forests

MDPI

*Review*

# Contribution to Knowledge of the Oriental Taxa of the *Diduga* (Lepidoptera: Erebidae: Arctiinae)

**Ulziijargal Bayarsaikhan [1,2,3], John B. Heppner [4], Karol Bucsek [5], Yeong-Bin Cha [1], Yang-Seop Bae [1,2,*] and Hyung Wook Kwon [1,3,*]**

1 Division of Life Sciences, College of Life Sciences and Bioengineering, Incheon National University, Songdo-dong, Incheon 22012, Republic of Korea; uug0228@gmail.com (U.B.); cyb0201@naver.com (Y.-B.C.)
2 Bio-Resource and Environmental Center, Division of Life Sciences, College of Life Sciences and Bioengineering, Incheon National University, Songdo-dong, Incheon 22012, Republic of Korea
3 Convergence Research Center for Insect Vectors, Division of Life Sciences, College of Life Sciences and Bioengineering, Incheon National University, Songdo-dong, Incheon 22012, Republic of Korea
4 McGuire Center for Lepidoptera and Biodiversity, Florida Museum of Natural History, University of Florida, Gainesville, FL 32611, USA; jheppner@flmnh.ufl.edu
5 Slovak Academy of Sciences, Institute of Zoology, Dúbravská cesta 9, 845 06 Bratislava, Slovakia; monosyntaxis@gmail.com
* Correspondence: baeys@inu.ac.kr (Y.-S.B.); hwkwon@inu.ac.kr (H.W.K.)

**Abstract:** The type material of *Diduga costata* Moore, [1887], *D. flavicostata* (Snellen, 1879), *D. fulvicosta* Hampson, 1891, *D. barlowi* Holloway, 2001, and *D. zetes* Bucsek, 2014 are presented. Three new species are described based on the genitalia of type specimens from Indonesia (Sulawesi) and Laos. Three new combinations and one new synonym are established. An updated checklist of known species of the genus are presented with information of depositors and distributions. Illustrations of the adults and genitalia of the type materials and examined species are provided.

**Keywords:** insect; mosquito; moth; identification; new species; distribution



**Citation:** Bayarsaikhan, U.; Heppner, J.B.; Bucsek, K.; Cha, Y.-B.; Bae, Y.-S.; Kwon, H.W. Contribution to Knowledge of the Oriental Taxa of the *Diduga* (Lepidoptera: Erebidae: Arctiinae). *Forests* **2023**, *14*, 889. https://doi.org/10.3390/f14050889

Academic Editor: Dariusz J. Gwiazdowicz

Received: 14 March 2023
Revised: 20 April 2023
Accepted: 21 April 2023
Published: 26 April 2023



## 1. Introduction

Erebidae is one of the taxonomically more diverse families of the superfamily Noctuoidea, with a global total of 24,500 described species of about 1750 genera in 18 subfamilies [1,2]. The synapomorphy of the subfamily Arctiinae is a prespiracular countertympanal hood (earlike structure) [2]. Locations of the tympanal ears of insects are different for each group: on the thorax (Noctuoidea, Corixidae, etc.), abdomen (Pyraloidea, Geometroidea, Drepanoidea, Cicadoidea, etc.), wings (Hedyloidea, Papilionoidea, Chrysopidae, etc.), forelegs (Grylloidea, Tettigonioidea, etc.), mouth-parts (Bombycoidea), antenna (Culicoidea, Tephritidae, Corbiculata-*Apis*), etc. The presence of a pair of dorsal pheromone glands of females [3–5] and vein Sc of the hindwing, which tends to be swollen basally in both sexes [3], are the best synapomorphic characters of this subfamily.

The genus *Diduga* Moore, [1887] (in 1884–1887) is one of the smaller genera within the tribe Lithosiini (Arctiinae). It was erected for its type species, *Diduga costata* Moore, 1887 from Sri Lanka. Until the early 2000s, the type species of *Diduga* was designated as *Pitane flavicostata* Snellen following Hampson's catalogue [6]. Holloway [7] characterized the adults and genitalia of this genus and redesignated *D. costata* Moore as the type species of this genus without illustrations of the two candidate species. Meanwhile, Fang [8] recorded *D. flavicostata* from China as the type species as *D. costata*.

Recently, Zhao & Han [9] listed this genus with the inclusion of 43 species, but the species *Utriculoferiana macroplaga* (Hampson, 1900) was erroneously included in the present genus. One new species, *D. weiweii* Zhao, Wu & Han, 2020, has been described by Zhao et al. [10] from Malaysia; one new species, *D. sphaeracephalus* Bayarsaikhan & Bae, 2020 by Bayarsaikhan et al. [11] from Thailand; two new species, *D. hastata* Bayarsaikhan &

Bae, 2021 and *D. mucronata* Bayarsaikhan & Bae, 2021 by Bayarsaikhan et al. [12] from Laos; and one new species, *D. nantouensis* Bayarsaikhan & Bae, 2021 by Bayarsaikhan et al. [13] from Taiwan. To date, 47 described species are known in the genus *Diduga* in the world.

At this time, a new synonym, *D. zetes* **syn. nov.** for *D. barlowi* Holloway and three new combinations, *Tospitis metaleuca* (Hampson), **comb. nov.**, *T. amoenusa* (Bucsek), **comb. nov.**, and *T. ambigua* (Bucsek), **comb. nov.** to the genus *Tospitis* Walker, 1863, are proposed. Additionally, three new species, two from Indonesia (northern Sulawesi) and one from Laos (Bolikhamsai province), are described based on the genitalia of the type species *D. costata* and *D. flavicostata*.

## 2. Materials and Methods

The present study was based on the collections of Incheon National University (Incheon, Republic of Korea) and McGuire Center for Lepidopteran and Biodiversity, Florida Museum of Natural History (Gainesville, FL, USA). All types of the *D. robdevosi* **sp. nov.** are deposited in the INU, and *D. minahasa* **sp. nov.** and *D. dumoga* **sp. nov.** are in the MGCL. Figures of the holotypes and syntypes of the species *D. costata*, *D. flavicostata*, *D. fulvicosta*, *D. barlowi*, *D. zetes*, *D. metaleuca*, *D. amoenusa*, and *T. ambigua* are based on material from collections of Museum WITT München (München, Germany), the Natural History Museum (London, UK), and the Naturalis Biodiversity Center (Leiden, The Netherlands).

## 3. Results

### *3.1. Systematic Accounts of the Genus Diduga Moore, [1887]*

*Diduga* Moore [14]: 535. TS: *Diduga costata* Moore, [1887].
*Androstigma* Hampson [15]: 13, 82. TS: *Diduga albicosta* Hampson, 1891.

- Note. *Diduga* was recently characterized by Holloway [7].

### *3.2. The Species of Diduga*

#### 3.2.1. *Diduga costata* Moore [1887]

*Diduga costata* Moore [14]: 535. TL: Sri Lanka (Dickoya).

Type material examined. Holotype of *Diduga costata*: male (Figure 1a), "Ceylon | ♂ | Green | 12"/"*Diduga costata* ♂ | Type. Moore"/red ring "Type" label/"Moore Coll. | 94–106."/QR-code label with a unique number: "NHMUK010598569" (prepared by Volynkin) (NHMUK).

Redescription. *Adult* (Figure 1a). Wingspan 16 mm in the male. Head and patagium deep yellow. Thorax dark brown. Ground color of narrow triangular forewing dark brown, with broad, deep yellow costal and terminal border. Costal margin with two dark brown, irregularly triangular patches in antemedial and postmedial lines edged by a narrow dark line from basal to antemedial patch. Cilia deep yellow. Hindwing pale brown. Cilia pale brown. Abdomen pale brown. *Male genitalia* (Figure 2a). Uncus irregularly conic, with hook-shaped apical process, heavily covered with long setae. Tegumen triangular, weakly sclerotized. Symmetric valvae stout, with a long, slender, waved, spine-shaped projection in the upper angle and a stout, short (half-length of upper one), waved, finger-shaped projection in the lower angle; costal area broadly rounded, with sclerotized margin; and sacculus blunted, roundly angled, with stronlgy sclerotized margin and membranous sacculus process elongated, almost the same length with an upper angle's projection. Juxta weakly sclerotized, elongated, arch-shaped. Vinculum strongly sclerotized, short (one-third length of tegumen), saccus rectangular. Aedeagus (broken in the slide) and vesica covered with short, thin spines and a bundle of large (3–4 times longer than thin spines) spines consisting of nine same-sized spines. *Male pregenital plate* (Figure 2b). Abdomen with median apodeme structure of lyrelike shape on pregenital tergite and directed anteriorly as twin thin arms with slightly recurved apices. *Female genitalia* (Figure 3a). Papillae anales weakly covered with setae. Antevaginal plate broadly U-shaped, weakly sclerotized. Ductus bursae tubular, membranous, with a large sclerotized rounded plate. Bulla membranous, broadly tubular. Ovoid corpus bursae membranous, without signum. *Female pregenital plate*

(Figure 3b). The female pregenital sternite, laterally on each side to a sclerotized pouch on the intersegmental membrane.


**Figure 1.** Adults of type materials of the genus *Diduga* spp. (**a**) *D. costata*, holotype, male; (**b**) *D. fulvicosta*, holotype, female (deposited in NHMUK); (**c**) *D. flavicostata*, syntype, male; (**d**) *ditto*, syntype, female (deposited in RMNH).

Distribution. India [16], Sri Lanka [14].

3.2.2. *Diduga flavicostata* (Snellen, 1879)

*Pitane flavicostata* Snellen [17]: 92. TL: Indonesia (Makassar).
*Diduga fulvicosta* Hampson [18]: 52. TL: India (Nilgiris).
*Diduga flavicostata*: Hampson [6]: 541.
*Diduga costata*: Hampson [6]: 541.

Type material examined. Syntypes: two males (Figure 1c), Indonesia, Makassar, Cat. No. 12, RMNH.INS.1098990 and Cat. No. 13, RMNH.INS.1098991; one female (Figure 1d), Indonesia Bonthain, Cat. No. 11, RMNH.INS.1098992; two females, Indonesia, Takalar, Cat. No. 14, RMNH.INS.1098993 and Cat. No. 15, RMNH.INS.1098994. Holotype of *Diduga fulvicosta*: female (Figure 1b), "NILGIRIS. | Hampson Coll. | 89–129."/"296. | *A*."/"*Diduga fulvicosta*. | -Hampson. | type ♀"/red ring "Type" label/QR-code label with a unique number: "NHMUK010598570" (NHMUK).

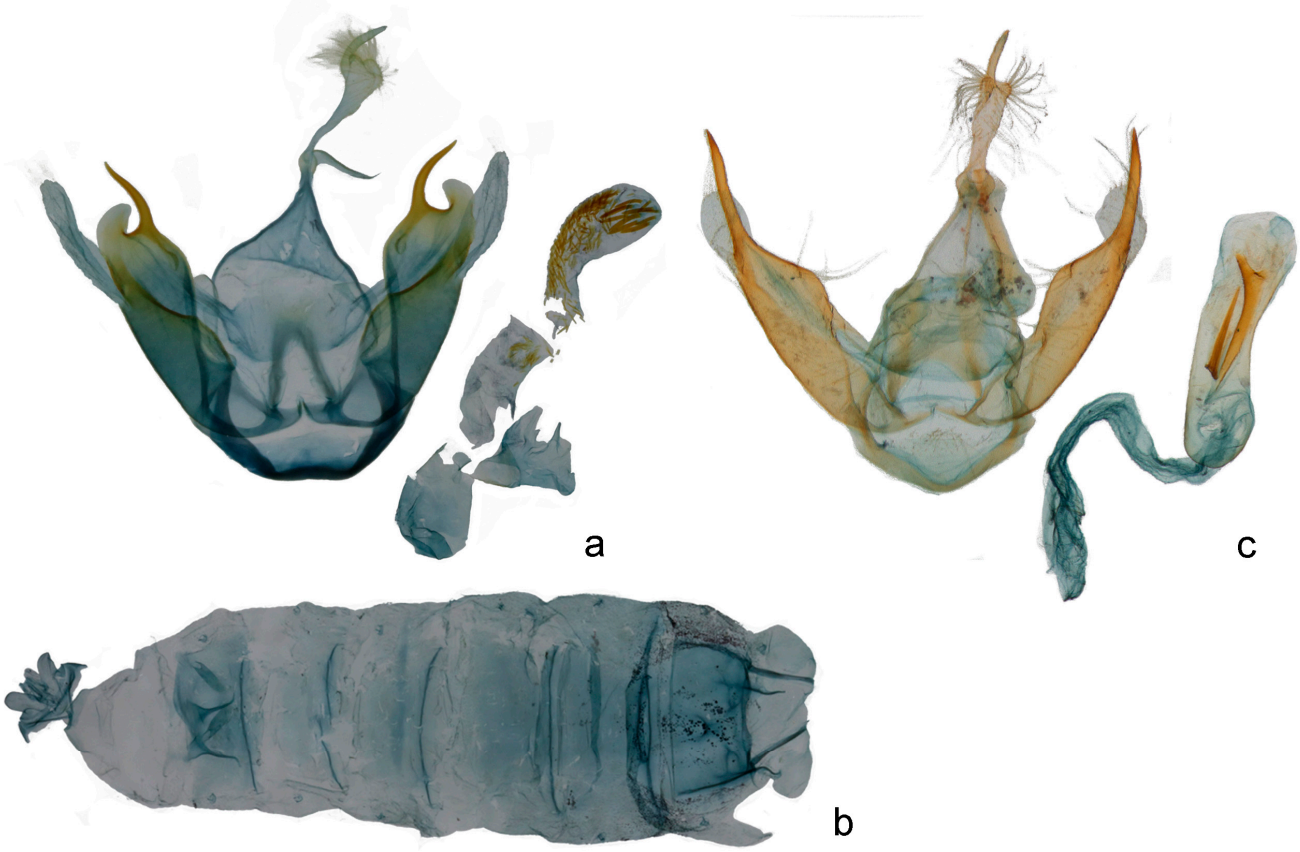


**Figure 2.** Male genitalia and pregenital abdomen of type materials of the genus *Diduga* spp. (aedeagi to right). (**a**) *D. costata*, slide Arc4684 Volynkin; (**b**) *ditto*, pregenital abdomen, slide Arc4683 Volynkin; (**c**) *D. flavicostata*, syntype, slide RMNH.INS.1098990 Rob de Vos.

Redescription. *Adult* (Figure 1b–d). Wingspan 10 mm in male, 11 mm in female. Head and patagium light yellow. Thorax dark brown. Ground color of broadly triangular forewing dark brown, with broad, deep yellow costal and terminal border. Costal area with several small dark brown dots or absent, and costal margin more deep yellow, edged by a narrow dark line in the basal area. Cilia light yellow. Hindwing pale brown. Cilia pale brown. Abdomen pale brown, with pale yellow anal tuft in both sexes. *Male genitalia* (Figure 2c). Uncus irregularly conic, with a hook-shaped apical process, heavily covered with long setae. Tegumen triangular, weakly sclerotized. Symmetric valvae elongated, with a spine-shaped apex; costal area broadly rounded and sclerotized; sacculus sclerotized, and rounded saccular process membranous, shorter than apex of valva. Juxta weakly sclerotized, irregularly arch-shaped. Vinculum sclerotized, short, and saccus rounded. Aedeagus stout and vesica with a large spine and an elongated sclerotized plate. *Male pregenital plate*. Not provided. *Female genitalia* (Figure 3c). Papillae anales weakly covered with setae. Ductus bursae broadly tubular, weakly sclerotized. Ovoid corpus bursae membranous, with a large and sharply flexed band, covered with diverse-sized spines. *Female pregenital plate*. Not provided.

Distribution. India [19,20], China [8], Thailand [21], Cambodia and Malaysia [22], and Indonesia (Sulawesi, Java) [17, present paper].

Remarks. The adults and male genitalia of *D. flavicostata* were first illustrated by Bucsek [22], but after checking the syntypes of this species, it was found to belong to a new species. Indeed, all reports of *D. flavicostata* from the countries mentioned earlier may need further confirmation.

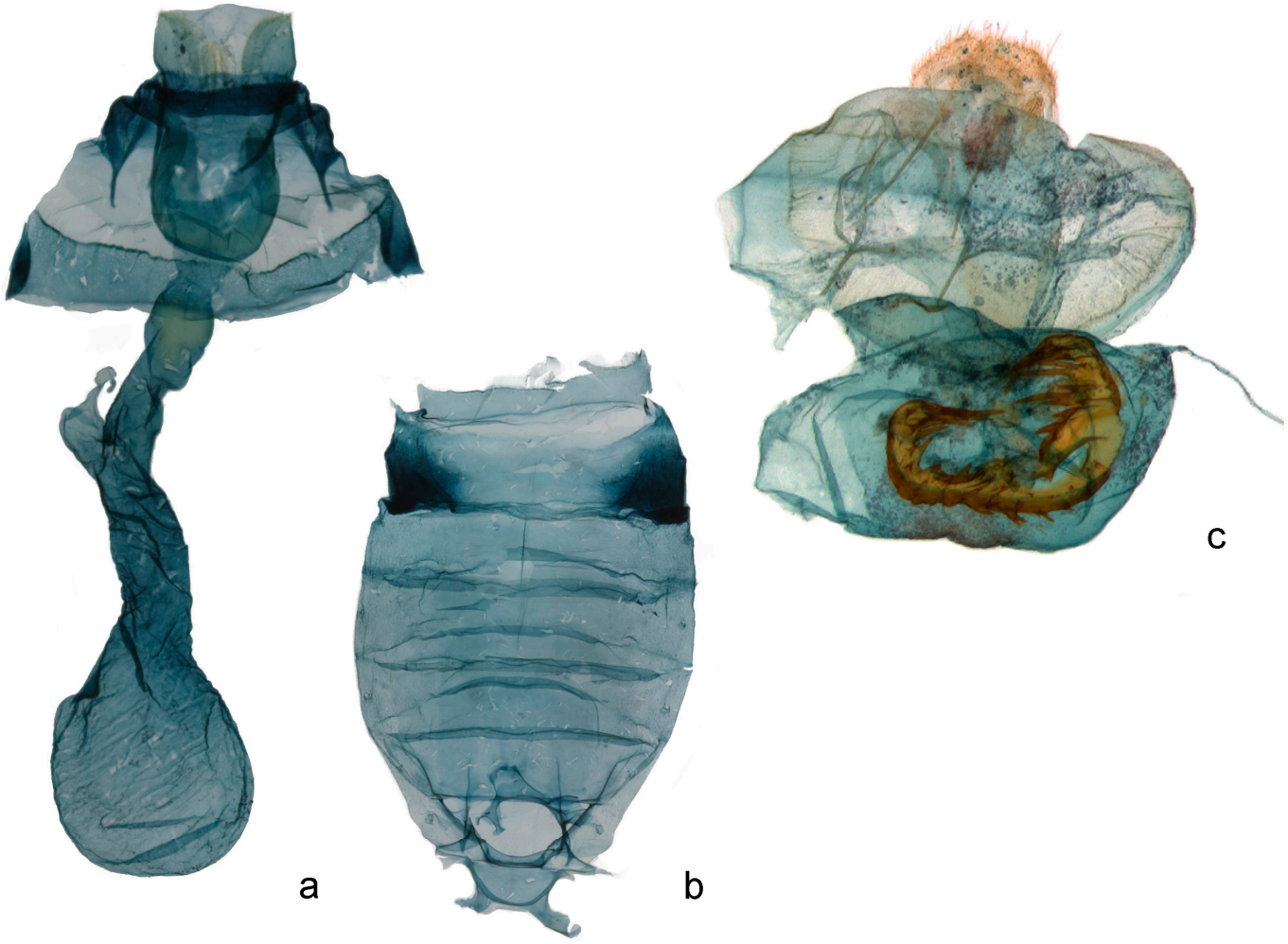


**Figure 3.** Female genitalia and pregenital abdomen of type materials of the genus *Diduga* spp. (**a**) *D. costata*, slide Arc4684 Volynkin; (**b**) *ditto*, pregenital abdomen, slide Arc4684 Volynkin; (**c**) *D. flavicostata*, syntype, slide RMNH.INS.1098992 Rob de Vos.

3.2.3. *Diduga minahasa* Bayarsaikhan, Heppner and Bae, **sp. nov.**

Type materials. Holotype ♂, Indonesia, Sulawesi, Dumoga-Bone National Park, 11–15 October 1985 (JBH), adult no. ARCT14578M and gen. slide no. JBH–3935, deposited in MGCL. Paratype (one female) INDONESIA: same data as holotype, adult no. ARCT14579F and gen. slide no. JBH–3936, deposited in MGCL.

Diagnosis. The wing pattern of this species is hardly distinguishable from many others of the genus *Diduga*. The male genitalia structure of the new species is similar to *D. ciliata* Holloway, 2001, but can be distinguished from the latter by the costal processes being symmetric, strongly flexed, with dilated apex and the left saccular process broader than the right; both processes are heavily covered with setae. In *D. ciliata*, the costal processes are asymmetric; the left one is tongue-shaped and the right one is hammer-headed, and the left saccular process is narrower than the right, not covered with setae [7].

In the female genitalia, membranous corpus bursae ovoid and wrinkled, with dentate and strongly sclerotized bands, cover the whole of bursae, separating this species well from all the other known *Diduga*.

Description. *Adult* (Figure 4a,b). Wingspan 11.5 mm in male (n = 1), 10.5 mm in female (n = 1). Head and patagium light yellow. Thorax dark brown. Ground color of broadly and roundly triangular forewing dark brown, with broad, deep yellow costal and terminal border. Costal area with two dark brown, triangular patches in antemedial (almost two times larger than postmedial patch) and postmedial lines and a row of small, dark dots

or patches from basal of costa to tornus, edged by a narrow dark line in the basal area. Cilia deep yellow. Hindwing dark brown. Cilia dark brown. Abdomen dark brown, with pale yellow anal tuft in the male and dark brown in the female. *Male genitalia* (Figure 5a). Uncus slender, with small apical spine, heavily covered with setae. Tegumen triangular, weakly sclerotized, shorter than uncus. Asymmetric valvae with two symmetric basal costal processes, weakly sclerotized and strongly curved with a dilated apex; stout right valva weakly sclerotized, with a pointed apex, sacculus weakly sclerotized, and saccular process with a bundle of strong setae; apex of broader left valva heavily covered with strong setae. Juxta weakly sclerotized and plate-shaped. Vinculum strongly sclerotized, short (almost same size with tegumen), and saccus rectangular. Aedeagus slender, two times strongly angled, with rounded coecum, and vesica with a long, slender spine-shaped cornutus and an ovoid, sclerotized plate near apical cornutus. *Male pregenital plate* (Figure 6a). Abdomen with median apodeme structure of lyrelike shape on pregenital tergite. *Female genitalia* (Figure 7a). Papillae anales weakly covered with setae. Antrum rounded, with sclerotized ring. Ductus bursae broadly tubular, weakly scobinated partially. Corpus bursae globose, membranous, with dentate, strongly sclerotized bands that wholly cover bursae. *Female pregenital plate*. The female abdomen has no pregenital structure.

Distribution. Indonesia (northern Sulawesi).

Etymology. Named after the name of northern Sulawesi, Minahasa, Indonesia.

3.2.4. *Diduga dumoga* Bayarsaikhan, Heppner and Bae, **sp. nov.**

Type materials. Holotype ♂, Indonesia, Sulawesi, Dumoga-Bone National Park, 6–10 October 1985 (JBH), adult no. ARCT15430M and gen. slide no. JBH–3942, deposited in MGCL. Paratypes (one male, one female) INDONESIA: 1♂, Sulawesi, Dumoga-Bone National Park, 6–10 October 1985 (JBH), gen. slide no. JBH–3958; 1♀, Dumoga-Bone National Park, 11–15 October 1985 (JBH), adult no. ARCT15431F and gen. slide no. JBH–3957, deposited in MGCL.

Diagnosis. The male genitalia structure of the new species is similar to *D. minahasa* **sp. nov.**, but can be distinguished from the latter by the asymmetric costal processes being half the length of tegumen, and the aedeagus is S-shaped with a subapical sclerotized plate covered by spines and a pointed coecum, and vesica with two large, irregularly shaped cornuti in male genitalia. In female genitalia, a broadly tube-shaped corpus bursae sclerotized the whole length and membranous ductus bursae obryriform, with a large, dentate, strongly sclerotized band from the cervix to the proximal end of bursae.

Description. *Adult* (Figure 4c,d). Wingspan 12 mm in male (n = 2), 11.3 mm in female (n = 1). Head and patagium pale yellow. Thorax dark brown. Ground color of braodly and roundly triangular forewing dark brown, with broad, pale yellow costal and terminal border. Costal area with 2–3 dark brown patches in subbasal (on the costal margin), antemedial (indistinct line, consist of brown scales) and postmedial lines edged by a narrow dark line in the basal area. Cilia pale yellow. Hindwing dark brown. Cilia dark brown. Abdomen dark brown. *Male genitalia* (Figure 5b). Uncus slender, with small apical spine, heavily covered with setae. Tegumen triangular, weakly sclerotized, almost same size with uncus. Asymmetric valvae with two strongly sclerotized, short, asymmetric costal processes with bifurcated apex; apex of valvae with two asymmetric, almost same-sized processes, upper one weakly elongated and rounded apex (more curved in left valva,) and stout, strongly sclerotized lower one covered with setae and with acute apex (rounded and crenated in left valva); and sacculus weakly sclerotized. Juxta ringed by narrow, sclerotized band. Vinculum weakly sclerotized, short (almost same size as tegumen), saccus rounded. Aedeagus slender, S-shaped, weakly sclerotized, with a subapical band-shaped plate covered by slender spines and pointed coecum, and vesica with two irregular shaped cornuti and weakly coverd by spiniculum. *Male pregenital plate* (Figure 6b). Abdomen with median apodeme structure of lyrelike shape on pregenital tergite. *Female genitalia* (Figure 7b). Papillae anales weakly covered with setae. Antrum rounded, strongly sclerotized wholly. Ductus bursae broadly tubular, sclerotized whole

of length. Corpus bursae obryriform, and membranous, with a large, elongated, dentate, strongly sclerotized band from cervix to proximal end of bursae. *Female pregenital plate.* The female abdomen has no pregenital structure.

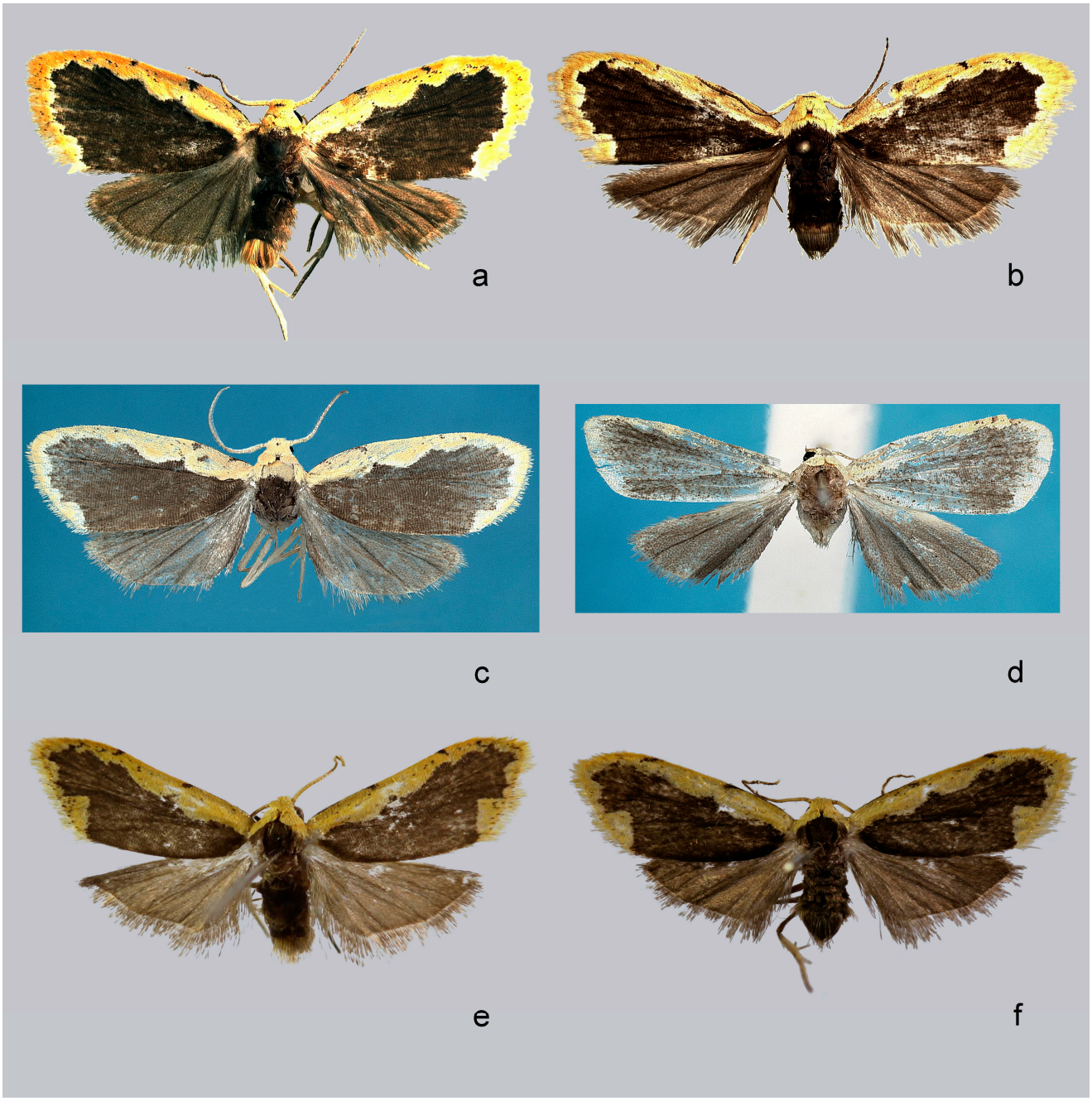


**Figure 4.** Adults of new species of the genus *Diduga*. (**a**) *D. minahasa* **sp. nov.**, holotype, male ARCT14578M; (**b**) *ditto*, paratype, female ARCT14579F (deposited in MGCL); (**c**) *D. dumoga* **sp. nov.**, holotype, male ARCT15430M; (**d**) *ditto*, paratype, female ARCT15431F (deposited in MGCL); (**e**) *D. robdevosi* **sp. nov.**, holotype, male INU-1905L; (**f**) *ditto*, paratype, female INU-10406L (deposited in INU).

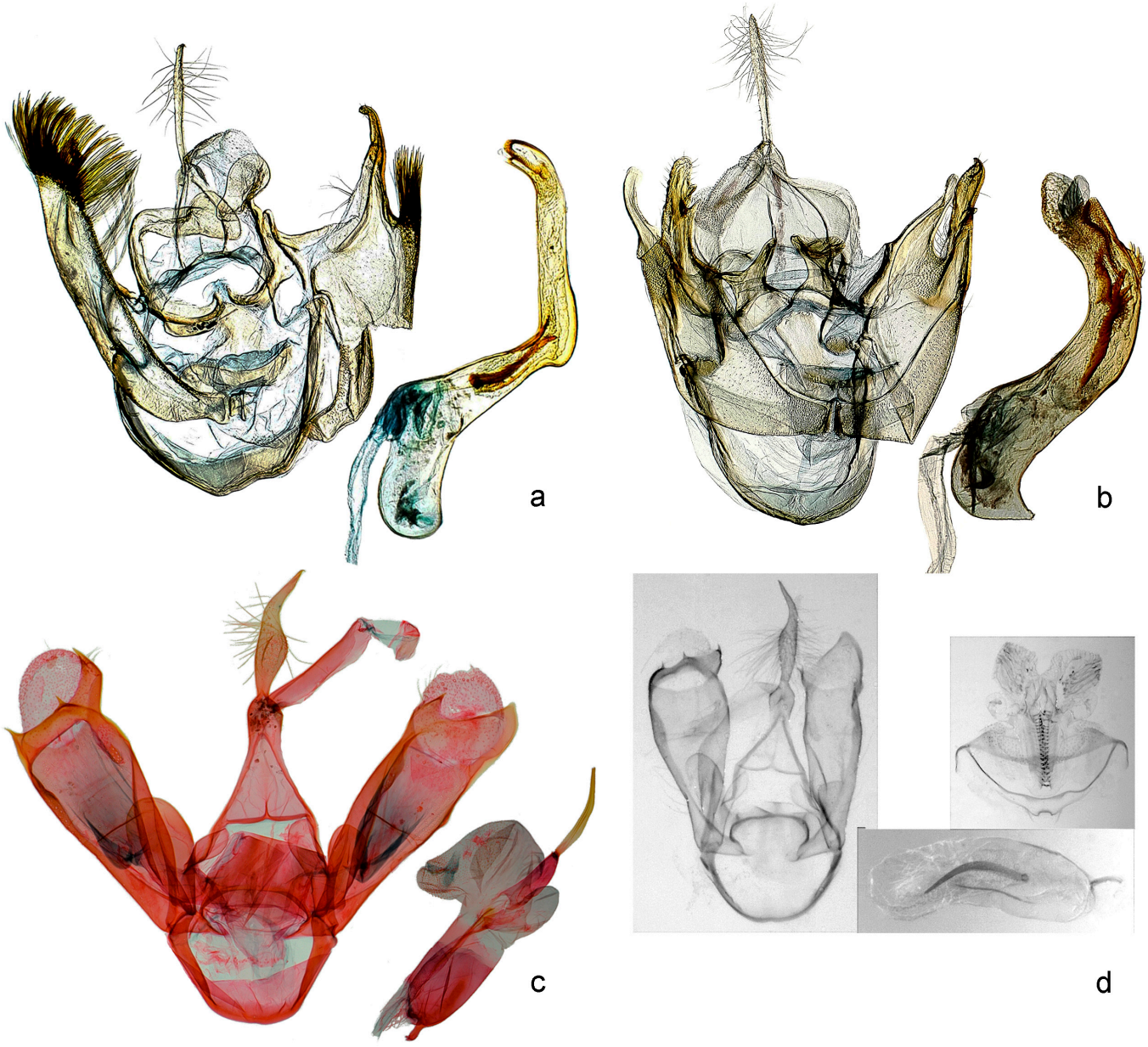


**Figure 5.** Male genitalia of type materials of the genus *Diduga* spp. (aedeagi to right). (**a**) *D. minahasa* **sp. nov.**, holotype, slide JBH-3935M Heppner (left valva seen an edge); (**b**) *D. dumoga* **sp. nov.**, holotype, slide JBH-3942M Heppner (left valva seen an edge); (**c**) *D. robdevosi* **sp. nov.**, holotype, slide INU-1905L Bayarsaikhan; (**d**) *D. flavicostata*, slide Mal191 Bucsek.

Distribution. Indonesia (northern Sulawesi).

Etymology. Named after the type-locality, Dumoga-Bone National Park, Sulawesi, Indonesia.

3.2.5. *Diduga robdevosi* Bayarsaikhan and Bae, **sp. nov.**

Type materials. Holotype ♂, Bolikhamsai Prov., Tad Leuk Waterfall (N 18°23′42.81″, E 103°04′18.70″ Alt: 206 m), 10 November 2015 (YS Bae, BS Park, SM Na, JW Kim, DJ Lee), adult and gen. slide no. INU–1905L, deposited in INU. Paratypes (11 males 2 females) LAOS: 1♂, Bolikhamsai Prov., Tad Xai Waterfall (N 18°27′05.98″, E 103°08′40.06″ Alt: 321 m), 8 November 2015 (YS Bae, BS Park, SM Na, JW Kim, DJ Lee), adult and gen. slide no. INU–1904L; 1♂, Bolikhamsai Prov., PKK Nat. Park (N 18°27′18.20″, E 103°03′17.60″ Alt: 465 m), 5 August 2016 (YS Bae, BS Park, SM Na, DJ Lee, JH Ko), adult and gen. slide

no. INU–1968L; 1♂, Bolikhamsai Prov., PKK Nat. Park (N 18°27′23.76″, E 103°03′05.15″ Alt: 470 m), 22 July 2018 (YS Bae, DJ Lee, JH Ko, TG Lee, CM Jang, U Bayarsaikhan), adult and gen. slide no. INU–10061L; 3♂, Bolikhamsai Prov., PKK Nat. Park (N 18°25′11.75″, E 103°05′12.59″ Alt: 290 m), 29 August 2018 (YS Bae, SM Na, DJ Lee, JH Ko, TK Lee, YB Cha, CM Jang), gen. slide no. INU–10137L, 10125L, 10128L; 5♂, 2♀, Bolikhamsai Prov., PKK Nat. Park (N 18°25′11.75″, E 103°05′12.59″ Alt: 290 m), 3 September 2018 (YS Bae, SM Na, DJ Lee, JH Ko, TG Lee, CM Jang, CM Jang), adult and gen. slide no. INU–10143L, gen. slide no. INU–10145L, 10153L, 10147L, 10152L, 10144L (female), 10155L (female), deposited in INU.

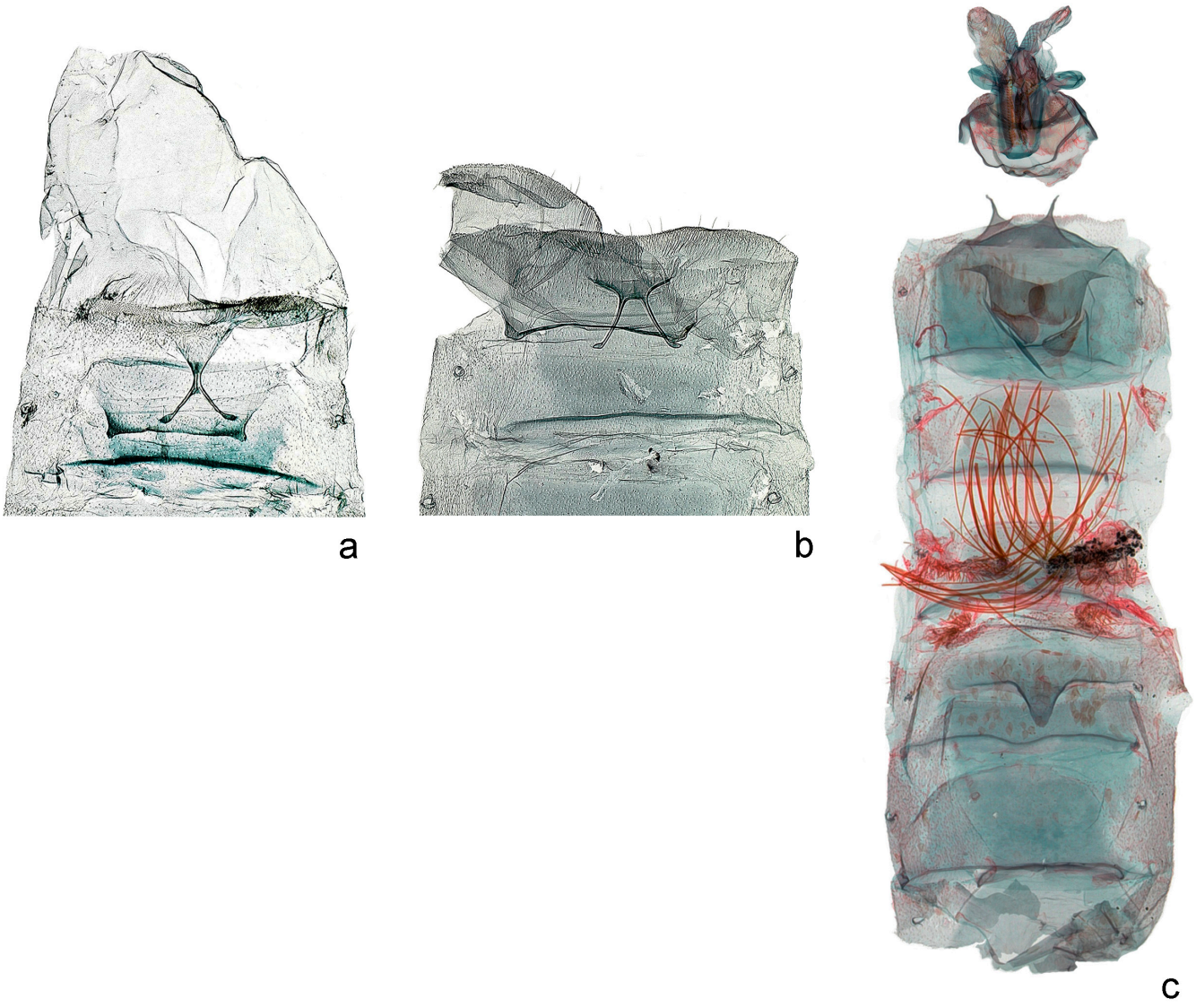


**Figure 6.** Male pregenital abdomen of new species of the genus *Diduga* spp. (**a**) *D. minahasa* **sp. nov.**, slide JBH-3935M Heppner; (**b**) *D. dumoga* **sp. nov.**, slide JBH-3942M Heppner; (**c**) *D. robdevosi* **sp. nov.**, slide INU-10143L Bayarsaikhan.

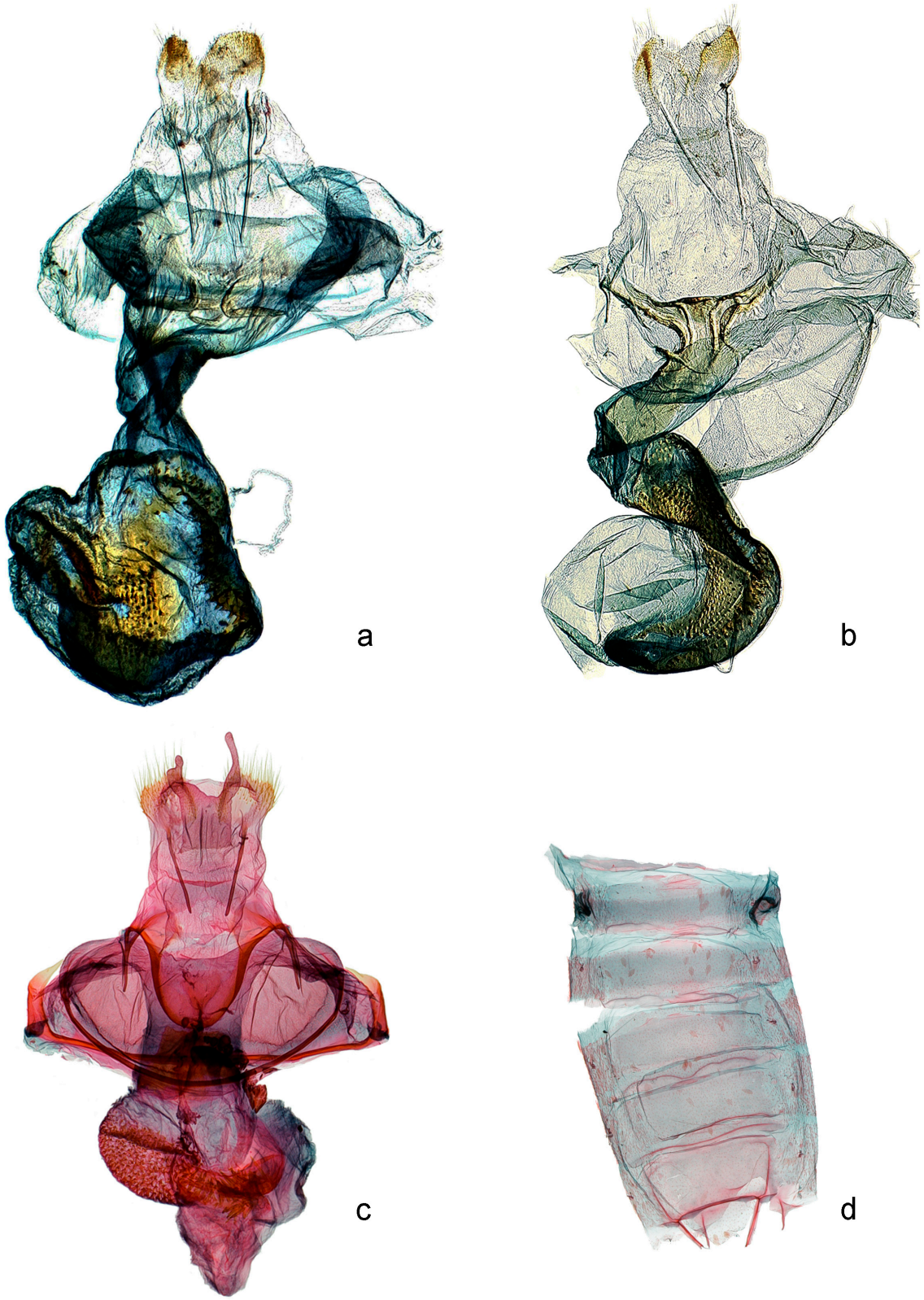


**Figure 7.** Female genitalia and pregenital abdomen of type materials of the genus *Diduga* spp. (**a**) *D. minahasa* **sp. nov.**, paratype, slide JBH-3936F Heppner; (**b**) *D. dumoga* **sp. nov.**, paratype, slide JBH-3957F Heppner; (**c**) *D. robdevosi* **sp. nov.**, paratype, slide INU-10144L Bayarsaikhan; (**d**) *ditto*, pregenital abdomen, slide INU-10144L Bayarsaikhan.

Diagnosis. *Diduga robdevosi* **sp. nov.** has no remarkable external differences from a number of other members of the genus. However, in male genitalia, asymmetric valvae with a pair of different-sized, symmetric, rounded spur-shaped costal processes basally and apex of valvae with two and three diverse-sized processes (two in right, three in left), and aedeagus vesica with a long, slender spine-shaped cornutus and weakly scobinated; in female genitalia, irregularly triangular corpus bursae covered by diverse-sized short spines in distal half, and proximal half of bursae weakly wrinkled distinguishes this species well from all the other known *Diduga*.

Description. *Adult* (Figure 4e,f). Wingspan 11–11.5 mm in male (n = 13), 11.5 mm in female (n = 2). Head and patagium deep yellow. Thorax brown. Ground color of narrowly triangular forewing brown, with broad, deep yellow costal and terminal border. Costal area with two dark brown, irregularly triangular patches in antemedial and postmedial lines and a row of small, dark dots or patches from basal of costa to tornus; edged by a narrow dark line in the basal area. Cilia deep yellow. Hindwing pale brown. Cilia pale brown. Abdomen pale brown, with pale yellow anal tuft in the male and brown in the female. *Male genitalia* (Figure 5c,d). Uncus stout, curved apically, broadened medially, with a small apical spine, heavily covered with setae. Almost same length with tegumen. Tegumen triangular, weakly sclerotized. Asymmetric valvae with a pair of different sized, symmetric, rounded spur-shaped costal processes basally, weakly sclerotized; stout right valva weakly sclerotized, with a gap in the apex, upper, and lower processes pointed and different sized; apex of stout left valva with one large and two small apical processes; and saccular processes of both valvae rounded, membranous, and longer than apex of valva. Juxta weakly sclerotized, tubular. Vinculum sclerotized, almost same size with tegumen and saccus rectangular. Aedeagus stout, straight and with a short process in rounded coecum, and vesica with a long, slender spine-shaped cornutus, weakly scobinated. *Male pregenital plate* (Figure 6c). Abdomen with median apodeme structure of lyrelike shape on pregenital tergite and directed previously as twin broad arms. In segments 4–5 with two bundles of the strongly sclerotized and weakly waved spines. *Female genitalia* (Figure 7c). Papillae anales weakly covered with setae. Antrum rounded, U-shaped. Ductus bursae membranous, broad, short, with a strongly sclerotized plate, it is the same length with ductus bursae. Corpus bursae irregularly triangular, membranous, covered by diverse-sized short spines in distal half, and proximal half of bursae weakly wrinkled. *Female pregenital plate* (Figure 7d). The female pregenital sternite laterally on each side to a sclerotized pouch on the intersegmental membrane.

Distribution. Laos (Bolikhamsai province) and Malaysia [22].

Etymology. The species name is dedicated to Dr. Rob de Vos (Naturalis Biodiversity Center, Leiden, The Netherlands), the excellent entomologist (Lepidoptera) on Arctiinae of the Oriental region (Papua, Indonesia).

Remarks. This new species was previously reported in Malaysia by Bucsek [22] as *D. flavicostata*. However, based on the type specimen, we describe this as a new species herein.

### *3.3. The Checklist of Diduga Species in the World*

A total of 47 *Diduga* species are listed herein, including three new species from Indonesia (Sulawesi) and Laos (Bolikhamsai province) (Table 1). Based on an examination of the genitalia structures of the type specimens, *D. zetes* Bucsek [23] is synonym of *D. barlowi* Holloway [7] (Figure 8a–e) and *D. metaleuca* Hampson, *D. amoenusa* Bucsek, and *D. ambigua* Bucsek are transferred to the genus *Tospitis* Walker, 1863 (Figures 9 and 10).

**Table 1.** A synoptic list of the genus *Diduga* in the World, with depository of types and distributions.

| | Species | Depositor | Distribution |
|---|---|---|---|
| 1 | *Diduga albicosta* Hampson, 1891 | NHMUK | India, Sri Lanka, China, Laos, Thailand, Cambodia, peninsular Malaysia |
| 2 | *Diduga albida* Hampson, 1914 | NHMUK | Dutch New Guinea |
| 3 | *Diduga allodubatolovi* Bayarsaikhan, Li & Bae, 2020 | NKU | China, Laos, Thailand |
| 4 | *Diduga alternota* Bucsek, 2014 | MWM | Laos, Thailand, Cambodia, Vietnam, Malaysia, Indonesia |
| 5 | *Diduga annulata* Hampson, 1900 | NHMUK | Laos, Thailand, Cambodia, peninsular Malaysia, Indonesia (Borneo, Sumbawa) |
| 6 | *Diduga barlowi* Holloway, 2001 =*Diduga zetes* Bucsek, 2014, **syn. nov.** | NHMUK | Cambodia, Malaysia, Indonesia (Borneo) |
| 7 | *Diduga bayartogtokhi* Bayarsaikhan & Bae, 2019 | INU | Vietnam |
| 8 | *Diduga bispinosa* Bayarsaikhan & Bae, 2018 | INU | Thailand, Cambodia |
| 9 | *Diduga chebalinga* Zhao & Han, 2020 | NEFU | China |
| 10 | *Diduga chewi* Zhao & Han, 2020 | NEFU | Malaysia |
| 11 | *Diduga ciliata* Holloway, 2001 | NHMUK | Indonesia (Borneo) |
| 12 | *Diduga costata* Moore, [1887] | NHMUK | India, Sri Lanka |
| 13 | *Diduga cucphuonga* Dubatolov & Bucsek, 2016 | SZMN | Vietnam |
| 14 | *Diduga dorsolobata* Holloway, 2001 | NHMUK | Indonesia (Borneo) |
| 15 | *Diduga dubatolovi* Bayarsaikhan & Bae, 2018 | INU | Thailand, Cambodia |
| 16 | *Diduga dumoga* Bayarsaikhan, Heppner & Bae, **sp. nov.** | MGCL | Indonesia (northern Sulawesi) |
| 17 | *Diduga excisa* Hampson, 1918 | NHMUK | the Philippines |
| 18 | *Diduga flavicostata* (Snellen, 1879) | RMNH | India, China, Thailand, Cambodia, Indonesia (Sulawesi, Java) |
| 19 | *Diduga flavifinis* Bucsek, 2014 | MWM | Malaysia |
| 20 | *Diduga fumipennis* Hampson, 1891 | NHMUK | India |
| 21 | *Diduga haematomiformis* van Eecke, 1920 | RMNH | Indonesia (W. Java) |
| 22 | *Diduga hainanensis* Bayarsaikhan, Li & Bae, 2020 | NKU | China |
| 23 | *Diduga hanoiensis* Bayarsaikhan & Bae, 2019 | INU | Vietnam |
| 24 | *Diduga hastata* Bayarsaikhan & Bae, 2021 | INU | Laos |
| 25 | *Diduga hollowayi* Zhao & Han, 2020 | NEFU | Malaysia |
| 26 | *Diduga iriomotensis* Bae, Kishida & Bayarsaikhan, 2019 | CYKJ | Japan |
| 27 | *Diduga khounngeuna* Bucsek, 2020 | SNM | Laos |
| 28 | *Diduga kohkongensis* Bayarsaikhan & Bae, 2018 | INU | Cambodia |
| 29 | *Diduga luteogibbosa* Bayarsaikhan, Li & Bae, 2020 | NKU | Laos, China |
| 30 | *Diduga minahasa* Bayarsaikhan, Heppner & Bae, **sp. nov.** | MGCL | Indonesia (northern Sulawesi) |
| 31 | *Diduga mininota* Bucsek, 2014 | MWM | Malaysia |
| 32 | *Diduga mucronata* Bayarsaikhan & Bae, 2021 | INU | Laos |
| 33 | *Diduga nantouensis* Bayarsaikhan & Bae, 2021 | INU | Taiwan |
| 34 | *Diduga nigridentata* Bayarsaikhan & Bae, 2019 | INU | Vietnam |
| 35 | *Diduga nota* Bucsek, 2012 | MWM | Malaysia |
| 36 | *Diduga pectinifer* Hampson, 1900 | NHMUK | Indonesia (Borneo) |
| 37 | *Diduga plumosa* Hampson, 1911 | NHMUK | Indonesia |
| 38 | *Diduga quinquicornuta* Bayarsaikhan & Bae, 2019 | INU | Vietnam |
| 39 | *Diduga robdevosi* Bayarsaikhan & Bae, **sp. nov.** | INU | Laos, peninsular Malaysia |
| 40 | *Diduga rufidisca* Hampson, 1898 | NHMUK | India |
| 41 | *Diduga scalprata* Bayarsaikhan, Li & Bae, 2020 | NKU | Laos, China |
| 42 | *Diduga simianshana* Zhao & Han, 2020 | NEFU | China |
| 43 | *Diduga sphaeracephalus* Bayarsaikhan & Bae, 2020 | OPU | Thailand |
| 44 | *Diduga spinosusa* Bucsek, 2012 | MWM | Malaysia |
| 45 | *Diduga taiwana* Bayarsaikhan & Bae, 2021 | INU | Taiwan |
| 46 | *Diduga trichophora* Hampson, 1900 | NHMUK | Myanmar, Thailand, peninsular Malaysia, Indonesia (Bali, Borneo, S. Burma, Sumatra, Java) |
| 47 | *Diduga weiweii* Zhao, Wu & Han, 2020 | NEFU | Malaysia |

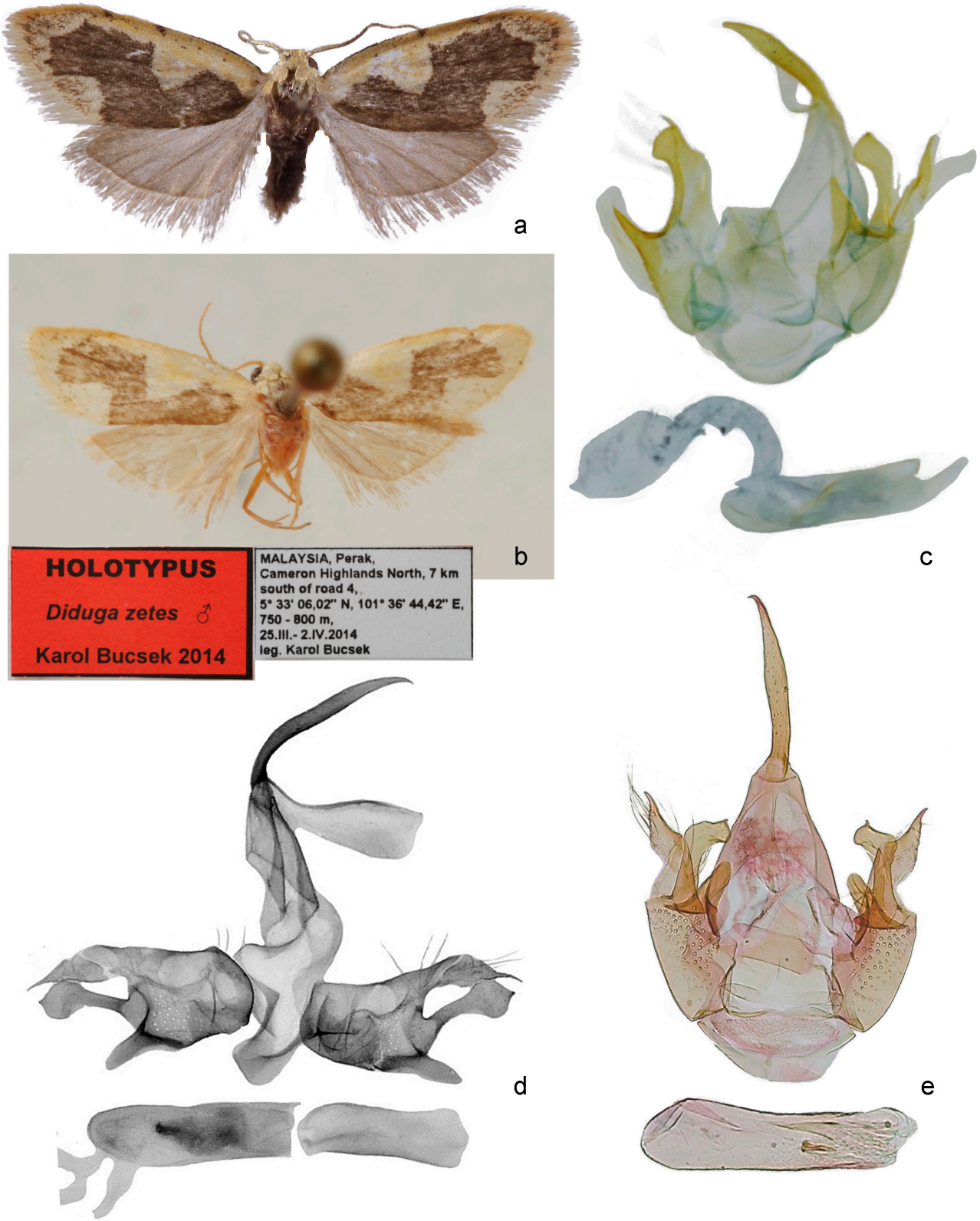


**Figure 8.** Adults and male genitalia of *Diduga barlowi* Holloway, 2001. (**a**) Adult, Cambodia, male INU-1410C Bayarsaikhan; (**b**) Adult of *D. zetes* Bucsek, 2014, **syn. nov.**, holotype; (**c**) Male genitalia, Borneo, holotype, slide Arct5054 JDH; (**d**) Male genitalia of *D. zetes* Bucsek, 2014 **syn. nov.**, Malaysia, holotype, slide gen. MalS08 Bucsek; (**e**) Male genitalia, Cambodia, slide INU-1410C Bayarsaikhan (aeadeagi below each).

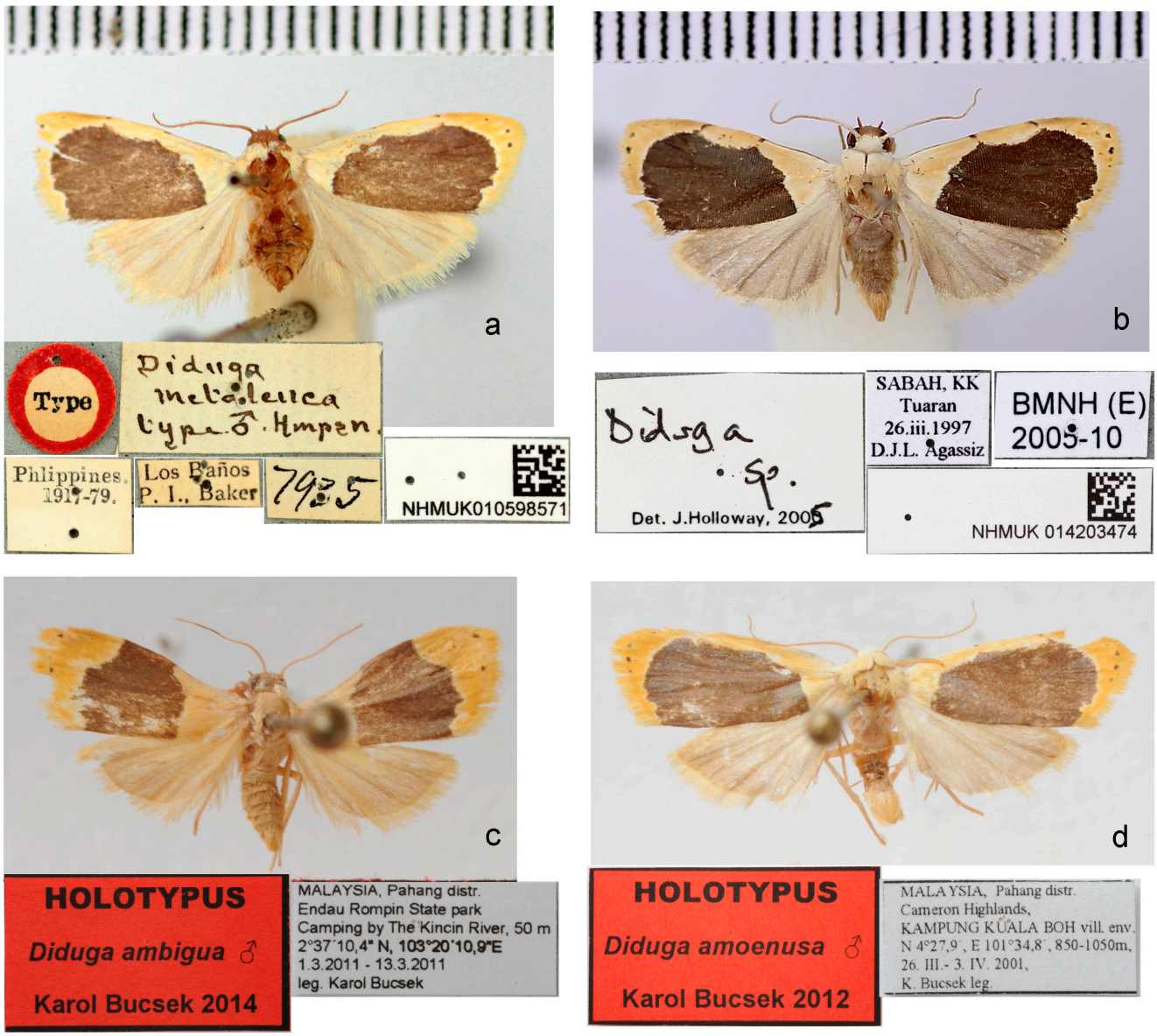


**Figure 9.** Adults of new combinations to the genus *Tospitis* Walker. (**a**) *Diduga metaleuca* Hampson, **comb. nov.**, male, holotype, the Philippines, NHMUK010598571; (**b**) *ditto*, male, Sabah, NHMUK014203474 J.Holloway; (**c**) *D. ambigua* Bucsek, **comb. nov.**, male, holotype, Malaysia; (**d**) *D. amoenusa* Bucsek, **comb. nov.**, male, holotype, Malaysia.

The genus *Tospitis* Walker, 1863 is one of the smaller genera within the tribe Lithosiini, comprising only 16 described species, which have been worked on by Walker [24], Hampson [25], Holloway [7], and Bucsek [22,23]. In this study, the examination of the genitalia structures of three species has led us to conclude that these species belong to the genus *Tospitis* Walker.

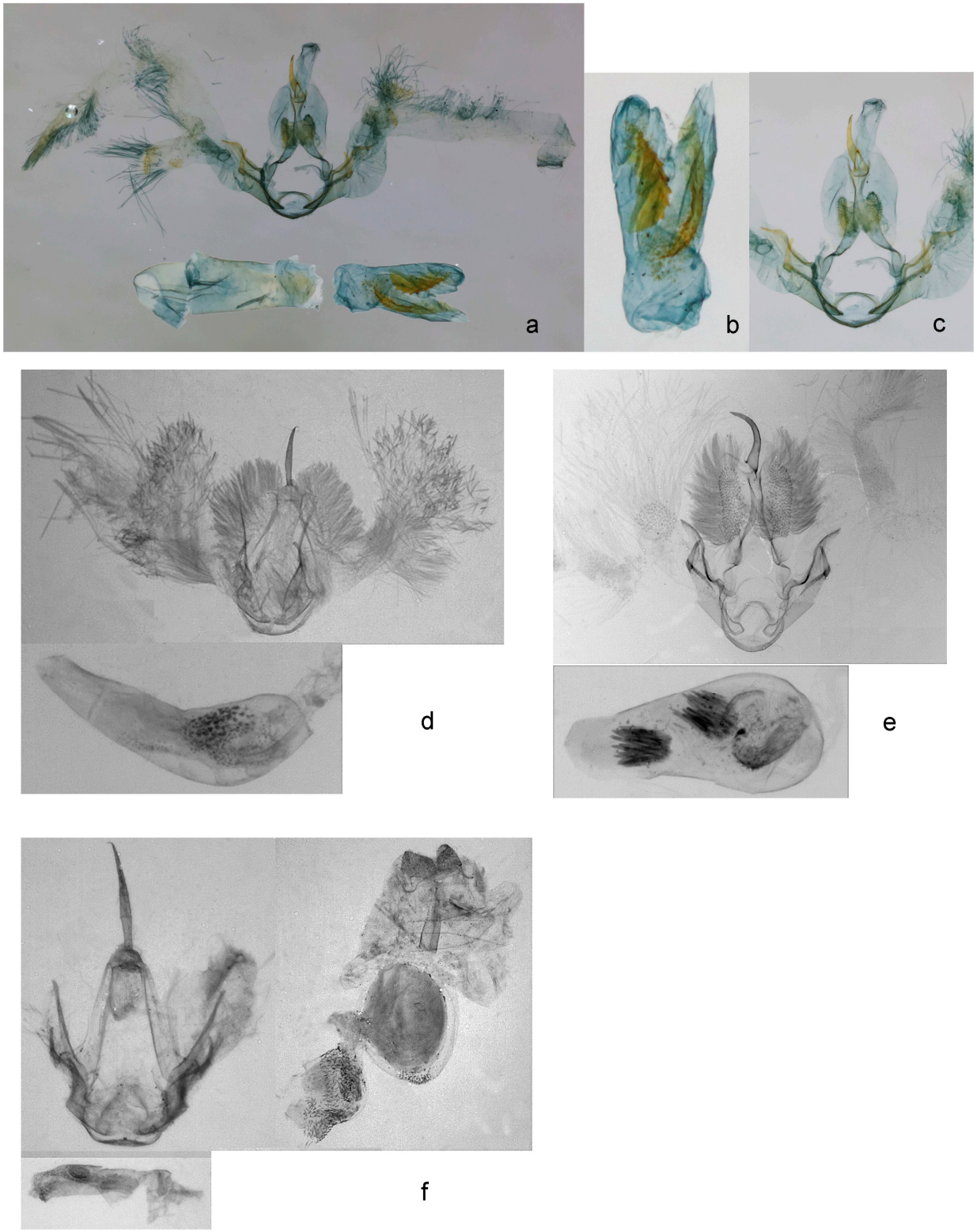


**Figure 10.** Genitalia of new combinations to the genus *Tospitis* Walker. (**a**) Male genitalia of *Diduga metaleuca* Hampson, **comb. nov.**, Sabah, NHMUK014203474 J.Holloway; (**b**) *ditto*, cornuti of aedeagus vesica; (**c**) *ditto*, uncus, tegumen, vinculum, and basal area of genitalia capsule; (**d**) Male genitalia of *D. ambigua* Bucsek, **comb. nov.**, holotype, Malaysia, Mal212; (**e**) Male genitalia of *D. amoenusa* Bucsek, **comb. nov.**, Malaysia, Mal022a; (**f**) Male and female genitalia of *T. mulliferana* Walker, Malaysia, Mal208, type species of the genus *Tospitis* Walker.

## 4. Discussion

In our study, we have listed a total of 47 *Diduga* species (Table 1), of which 38 (81%) have a typical wing pattern characterized by a dark brown ground color of the forewing with deep yellow costal and terminal bands. As a result, identification of these species must be based on genitalia structures, which can pose a challenge. For a century, the species *D. flavicostata* has been recorded in multiple countries, India, China, Taiwan, Thailand, Cambodia, and Malaysia, by different authors while the present type species, *D. costata*, was a junior synonym of *D. flavicostata* [8,11,16,22].

Members of this genus show much diversity of genitalia structure and it is probable that the genus is not monophyletic, caused typically by three kinds of valva shapes examined: simple and symmetric valvae have a needle-shaped apex, widened and asymmetric valvae are processed or branched/complicated, etc. Therefore, we suggest that the genus *Diduga* be subdivided into two or more distinct species groups or even different genera (slim chance). More evidence is needed and it should be deeply studied in the future.

Furthermore, it is also necessary to identify type specimens of some species that have not been recorded or collected for a long time at their type localities or in other countries, such as *D. albida*, *D. excisa*, *D. fumipennis*, *D. plumosa*, and *D. rufidisca*.

**Author Contributions:** U.B. and collected one new and some of the described species, wrote the original manuscript, and prepared dissections of genitalia of INU collections; J.B.H. collected two of the new species and prepared adult and dissections of genitalia of MGCL collections, and also read and checked the early draft of this paper; K.B. sent original figures of Malayan specimens and prepared dissections of genitalia of MWM collections; Y.-B.C. prepared dissections of genitalia and take figures of some type materials of NHMUK collections; Y.-S.B. conceptualization, methodology and review and editing, and collection of one new species; H.W.K. conceptualization, methodology and review, funding acquisition. All authors have read and agreed to the published version of the manuscript.

**Funding:** This work was supported by Incheon National University Research Grant in 2018.

**Data Availability Statement:** Not applicable.

**Acknowledgments:** We are grateful to Rob de Vos (Naturalis Biodiversity Center, Leiden, The Netherlands), Alberto Zilli (Insect Division, Natural History Museum, London, UK), Anton V. Volynkin (Altai State University, Barnaul, Russia) and T.G. Lee (Incheon National University, Incheon, Korea), for preparing dissections of genitalia and taking/sending figures of type materials, which are deposited in NHMUK and RMNH.

**Conflicts of Interest:** The authors declare no conflict of interest.

## Abbreviations

| | |
|---|---|
| TL | Type locality; |
| TS | Type species; |
| CYKJ | private collection of Dr. Yasunori Kishida; |
| INU | Incheon National University, Incheon, Republic of Korea; |
| MGCL | McGuire Center for Lepidopteran and Biodiversity, Florida Museum of Natural History, University of Florida, Gainsville, Florida, USA; |
| MWM | Museum WITT München, München, Germany; |
| NEFU | Northeast Forestry University, Harbin, China; |
| NHMUK | Natural History Museum (formerly British Museum of Natural History), London, UK; |
| NKU | Nankai University, Tianjin, China; |
| OPU | Osaka Prefecture University, Osaka, Japan; |
| RMNH | Naturalis Biodiversity Center, Leiden, the Netherlands; |
| SNM | Slovak National Museum, Bratislava, Slovakia; |
| SZMN | Sibirian Zoological Museum of the Institute of Animal Systematics and Ecology. |

## References


1. Van Nieukerken, E.J.; Kaila, L.; Kitching, I.J.; Kristensen, N.P.; Lees, D.C.; Minet, J.; Mitter, C.; Mutanen, M.; Regier, J.C.; Simonsen, T.J.; et al. Animal biodiversity: An outline of higher-level classification and survey of taxonomic richness. *Zootaxa* **2011**, *3148*, 212–221.
2. Zahiri, R.; Holloway, J.D.; Kitching, I.J.; Lafontaine, D.; Mutanen, M.; Wahlberg, N. Molecular phylogenetics of Erebidae (Lepidoptera, Noctuoidea). *Syst. Entomol.* **2012**, *37*, 102–124. [CrossRef]
3. Holloway, J.D. *The Moths of Borneo: Family Arctiidae, Subfamilies Syntominae, Euchromiinae, Arctiinae, Noctuidae Misplaced in Arctiidae (Camtoloma, Aganainae)*; Malayan Nature Society: Kuala Lumpur, Malaysia, 1988; pp. 1–101.
4. Bendib, A.; Minet, J. Female pheromone glands in Arctiidae (Lepidoptera). Evolution and phylogenetic significance. *Comptes Rendus De l'Académie Des Sci. Ser. III Sci. De La Vie* **1998**, *321*, 1007–1014. [CrossRef]
5. Kitching, I.J.; Rawlins, J.E. The Noctuidae. In *Handbuch der Zoologie 4, 2, 35 Lepidoptera*; Kristensen, N.P., Ed.; Walter de Gruyter: Berlin, Germany, 1998; pp. 355–401.
6. Hampson, G.F. Catalogue of the Arctiadae (Nolinae, Lithosianae) in the collection of the British Museum. In *Catalogue of the Lepidoptera Phalaenae in the British Museum*; British Museum: London, UK, 1900; pp. 539–542.
7. Holloway, J.D. The Moths of Borneo: Family Arctiidae, Subfamily Lithosiinae. *Malay. Nat. J.* **2001**, *55*, 279–469.
8. Fang, C. *Fauna Sinica Insecta (Lepidoptera: Arctiidae)*; Science Press: Beijing, China, 2000; p. 589.
9. Zhao, T.T.; Han, H.L. Four new species of the genus *Diduga* Moore, [1887] (Lepidoptera, Erebidae, Arctiinae) from China and Malaysia. *ZooKeys* **2020**, *985*, 127–141. [CrossRef] [PubMed]
10. Zhao, T.T.; Wu, J.; Han, H.L. Description of a new species in the genus *Diduga* Moore (Lepidoptera: Erebidae: Arctiinae) from Borneo, Malaysia. *Entomotaxonomia* **2020**, *42*, 265–269.
11. Bayarsaikhan, U.; Hirai, N.; Černy, K.; Kwon, H.W.; Bae, Y.S. A new species and four new records of *Diduga* Moore (Lepidoptera, Erebidae, Arctiinae) from Thailand. *Zootaxa* **2020**, *4860*, 393–400. [CrossRef] [PubMed]
12. Bayarsaikhan, U.; Cha, Y.B.; Lee, T.G.; Jang, C.M.; Kwon, H.W.; Bae, Y.S. Two new species and four new records of *Diduga* (Lepidoptera, Erebidae, Arctiinae) from Laos. *Zootaxa* **2021**, *4970*, 131–142. [CrossRef] [PubMed]
13. Bayarsaikhan, U.; Heppner, J.B.; Kwon, H.W.; Bae, Y.S. Review of the genus *Diduga* Moore (*Lepidoptera, Erebidae, Arctiinae*) of Taiwan, with description of two new species. *Zootaxa* **2021**, *5032*, 216–224. [CrossRef] [PubMed]
14. Moore, F. *The Lepidoptera of Ceylon*; L. Reeve and Co.: London, UK, 1884; p. 578.
15. Hampson, G.F. The macrolepidoptera heterocera of Ceylon. In *Illustrations of Typical Specimens of Lepidoptera Heterocera in the Collection of the British Museum*; Natural History Museum (London) Publications: London, UK, 1893; Volume 9, pp. 1–182, pls. 157–176.
16. Kirti, J.S.; Singh, N. *Arctiid Moths of India*; Nature Books India: New Delhi, India, 2015; Volume 1, p. 205.
17. Snellen, P.C.T. Lepidoptera van Celebes verzameld door Mr. M.C. Piepers, met aanteekeningen en beschrijving der nieuwe soorten. *Tijdschr. Voor Entomol.* **1879**, *22*, 61–126, pls. 6–10.
18. Hampson, G.F. The macrolepidoptera heterocera of Ceylon. In *Illustrations of Typical Specimens of Lepidoptera Heterocera in the Collection of the British Museum*; Natural History Museum (London) Publications: London, UK, 1891; Volume 8, pp. 1–144, pls. 139–156.
19. Strand, E. Arctiidae: Subfam, Lithosiinae. In *Lepidopterum Catalogus*; Wagner, H., Ed.; W. Yunk: Berlin, Germany, 1922; Volume 26, pp. 1–899.
20. Singh, N.; Joshi, R.; Kirti, J.S.; Bisht, S.S.; Param, H.S. A catalogue of Indian Arctiinae (*Erebidae, Lepidoptera*). *Zootaxa* **2021**, *5058*, 1–118. [CrossRef] [PubMed]
21. Černy, K.; Pinratana, A. *Moths of Thailand, Volume 6. Arctiidae*; Brothers of Saint Gabriel in Thailand: Bangkok, Thailand, 2009; p. 283.
22. Bucsek, K. *Erebidae, Arctiinae (Lithosiini, Arctiini) of Malaya Peninsular Malaysia*; Institute of Zoology SAS: Bratislava, Slovakia, 2012; p. 170.
23. Bucsek, K. *Erebidae, Arctiinae (Lithosiini, Arctiini) of Malaya Peninsular Malaysia (Supplementum)*; Institute of Zoology SAS: Bratislava, Slovakia, 2014; p. 45.
24. Walker, F. Catalogue of Lepidoptera Heterocera. Sixth series. Fam. Tortricidae (continued). In *List of the Specimens of Lepidopterous Insects in the collection of the British Museum*; Crambites & Tortricites: London, UK, 1863; Part XXVII; pp. 287–562.
25. Hampson, G.F. Descriptions of New genera and Species of Amatidae, Lithosidae, and Noctuidae. *Novit. Zool.* **1918**, *25*, 93–217. [CrossRef]