length: 20 mm, width: 8 mm; HW length: 17 mm, width: 7 mm.

Head: Covered with dense greyish, piliform scales. Antenna grey, filiform (Fig. 2); scape barrel-shaped, covered with piliform scales. Labial palps not examined.

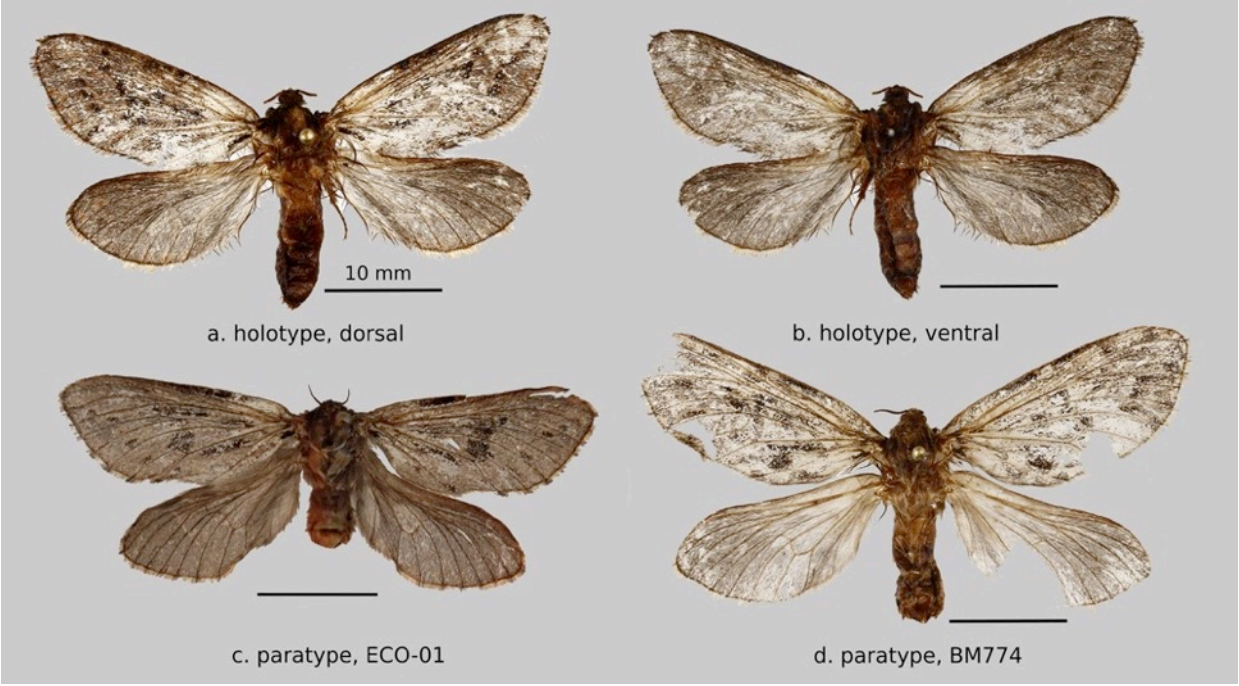
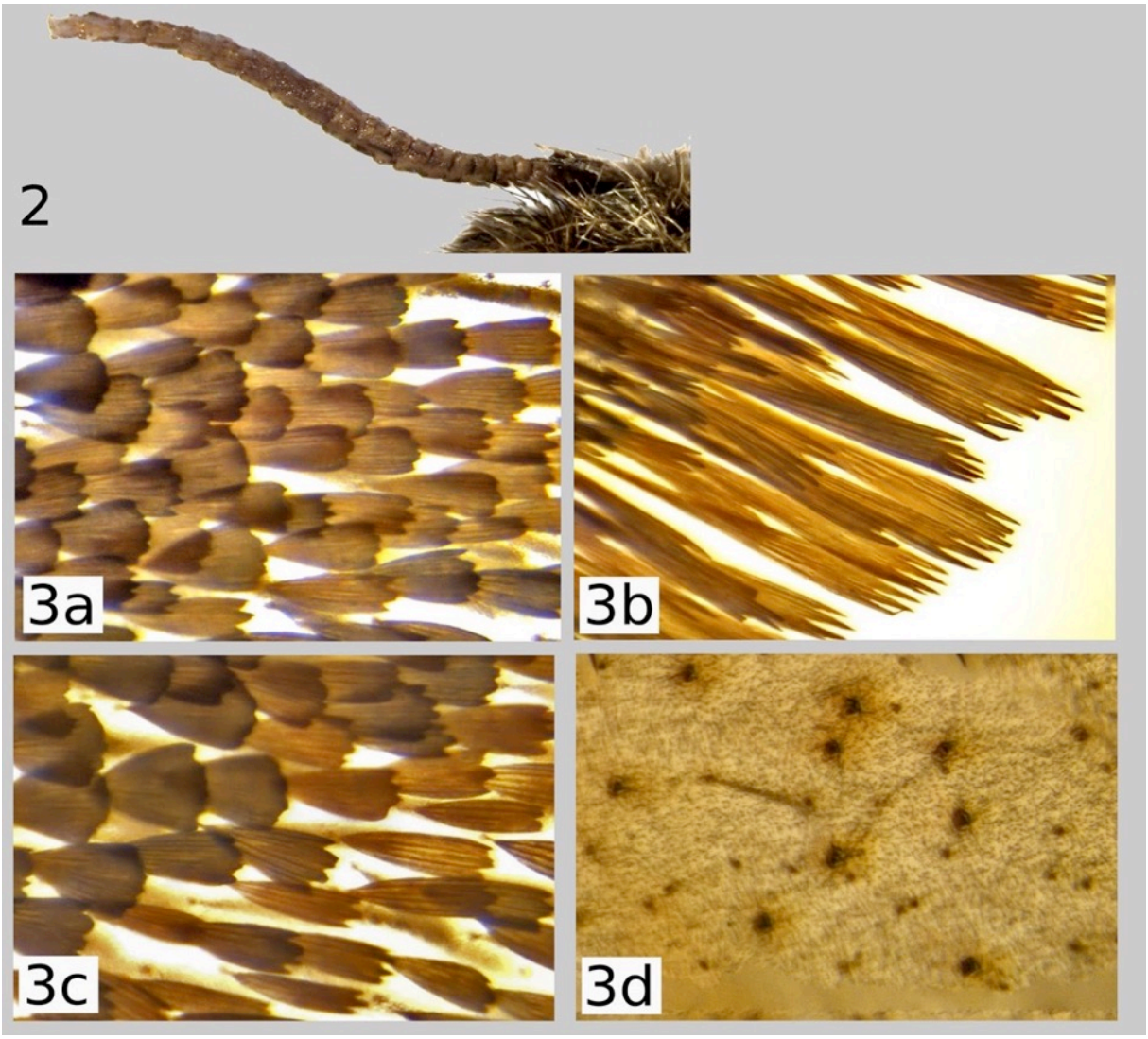


Fig. 1. *Thitarodes balmiya* sp. n. (a-b) holotype male, dorsal (a), ventral (b); paratypes (c) ECO-01: M B Govern ment Postgraduate College, Haldwani, (d) BM774: National Centre for Biological Sciences, Bengaluru. Photos 1a, b, d by Dipendra Nath Basu, 1c by Chandra Singh Negi.

Thorax: Covered with dense, dark brown piliform scales. Wings mostly covered by lamellar scales, either broad, slightly wider distally, apical margin dentate, points shallow, two medial points and single lateral point either side (Fig. 3a), or elongate with three distal points (Fig. 3b). Fringe with elongate lamellar scales with about four elongate points (Fig. 3c). Basal integument anterior to Sc with faint dark pits. Venation 'hepialine' (Fig. 4), Sc1 absent; FW: common stalk of Rs1 + Rs2 near apex; Sc and R widely spaced from each other. FW: costal margin almost straight, curving distally

to broad apex; outer margin slightly concave between CuA2 and A, tornus indistinct; ground color dark reddish-brown to grey with scattered darker grey spots and patches. HW: costal margin slightly concave, apex broad, rounded; outer margin meeting anal margin without distinct tornus. Ground color greyish brown with reddish-brown between R and costal margin. Vein A extends to wing margin. FW and HW ventral ground color greyish brown; marginal fringe pale yellowish-brown with greyish-brown spots at each vein. Legs not examined.



Figs. 2, 3. *Thitarodes balmiya* sp. n. (2) female head and antenna, dorsal view; (3) wing structures: dorsal forewing scales (a, c); forewing margin scales (b); point marks of wing integument in anal region of forewing (d). Photos by Dipendra Nath Basu.

Pregenital abdomen: Tergosternal sclerite (Fig. 5a) with narrow, elongate tergosternal bar wider at the distal end connecting with SII; lateral brace narrow, dorsal brace short relative to lateral brace, not connected with anterior margin of TII, posterior margin serrated from the lateral ridge of TII. Abdominal sclerites (Fig. 5b) weakly sclerotized; tergum II rectangular, anterior ridge not fused across median, lateral ridge robust and concave; sternum II with strongly sclerotized elongate anterolateral arms, laterally edged with slightly curved sclerotized ridge; tergum VIII rectangular, wider than long; sternum VIII weakly sclerotized, shape indistinct.

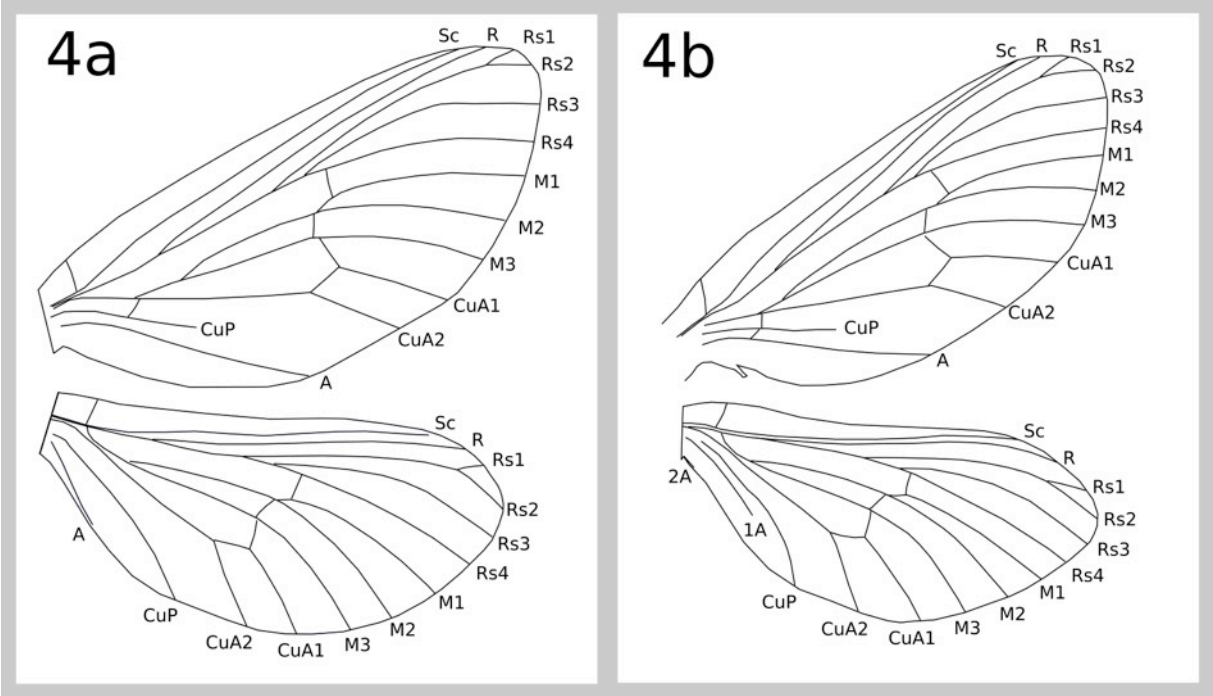


Fig. 4. *Thitarodes balmiya* sp. n. Wing venation. (a) holotype male, (b) paratype female (dissection BM774).

Genitalia (Fig. 6): Tergal lobes sclerotized, forming shallow postero dorsal ridge. Pseudotegumen dorsally fused across median, anogenital field drop-shaped, tapering to point at the apex of the pseudoteguminal arms, and dorsally forming a U-shaped margin with convex edge laterally; posterodorsally extended as a lateral shelf; anogenital margin of pseudoteguminal arms strongly sclerotized. Tegumen narrow, weakly sclerotized, not fused with pseudotegumen Valva sinuate, s-shaped, distally narrowed to a narrow, rounded point oriented anteriorly; setose, sacculus with antero-basal strongly sclerotized shallow spine with apex oriented medially and ventrally; fultura inferior weakly sclerotised, subrectangular, wider than long with concave posterior margin. Fultura superior well sclerotized, longer than wide, about half as wide as fultura inferior, extends to the base of pseudoteguminal arm. Saccus laterally narrow, posterior margin medially convex with a slight central notch, anterior margin with shallow medial notch boarded by a shallow convex edge. Apodemal suture (red dotted line in Fig. 5a) confluent with posterior saccus margin laterally, forming a concave margin medially.

♀ (Figs 1d, 5d-f, 7). Wingspan ~28 mm, FW length: 15 mm, width: 7 mm; HW length: 13 mm, width: 6 mm.

Head and thorax: As for male. HW vein 1A not extending to wing margin, 2A tiny, at wing base. Basal integument anteror to Sc and postero-basal to CuA2 with scattered dark spots or pits, intensity stronger than in male (Fig. 3d).

Pregenital abdomen: As for male with the following differences: SII wider, SVIII membranous.

Genitalia (Fig. 7): External genitalia strongly sclerotized, dorsal plate broadly fused across median, laterally forming a narrow, curved bar hinging with the lamella antevaginalis, anal papillae shallow, convex, setose; subanal sclerites trapezoidal, narrowly acute point ventro-medially, lamella antevaginalis forming a single plate with setose medial lobe projecting dorso-laterally. Internal

genitalia lacking distinction between corpus bursae and ductus bursae, together forming an elongate, irregularly shaped structure.

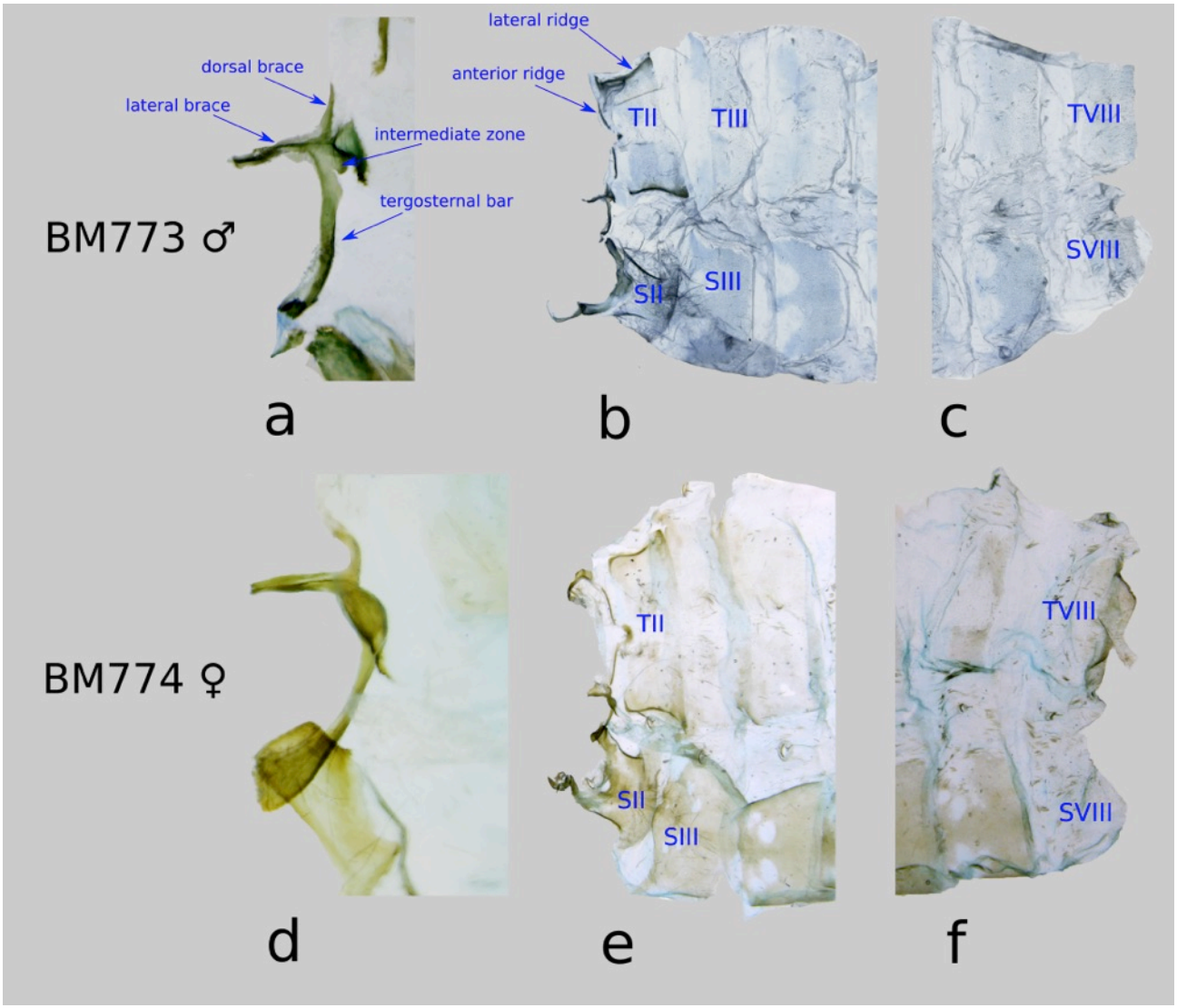


Fig. 5. *Thitarodes balmiya* sp. n. Abdominal sclerites, holotype male: (a) tergosternal sclerite, (b) anterior segments, (c) posterior segments. Paratype female: (d) tergosternal sclerite, (e) anterior segments, (f) posterior segments. Photos by Dipendra Nath Basu.

Habitat and phenology

Specimens were collected from an alpine meadow site between 3790 and 4000 m on the Balmiya ridge, located between the River Gauri, which flows out of the Milam glacier, and the River Mandakini, which flows out of the Balati glacier just to the north of the collection site, which is one of the principal glaciers of the Panchachuli range (Fig. 8). The collection site is located on a south-facing slope of 15-20º. Vegetation is dominated by low shrubs (Fig. 9), including *Anemone tetrasepala* Royle, *Geum elatum* Wallich ex D. Don (Ranunculaceae), *Polystichum stimulans* (Kunze ex Mett.) Bedds (Dryopteridaceae), *Caltha palustris* L., *Potentilla lineata* Trevir. ex Reich, *Anemone obtusiloba* D. Don, *Cortia depressa* (D. Don) Norman and *Carex setosa* Boott.

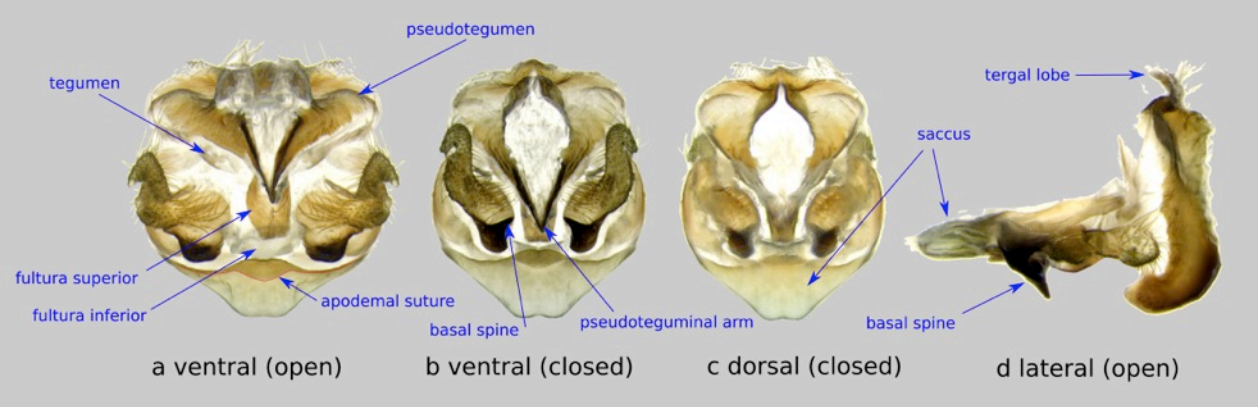


Fig. 6. *Thitarodes balmiya* sp. n. Holotype male genitalia in open (fultura superior and fultura inferior in the same plane), and closed (fultura superior and fultura inferior folded together) positions. Photos by Dipendra Nath Basu.

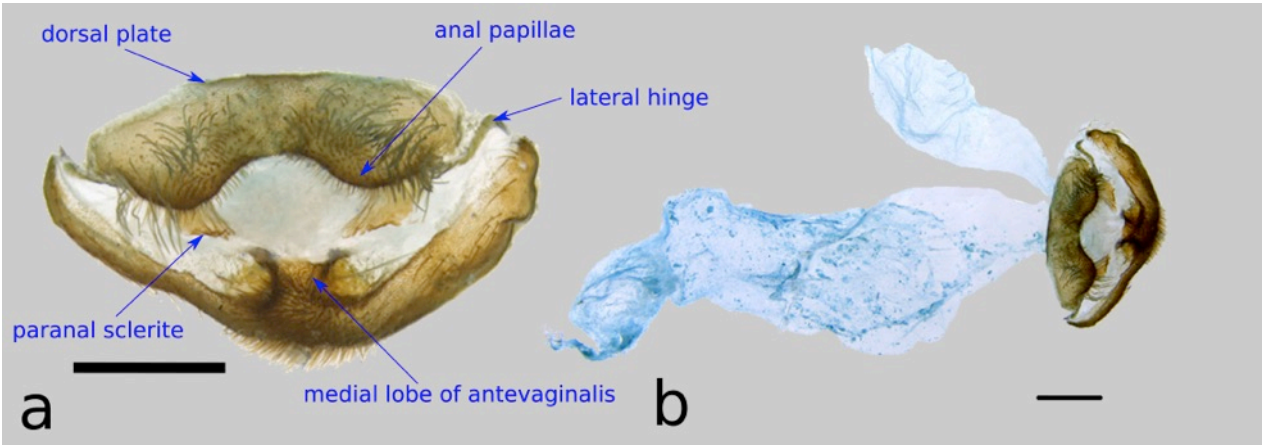


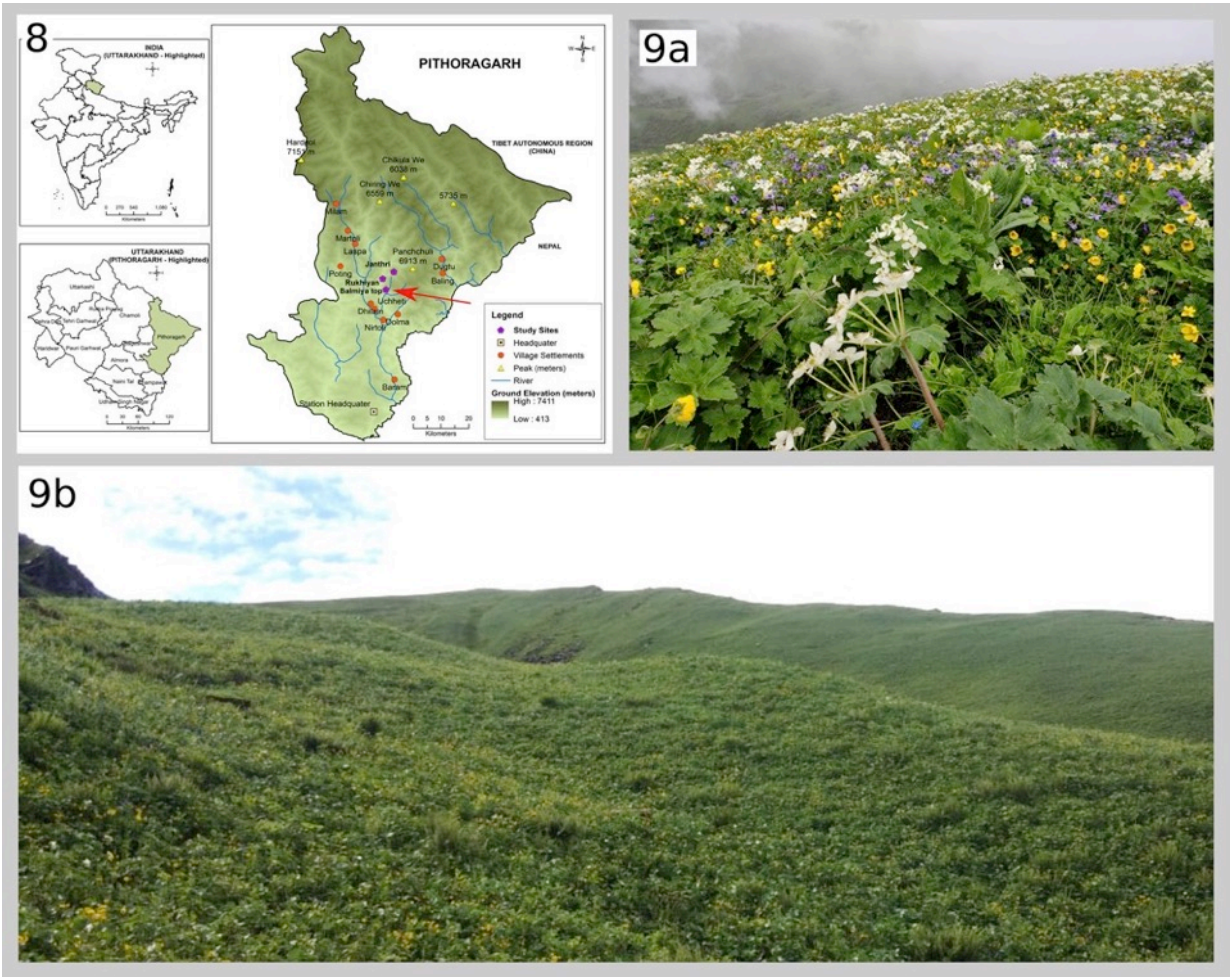
Fig. 7. *Thitarodes balmiya* sp. n. Paratype female genitalia. (a) posterior external view, (b) internal genitalia. Photos by Dipendra Nath Basu.

Moths were usually found hidden beneath plant leaves or other vegetation. Daytime conditions were moist, cloudy with intermittent drizzle, with ambient temperatures between 15-20ºC. No specimens were seen when daytime temperatures rose to about 27ºC, or on days experiencing a heavy downpour. Moths were observed flying at high speed during a brief window of time lasting about 10-15 minutes between 7:20 - 7:35 PM. In the western Himalaya, Yartsa Gunbu occurs where the average annual precipitation is at least 350 mm and usually more than 400 mm, and at altitudes of 3200-4800 m (Negi *et al*. 2014).

Discussion

The sinuous shape of the valva in *T. balmiya* sp. n. is the first recorded instance within the genus. This structural difference is sufficiently distinct to be considered a species-level difference rather than variation within known species. This is an important consideration as the illustration of male genitalia for *T. namnai* presents variations in the shape and sclerotization of the pseudotegumen apex (Maczey *et al*. (2010), and the generalized diagrammatic illustrations of some *Thitarodes* species show very little discernible difference in the male genitalia. The male genitalia are described for eight of the 10 previously known *Thitarodes* species from the Himalaya (Fig. 10). For the two species known by female genitalia only, *T. balmiya* sp. n. differs from *T. harutai* (Fig. 10i)

by a narrower lateral lamella antevaginalis, and *T. limbui* (Fig. 10j) by a dorso-ventrally broad dorsal plate. In addition, both of these species lack the dark, speckled forewing pattern of *T. balmiya* sp. n. (c.f. Ueda 2000; pl. 169, figs. 10-11).



Figs. 8-9. *Thitarodes balmiya* sp. n. distribution and habitat. (8) Type locality marked by the red arrow, (9) vegetation (a) and topography (b) of collecting site.

Our taxonomic assignment of *T. balmiya* sp. n. to *Thitarodes* is based on the similarity of its genitalia to a range of species currently included within *Thitarodes*, including the type species *T. armoricanus* (Oberthür, 1909) (Fig. 11a.6), and the absence of features corresponding to any of the other Eurasian genera (*Hepialus* Fabricius, 1775, *Pharmacis* Hübner, [1820], *Triodia* Hübner, [1820], and *Phymatopus* Wallengren, 1869 in northern Eurasia, and *Endoclita* C. & R. Felder, 1874, *Hepialiscus* Hampson, 1892, *Magnificus* Yan, 2000, and *Palpifer* Hampson, 1893, and *Parathitarodes* Ueda, 1999 in southern and eastern Asia. In the original description of the genus, Viette (1968) noted that above all, the genus was characterized by the presence of a more or less long spur, sometimes having only the shape of a point, at the base of the valva which is well sclerotized. The presence of the spur in *T. balmiya* sp. n. is therefore consistent with its inclusion in *Thitarodes* and corresponds to this feature being present in the type species.

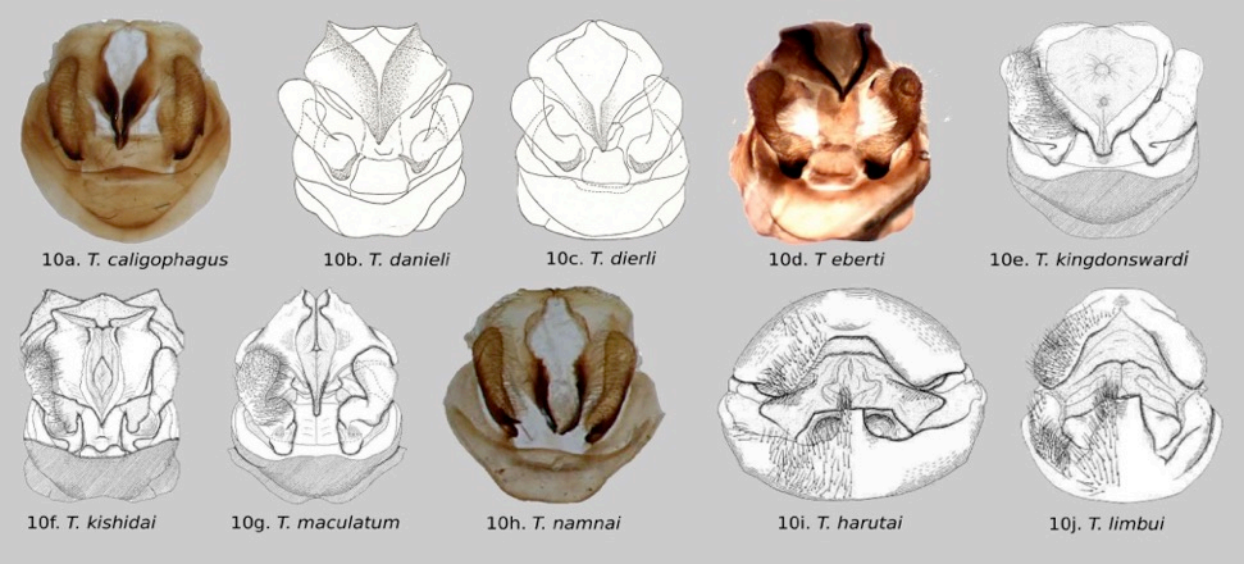


Fig. 10. Male and female genitalia of Himalayan *Thitarodes* species (female genitalia shown where male genitalia are not described). (a) *T. caligophagus* Maczey, 2010 in Maczey *et al*. (2010: fig. 29); (b) *T. danieli* Ueda 2000: fig. 1396b; (c) *T. dierli* Ueda, 2000: fig. 1408B, (d) *T. eberti* (JRG dissection M201), (e) *T. kingdonswardi* Ueda, 2000: fig. 1416A; 8.7, *T. kishidai* Ueda, 2000: fig. 1414B; (f) *T. maculatum* Ueda, 2000: fig. 1400A; (g) *T. namnai* Maczey, 2010 in Maczey *et al*. (2010: fig. 17); (h) *T. harutai* Ueda, 2000: fig. 148B; (i) *T. limbui* Ueda, 2000: fig. 1419A.

Subsequent to Viette's (1968) description of *Thitarodes*, many other species have been attributed to this genus. Since some species lack the basal spur (Figs. 11a & 11b) this feature is not diagnostic of the genus for all species currently included. The presence of a basal spur is a derived feature within the Hepialidae, since it is absent from the other hepialoid families Anomosetidae (Kristensen 1978), Neotheoridae (Simonsen & Kristensen 2017), Prototheoridae (Davis 1996), Palaeosetidae (Issiki & Stringer 1932, Kristensen & Nielsen 1994). However, its phylogenetic significance within *Thitarodes* is equivocal because the structure also occurs in the New World genera *Schausiana* Viette (Mielke *et al*. 2020), *Phthius* Mielke & Grehan, 2017 (Mielke & Grehan 2017) and *Pallas* Mielke & Grehan, 2015 (Mielke & Grehan 2015).

Zou *et al*. (2010) proposed limiting *Thitarodes* to a subset of species along with two new genera – *Ahamus* Zou, Liu, & Zhang, 2010 and *Parahepialus* Zou, Liu & Zhang, 2010, but their assessment did not include all species of the genus and the generic categories were described rather than cladistically delineated by one or more unique features. Jiang *et al*. (2016) doubted the validity of both new genera with reference to both morphology and molecular sequence similarities and formally synonymized *Parahepialus* under *Thitarodes* as listed by Nielsen *et al*. (2000). We accept *Thitarodes* as the currently valid taxonomic designation, including *Ahamus* as well as *Parahepialus* as junior synonyms. The genitalic illustration by Zou *et al*. (2010: fig. 7) for '*Ahamus*' *macilentus* (Eversmann, 1851) conforms to the northern Eurasian genus *Gazoryctra* (see also Tshistjakov 1996). The large number of species included within *Thitarodes*, along with the contrast between species with or without a basal spine in the male genitalia, may invite consideration of smaller generic units in the future, but this should be evaluated in a comprehensive systematic assessment where any proposed genera are substantiated by one or more morphologically unique features.

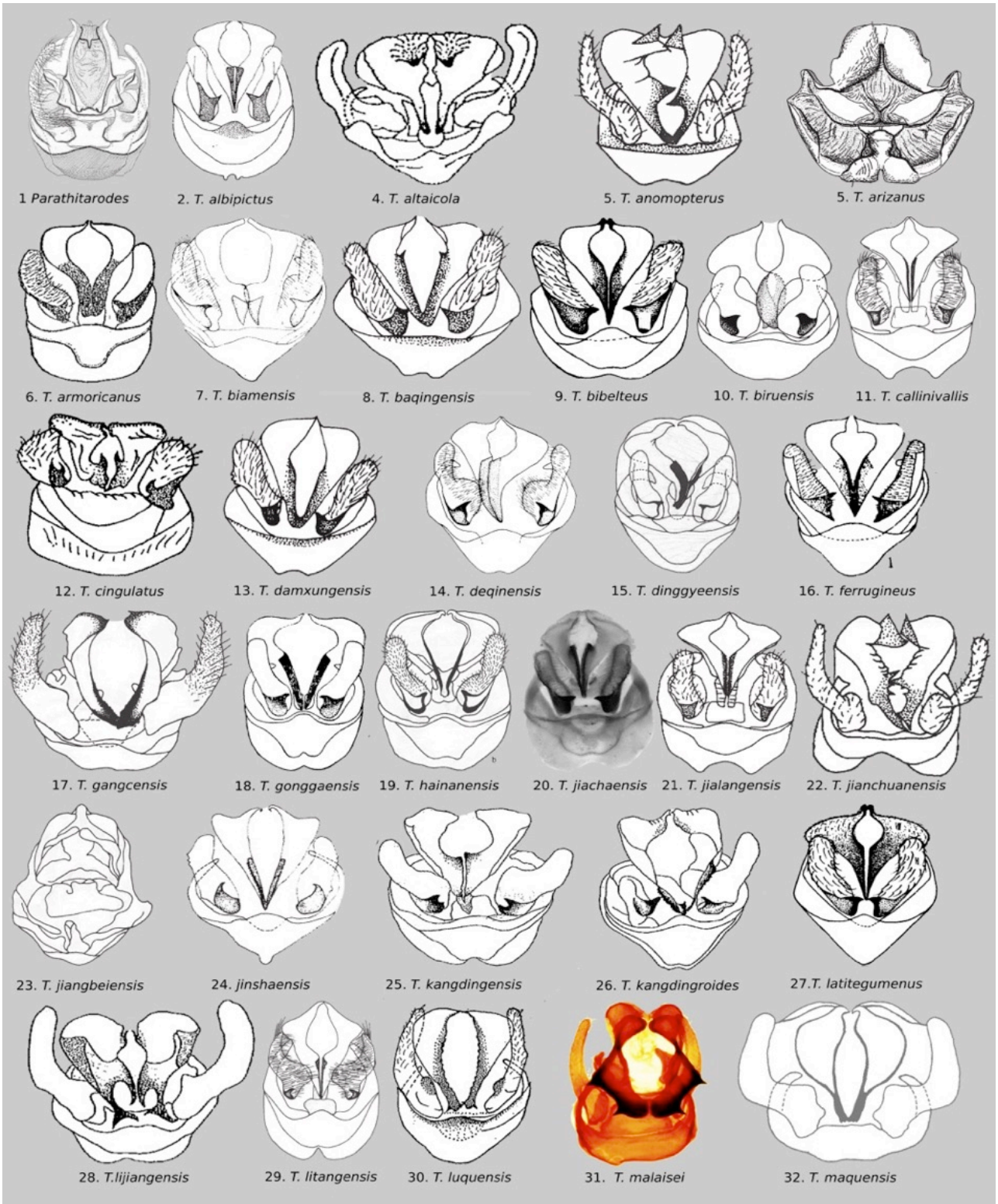


Fig. 11a (1-32). Genitalia of *Parathitarodes* and *Thitarodes* species outside the Himalaya (female genitalia shown where male genitalia are not described). (see details below)

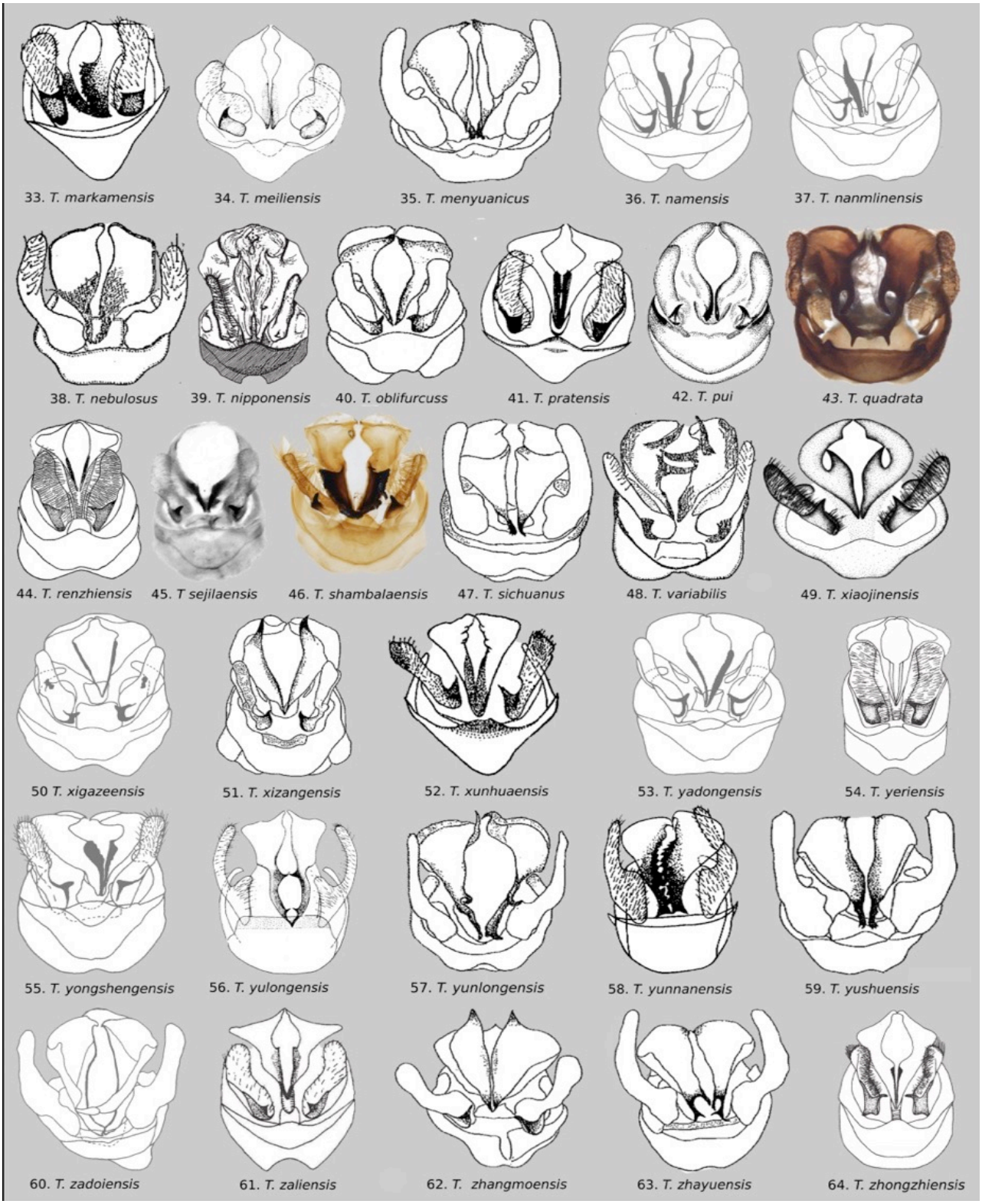


Fig. 11b (33-64). Genitalia of *Thitarodes* species outside the Himalaya (female genitalia shown where male genitalia are not described). (see details below)

Explanation of Fig. 11a: 1 *Parathitarodes changi* Ueda, 1999: fig. 1; **2** *T. albipictus* (Yang, 1993: fig. 1); **3** *T. altaicola* (Wang 1990: fig. 1b); **4** *T. anomopterus* (Yang, 1994: fig.4b); **5** *T. arizanus* (Matsumura, 1931) Ueda (1999: fig. 8a); **6** *T. armoricanus* (Oberthür, 1909) (Viette 1949, fig. 4); **7** *T. biamaensis* (Liang, 1988) in Liang *et al*. 1988: fig. 4); **8** *T. baqingensis* (Yang & Jiang, 1995: fig. 1B); **9** *T. bibelteus* Shen & Zhou, 1997: fig. 1); **10** *T. biruensis* (Fu, 2002 in Fu *et al*. 2002: fig. 1a); Fig. **11** *T. callinivalis* (Liang, 1995: fig. 7); **12** *T. cingulatus* (Yang & Zhang: in Yang *et al*. 1995: fig. 4); **13** *T. damxungensis* (Yang & Jiang, 1995: fig. 2B.); **14** *T. deqinensis* (Liang in Liang *et al*., 1988:); **15** *T. dinggyeensis* Chu & Wang (in Zhu, *et al*. 2004: fig. 108B); **16** *T. ferrugineus* (Li, Yang & Shen, 1993: fig. 1); **17** *T. gangacensis* (Chu & Wang, in Zhu *et al*. 2004: fig. 66b); **18** *T. gonggaensis* (Fu & Huang in Fu *et al*. 1991: fig. 2 [note that the subsequent figure in Zhu *et al*. (2004: fig. 95b) shows some differences to the original figure]; **19** *T. hainanensis* (Chu & Wang, in Zhu *et al*. 2004: fig. 116b); **20** *T. jiachaensis* Zou, Liu & Zhang, 2011: fig. 10a; **21** *T. jialangensis* (Yang, 1994: fig. 2b); **22** *T. jianchuanensis* (Yang, 1994: fig. 1b); **23** *T. jiangbeiensis* (Chu & Wang, in Zhu *et al*. 2004: fig. 125b); **24** *T. jinshaensis* (Yang, 1993: fig. 4); **25** *T. kangdingensis* (Chu & Wang, 1985: fig. 6); **26** *T. kangdingroides* (Chu & Wang, 1985: fig.18); **27** *T. latitegumenus* Shen & Zhou, 1997: fig. 5); **28** *T. lijiangensis* (Chu & Wang, 1985: fig. 24); **29** *T. litangensis* (Liang, 1995: fig. 10); **30** *T. luquensis* (Yang & Yang in Yang *et al*., 1995: fig. 10); **31** *T. malaisei* (Bryk, 1946), Swedish Museum of Natural History image; **32** *T. maquensis* (Chu & Wang in Zhu *et al*., 2004: 118).

Explanation of Fig. 11b: 33 *T. markamensis* (Yang, Li & Shen, 1992: fig. 2d); **34** *T. meiliensis* (Liang in Liang *et al*., 1988: fig. 7); 35 *T. menyuanicus* (Chu & Wang, 1985: fig. 14); **36** *T. namensis* (Chu & Wang in Zhu *et al*., 2004: 119b); **37** *T. nanmlinensis* (Chu & Wang in Zhu *et al*., 2004: fig. 88b); **38** *T. nebulosus* (Alphéraky, 1889) (Viette 1949: fig. 3); **39** *T. nipponensis* Ueda, 1996: fig. 6b); **40** *T. oblifurcus* (Chu & Wang, 1985: fig. 11); **41** *T. pratensis* (Yang, Li & Shen, 1992: fig. 3d); **42** *T. pui* Zhang, Gu & Lui, 2007: fig. 11); **43** *T. quadrata* Jiang, Li, Li, Li & Han, 2016: fig. 6; **44** *T. renzhiensis* (Yang, Shen, Yang, Liang, Dong, Chun, Lu & Sinaduji, 1991: fig. 1); **45** *T. sejilaensis* Zou, Liu & Zhang, 2011: 5a; **46** *T. shambalaensis* Wang, Zhuang, Wang & Pierce, 2019: fig. 4a; **47** *T. sichuanus* (Chu & Wang, 1985a: fig. 16); **48** *T. variabilis* (Bremer, 1861), Viette (1949: fig. 5); **49** *T. xiaojinensis* (Tu, Ma & Zhang, 2009: 123); **50** *T. xigazeensis* (Chu & Wang in Zhu *et al*., 2004: fig. 51b); **51** *T. xizangensis* (Chu & Wang, 1985a: fig. 38); **52** *T. xunhuaensis* (Yang & Yang in Yang *et al*., 1995: fig. 2); **53** *T. yadongensis* (Chu & Wang in Zhu *et al*., 2004: fig. 90b); **54** *T. yeriensis* (Liang, 1995: fig. 4); **55** *T. yongshengensis* (Chu & Wang in Zhu *et al*., 2004: fig. 83b); **56** *T. yulongensis* (Liang, 1988 in Liang *et al*. 1988: fig. 10); **57** *T. yunlongensis* (Chu & Wang, 1985: fig. 22); **58** *T. yunnanensis* (Yang, Li & Shen, 1992: fig. 1d); 5**59** *T. yushuensis* (Chu & Wang, 1985a: fig. 9); **60** *T. zadoiensis* (Chu & Wang in Zhu *et al*., 2004: 61b); **61** *T. zaliensis* (Yang, 1994: 3b); **62** *T. zhangmoensis* (Chu & Wang, 1985a: fig. 26); **63** *T. zhayuensis* (Chu & Wang, 1985a: 28); **64** *T. zhongzhiensis* (Liang, 1995: fig. 1).

Conservation and sustainability

As in other regions, the future sustainability of *Thitarodes balmiya* sp. n., and any other congeneric species in the alpine regions of Uttarakhand, is contingent upon the manner and intensity of harvesting larvae infected by *O. sinensis*. This situation is a prime example of a resource of immense economic value running the risk of being over-exploited, especially when its exploitation is treated as a 'common property resource'. The ever-increasing demand for this commodity in the international market, along with its concomitantly increasing commercial value, has resulted in both rampant exploitations and the degradation of the very habitat necessary for the viability of

Thitarodes along with its fungal parasite. One unintended consequence is that other economic resources such as herbal plants are being extracted before their flowering season and shedding seeds (Negi *et al*. 2016). These ecological threats may also be compounded by the impact of global climate change that is already affecting temperature and rainfall patterns. The Himalaya are among the regions's most vulnerable to the ecological and economic impacts of climate change (Shrestha *et al*. 2012, Wester *et al*. 2019). Community-based management may be the best approach to ensuring the future sustainability of Yartsa Gunbu harvesting, but for this to be accomplished it will be necessary for local communities to understand the problems arising out of commercial exploitation, and institute management mechanisms at the local level for sustainable harvesting (Negi *et al*. 2015).

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