



## Three new species of *Protosticta* Selys, 1885 (Odonata: Zygoptera: Platystictidae) from the Western Ghats, India, with taxonomic notes on *P. murtoni* Fraser, 1922 and rediscovery of *P. rufostigma* Kimmins, 1958

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### Abstract

Three new species of *Protosticta* Selys, 1885 (Odonata: Zygoptera: Platystictidae) from the Western Ghats biodiversity hotspot in India: *P. cyanofemora* sp. nov. (wet evergreen forests in Shendurney Wildlife Sanctuary, Kollam, Kerala and Kalakkad Mundanthurai Tiger Reserve, Tirunelveli, Tamil Nadu), *P. myristicaensis* sp. nov. (Myristica swamp at Kathalekan, Shivamogga, Karnataka) and *P. sholai* sp. nov. (montane sholas of Upper Manalar, Meghamalai Wildlife Sanctuary, Theni, Tamil Nadu) are described and illustrated. We compare these three new species with other *Protosticta* spp. from the Western Ghats based on new material and provide comprehensive differential diagnoses with determination key for males of all species occurring in the Western Ghats. The taxonomic validity of *P. murtoni* Fraser, 1922 is established with fresh specimens from Hassan, Karnataka, and rediscovery of *P. rufostigma* Kimmins, 1958 is reported from Kanyakumari Wildlife Sanctuary, Tamil Nadu.

**Key words:** New species, *Protosticta*, species description, taxonomy, species rediscovery, Karnataka, Kerala, Tamil Nadu, damselfly, diagnosis, endemic species

### Introduction

*Protosticta* Selys, 1885 is a diverse genus of damselflies (Odonata: Zygoptera: Platystictidae), with 49 named species (Paulson & Schorr 2020), distributed across southern and south-eastern Asia, from India to Borneo, Philippines and Sulawesi (van Tol 2008). Representatives of *Protosticta* are cryptic in their habits, usually frequenting densely vegetated shaded streams. Due to their dull colors, slender body, and relatively minute interspecific differences they are difficult to spot, collect, or identify (Bedjanič *et al.* 2016).

In India, 12 species of *Protosticta* are known, nine endemic to the Western Ghats, and three, viz., *Protosticta damacornu* Terzani & Carletti, 1998; *P. fraseri* Kennedy, 1936; and *P. himalaica* Fraser, 1922, occurring in the eastern Himalaya (Subramanian & Babu 2017). Here, we describe three more species from the central and southern Western Ghats. A detailed comparison with the nine known congeneric species from the Western Ghats, and an identification key to males of the species occurring in the Western Ghats are also provided. *Protosticta murtoni* Fraser, 1922 has been considered a junior synonym of *Protosticta gravellyi* Laidlaw, 1915 (Davies & Tobin 1984, Subramanian & Babu 2017, Paulson & Schorr 2020). We provide clarification on the status of *P. murtoni*, along with notes on rediscovery of *Protosticta rufostigma* Kimmins, 1958.

## Material and methods

Individuals were photographed in the field, collected with an insect net, subsequently either pinned with two legs preserved in molecular-grade ethanol (Wet & Dry) or preserved whole in ethanol (Wet Only). Specimens of the new species are deposited in the Research Collections of the National Centre for Biological Sciences, Bengaluru (NCBS hereafter), and National Zoological Collections, Southern Regional Centre, Zoological Survey of India, Chennai (SRC-ZSI hereafter) (details of the type material are given in Table 1). Of the nine described species of *Protosticta* from Western Ghats, six (excluding *P. antelopoides* Fraser, 1931, *P. hearseyi* Fraser, 1922, and *P. monticola* Emiliyamma & Palot, 2016) were studied based on specimens at NCBS and SRC-ZSI.

**TABLE 1.** *Protosticta* specimens described in this study.

Specimen deposited at	Voucher code	Species	Sex	Preservation method	Type	Abdomen + caudal appendages	Hindwing
NCBS	NCBS-BK825	<i>P. cyanofemora</i>	M	Dry Only	Holotype	37	22
NCBS	NCBS-BK826	<i>P. cyanofemora</i>	F	Dry Only	Paratype	33	20
NCBS	NCBS-QA009	<i>P. cyanofemora</i>	M	Wet Only	Paratype	37	21
NCBS	NCBS-QA011	<i>P. cyanofemora</i>	M	Wet and dry	Paratype	35	21
SRC-ZSI	I/OD/2210	<i>P. cyanofemora</i>	M	Wet Only	Paratype	38	21
SRC-ZSI	I/OD/2211	<i>P. cyanofemora</i>	M	Wet Only	Paratype	38	22
SRC-ZSI	I/OD/2212	<i>P. cyanofemora</i>	F	Wet Only	Paratype	33	23
SRC-ZSI	I/OD/2213	<i>P. cyanofemora</i>	F	Wet Only	Paratype	34	24
SRC-ZSI	I/OD/2214	<i>P. cyanofemora</i>	F	Wet Only	Other material	33	23
SRC-ZSI	I/OD/2215	<i>P. cyanofemora</i>	F	Wet Only	Other material	31	21
SRC-ZSI	I/OD/2216	<i>P. cyanofemora</i>	F	Wet Only	Other material	36	22
SRC-ZSI	I/OD/2217	<i>P. cyanofemora</i>	F	Wet Only	Other material	36	25
SRC-ZSI	I/OD/2218	<i>P. cyanofemora</i>	M	Wet Only	Other material	37	21
SRC-ZSI	I/OD/2219	<i>P. cyanofemora</i>	M	Wet Only	Other material	38	22
SRC-ZSI	I/OD/2220	<i>P. cyanofemora</i>	M	Wet Only	Other material	37	21
SRC-ZSI	I/OD/2221	<i>P. cyanofemora</i>	M	Wet Only	Other material	38	22
SRC-ZSI	I/OD/2222	<i>P. cyanofemora</i>	M	Wet Only	Other material	37	22
NCBS	NCBS-BH110	<i>P. myristicaensis</i>	M	Wet	Holotype	20	12
NCBS	NCBS-BH111	<i>P. myristicaensis</i>	F	Wet	Paratype	20	14
NCBS	NCBS-BH112	<i>P. myristicaensis</i>	F	Wet	Paratype	21	14
NCBS	NCBS-BM654	<i>P. myristicaensis</i>	M	Dry Only	Paratype	21	14
NCBS	NCBS-BM655	<i>P. myristicaensis</i>	M	Wet	Paratype	20	12
NCBS	NCBS-BM656	<i>P. myristicaensis</i>	M	Wet	Paratype	21	13
NCBS	NCBS-BM657	<i>P. myristicaensis</i>	F	Wet	Paratype	21	15
SRC-ZSI	I/OD/2223	<i>P. sholai</i>	M	Wet Only	Holotype	40	24
SRC-ZSI	I/OD/2224	<i>P. sholai</i>	M	Wet Only	Paratype	40	23
SRC-ZSI	I/OD/2225	<i>P. sholai</i>	M	Wet Only	Paratype	41	24
SRC-ZSI	I/OD/2226	<i>P. sholai</i>	F	Wet Only	Paratype	38	21

The specimens were studied and photographed with a Leica stereomicroscopes (Leica Microsystems, Germany) equipped with a camera, and LAS auto-imaging software. Other images were taken using Canon DSLR cameras (Canon Inc., Japan). Digital scale was added using the software ImageJ (Schneider *et al.* 2012). Type specimens of *P. antelopoides*, *P. davenporti* Fraser, 1931, *P. mortoni*, and *P. sanguinostigma* Fraser, 1922 were studied via images of specimens deposited at Natural History Museum, London (Natural History Museum 2014).

Descriptive terminology follows Garrisson *et al.* (2010). All measurements are given in millimetres unless

mentioned otherwise. Following abbreviations are used in the manuscript: FW = fore wing, HW = hind wing; Ax = antenodal; Px = postnodal nervures; Pt = pterostigma, S1–S10 = first to tenth abdominal segments; Alt. = Altitude; SJ = Shantanu Joshi; KAS = K.A. Subramanian; RB = R. Babu; KK = Krushnamegh Kunte; DS = Dattaprasad Sawant.

Details of all specimens of the three new species along with measurements of abdomen + caudal appendages and hindwing are given in Table 1 and nodal index is provided in Table 2. Illustrations of caudal appendages were drawn from fresh material except for *P. antelopoides*, *P. hearseyi*, and *P. monticola* which were re-drawn from Fraser (1933), and Emiliyamma & Palot (2016). All line-drawings are hand-drawn by DS.

**TABLE 2.** Nodal index of the three newly described *Protosticta* spp. RFW: Right Fore Wing; LFW: Left Fore Wing; RHW: Right Hind Wing; LHW: Left Hind Wing

Voucher code	Species	Sex	RFW	LFW	RHW	LHW
NCBS-BK825	<i>P. cyanofemora</i>	M	13	13	12	11
NCBS-BK826	<i>P. cyanofemora</i>	F	14	14	13	14
NCBS-QA009	<i>P. cyanofemora</i>	M	13	12	11	11
NCBS-QA011	<i>P. cyanofemora</i>	M	12	12	11	11
I/OD/2210	<i>P. cyanofemora</i>	M	13	13	12	12
I/OD/2211	<i>P. cyanofemora</i>	M	13	13	13	13
I/OD/2212	<i>P. cyanofemora</i>	F	13	13	12	12
I/OD/2213	<i>P. cyanofemora</i>	F	13	13	12	12
I/OD/2214	<i>P. cyanofemora</i>	F	13	13	12	12
I/OD/2215	<i>P. cyanofemora</i>	F	13	13	12	12
I/OD/2216	<i>P. cyanofemora</i>	F	14	14	13	13
I/OD/2217	<i>P. cyanofemora</i>	F	13	13	12	12
I/OD/2218	<i>P. cyanofemora</i>	M	12	12	11	11
I/OD/2219	<i>P. cyanofemora</i>	M	13	13	12	12
I/OD/2220	<i>P. cyanofemora</i>	M	13	13	12	12
I/OD/2221	<i>P. cyanofemora</i>	M	13	13	12	12
I/OD/2222	<i>P. cyanofemora</i>	M	13	13	13	13
NCBS-BH110	<i>P. myristicaensis</i>	M	11	11	10	9
NCBS-BH111	<i>P. myristicaensis</i>	F	12	12	10	10
NCBS-BH112	<i>P. myristicaensis</i>	F	12	12	10	10
NCBS-BM654	<i>P. myristicaensis</i>	M	10	10	9	9
NCBS-BM655	<i>P. myristicaensis</i>	M	11	10	10	10
NCBS-BM656	<i>P. myristicaensis</i>	M	11	11	9	10
NCBS-BM657	<i>P. myristicaensis</i>	F	12	12	11	10
I/OD/2223	<i>P. sholai</i>	M	13	13	12	12
I/OD/2224	<i>P. sholai</i>	M	12	12	12	11
I/OD/2225	<i>P. sholai</i>	M	14	14	13	13
I/OD/2226	<i>P. sholai</i>	F	13	13	12	12

Species distribution maps were prepared in QGIS v.2.4.0 (Quantum GIS Development Team 2019) for all 12 species of *Protosticta* known from the Western Ghats using 232 geo-referenced records based on collections present at SRC-ZSI and NCBS, personal observations, published literature, and records from online portals such as www.indianodonata.org (Joshi *et al.* 2020). Using the same dataset, we extracted bio-climatic variables with DIVA-GIS (Hijmans *et al.* 2001) for each individual species, which are given in Table 3.

## Results

### Description of new species

#### *Protosticta cyanofemora* sp. nov. Joshi, Subramanian, Babu & Kunte

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(Figs. 1–6, 12a–b)

**Holotype.** ♂ (NCBS-BK825), Pandimotta, Shendurney Wildlife Sanctuary, Kollam, Kerala, India (8.8271 N, 77.2167 E; Alt: 1,231 m), 5.iv.2014, Krushnamegh Kunte leg.

**Paratypes.** 2 ♂♂, 1 ♀ (NCBS-BK826, NCBS-QA009, & NCBS-QA011), location, date of collection, and collector same as holotype; 2 ♂♂, 2 ♀♀ (ZSI-SRCI I/OD/2210–2213), Oothu to Kuthiraivetti Road, Ambasamudram Range, Kalakkad Mundanthurai Tiger Reserve, Tirunelveli, Tamil Nadu, India (8.5879 N, 77.3414 E; Alt: 1,264 m), 22.viii.2019, R. Babu & K.A. Subramanian leg.

**Other material.** 4 ♂♂, 4 ♀♀, (ZSI-SRC I/OD/2214–2221), location, date of collection, and collector same as paratypes I/OD/2210–2213; 1 ♂ (ZSI-SRC I/OD/2222), Marapalam, near Nalumukku, Ambasamudram Range, Kalakkad Mundanthurai Tiger Reserve, Tirunelveli, Tamil Nadu, India (8.5437 N, 77.3749 E; Alt: 1,254 m), 25.viii.2019, R. Babu & K.A. Subramanian leg.

**Etymology.** The specific name *cyanofemora* is given for its bright blue (=cyan, from Greek 'kuaneos') femur (=femor, Latin).

**Description of holotype (Figs. 1, 2a–c).** [Note: markings described as blue or purple, especially for the head and legs relate to the life colors, which are white post-mortem]

**Head** (Fig. 1b). Dorsal half of middle lobe, lateral lobes of labrum and, anteclypeus pale bluish yellow, postclypeus black, base of antennae bright blue, rest of the face black; eyes bright blue.

**Thorax.** Prothorax (Fig. 1g) purple, marked extensively with black; small irregular median black marking at the posterior margin of anterior lobe; lateral lobes of middle lobe black, this marking faintly continuing to lateral margin of anterior lobe; posterior lobe black medially, laterally purple; propleuron with a broad black band, ventral border with a blue stripe; posterior margin of prothorax straight. Pterothorax (Fig. 1a,d): mesepisternum and metepisternum black, dorsum of mesepisternum and dorsal carina with faint brown sheen, metepimeron and mesepimeron creamish-white; ventrally creamish-white bordered with black. **Legs:** coxae and trochanter white; femur internally blue, black externally; tibia and tarsus dull white anteriorly, black posteriorly; claws black.

**Wings** (Fig. 1a,c) hyaline, Pt dark brown, occupying about 1¼ cells; one cell between junction of RP<sub>1</sub>-RP<sub>2</sub> and origin of IR<sub>1</sub> in FW, two in HW; Ab absent; Ax: 2 in all wings; Px: FW: left & right = 13, HW: left = 11, right = 12.

**Abdomen** (Fig. 1d–f). S1 laterally white, dorsally black; S2 with antero-lateral half white, rest of the segment black; S3–8 marked yellowish-white at anterior margins, markings more extensive laterally and caudally; yellowish-white lateral marking on S8 obtusely triangular, not connected dorsally, occupying 2/3<sup>rd</sup> length of the segment; S9–10 black.

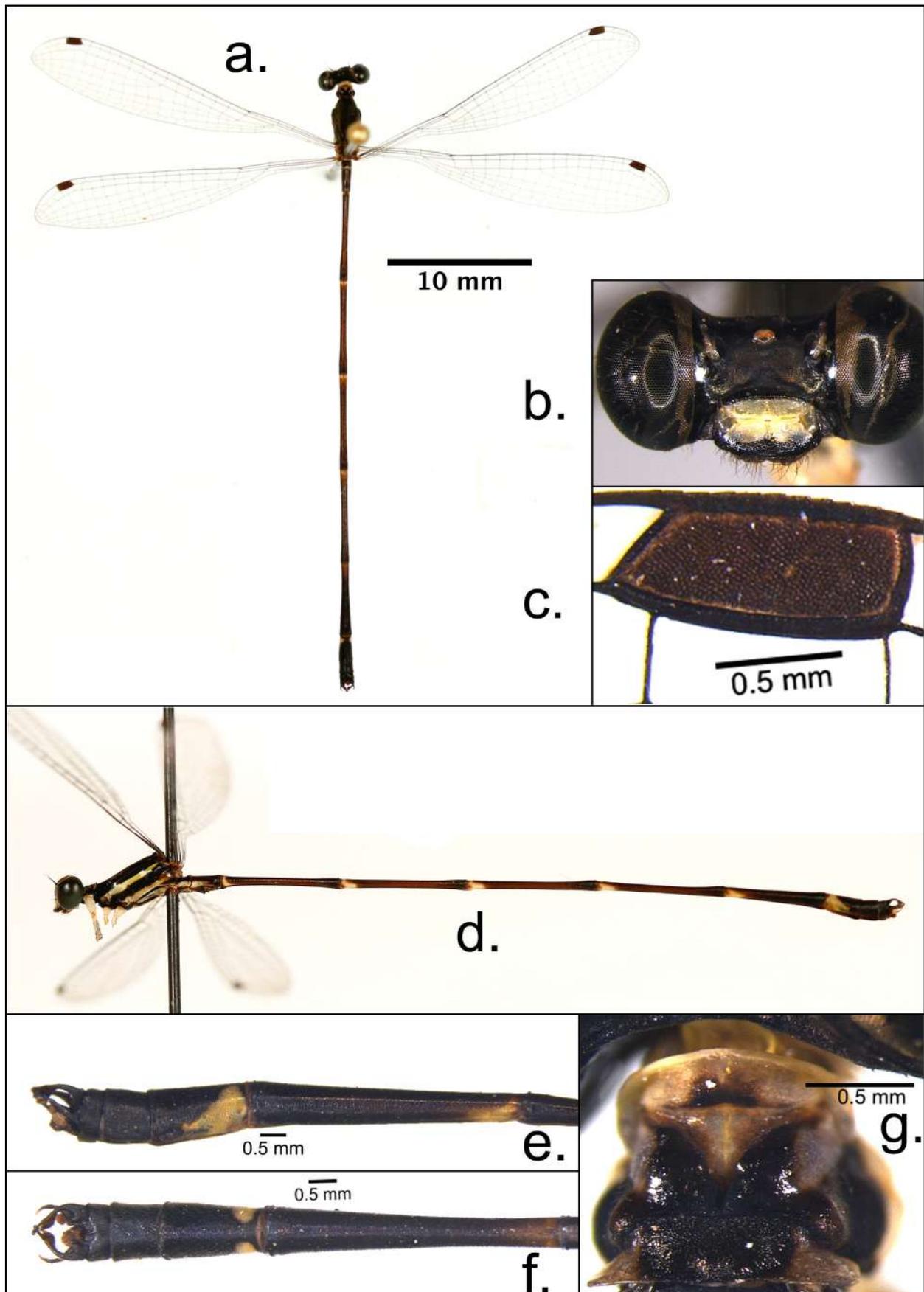
**Genital ligula** was not dissected for the holotypes. It has been described and illustrated for the paratype.

**Caudal appendages** (Fig. 2a–c) black, apices dark brown, about 3 times longer than S10; cerci with a triangular basal spine at inner margin situated about ¼ of total length, curved laterally inwards and backwards; cerci bifid at apices, curved inwards; dorsal arm thinner than ventral arm; thicker, and curved slightly at apices; ventral arm flattened, semi-circular in shape, wider than outer arm but both arms approximately same length; paraprocts thicker at base with a basal spine pointed dorsally, apices thin, sharply pointed, curved inwards, apex dorso-ventrally flattened.

Measurements: abdomen + caudal appendages = 37.3, FW = 22.6–23, HW = 21.9–22.2, cerci = 1, paraprocts = 0.9.

#### **Paratype male.**

Similar to the holotype. However, observed differences in males including paratypes are provided in the variation section.



**FIGURE 1.** *Protosticta cyanofemora* sp. nov. Holotype male [NCBS-BK825]: (a) habitus, dorsal view; (b) face; (c) pterostigma of right FW; (d) habitus, lateral view; (e) S7–10, lateral view; (f) S7–10, dorsal view; (g) prothorax, dorsal view.

Description of genital ligula for the paratypes NCBS-QA009 & ZSI-SRC I/OD/2220 (Fig. 4): first segment broader at base, black, tapering and thinner at junction with second segment; third segment expanded laterally at the juncture with second segment, translucent, dorsal surface with lateral ridges and a median ridge colored faint brown; apical surface curved ending in two long filaments.

**Variation in males (Figs. 2d–f, 3).** Variation in abdomen and hind wing length is provided in Table 1, and nodal index is given in Table 2. The colors (especially blue) of specimens preserved in ethanol are retained much better compared to pinned specimens. Medial black marking on anterior lobe of prothorax is variable, very faint in some individuals, while darker in immature males such as ZSI-SRC I/OD/2222. In NCBS-QA011 blue marking on S7 is extremely faded; one cell between junction of  $RP_1$ - $RP_2$  and origin of  $IR_1$ , two in right HW. In NCBS-QA009 metepimeron and mesepimeron with anterior 1/3<sup>rd</sup> greenish-yellow, posterior 2/3<sup>rd</sup> bright yellow; S9 with a small white marking at the ventral anterior margin. Immature males (e.g. ZSI-SRC I/OD/2222) have brighter brown Pt. Px: FW = 12; HW = 11–12.

**Description of paratype female (NCBS-BK826) (Figs. 5, 6a–b).** *Head* (Fig. 5d). Lateral lobes of labrum, anteclypeus and two horizontally elongated markings on dorsal margin of middle lobe of labrum blue; rest of the face black; base of antennae black, second segment and base of third segment yellowish; vertex and postocular lobes black with metallic sheen; eyes bluish, brown post-mortem.

*Thorax.* Prothorax (Fig. 5e): posterior lobe black, black markings continued towards anterior lobe as two black lines; lateral lobes of median lobe brown, black medially; anterior lobe brown; prothorax laterally black; propleuron pale yellow. Pterothorax (Fig. 5a–b): dorsal carina dark brown; mesepisternum black, metepimeron pale yellow, metepisternum black, and mesepimeron creamish-white; ventrum pale yellow. *Legs:* internal surface of femur and coxae pale-yellow, external surface of femur, trochanter, and tarsus pale brown; claws brown.

*Wings* (Fig. 5a,c) hyaline, anterior veins dark brown, rest black; Pt dark brown, occupying 1¼ cells; one cell between junction of  $RP_1$ - $RP_2$  and origin of  $IR_1$  in FW, two in HW; Ab absent; Ax: 2 in all wings; Px: FW: left & right = 14, HW: left = 14, right = 13.

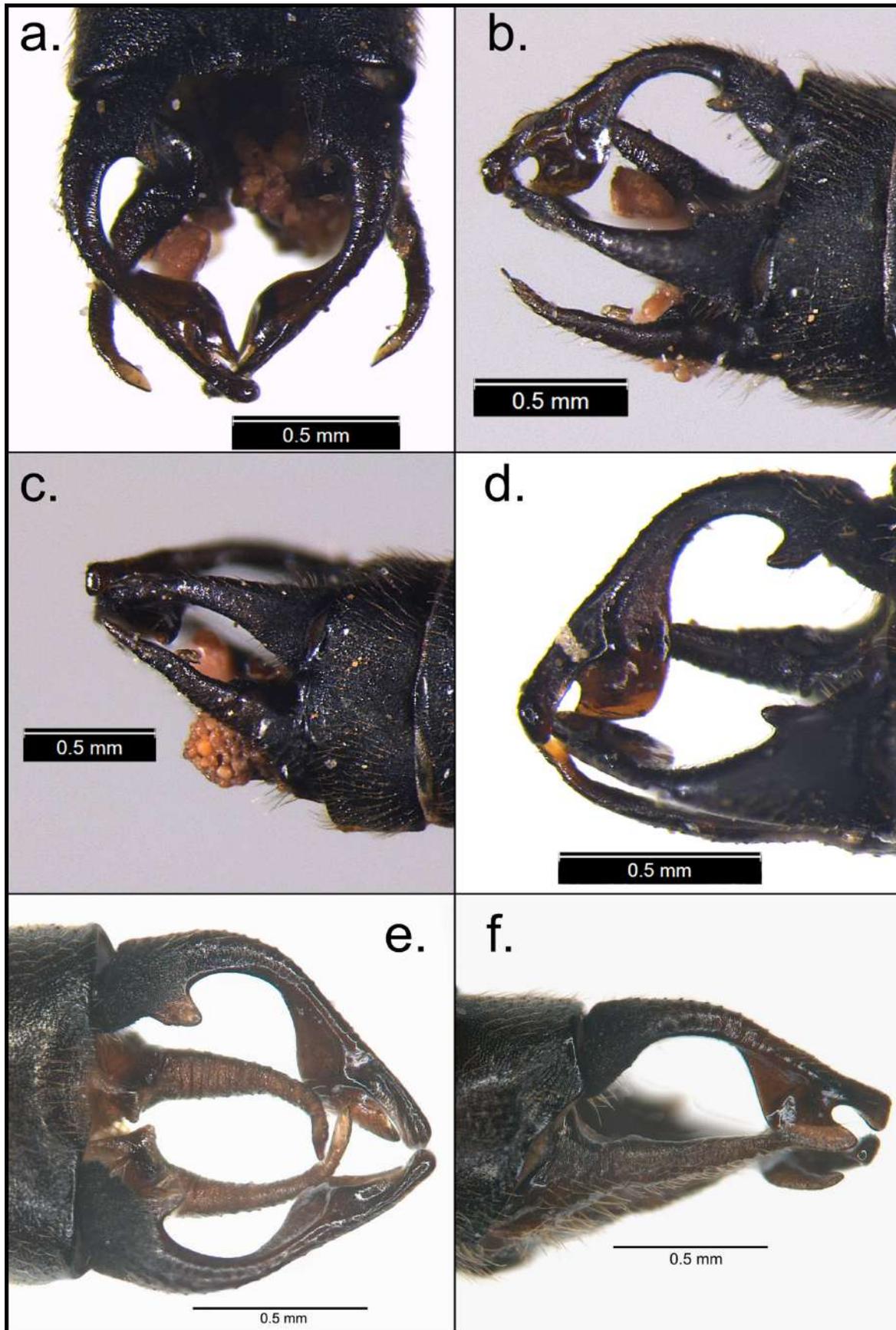
*Abdomen* (Fig. 5a–b). Black, becoming gradually dark brown from S7 apically. Marked as follows: latero-ventral half of S1 yellow; S2 marked with yellow at the latero-ventral border at anterior margin, marking broader at base, fainter posteriorly, reaching about ½ of S2; anterior margin of S3–8 with yellow annules, not connected dorsally only on S2 and S7, the annules extended laterally posteriorly, becoming more pronounced on consecutive segments; S8 with a faint latero-ventral yellow marking at the anterior margin; S9 brown; S10 black.

*Caudal appendages* (Fig. 6a–b). Cerci black, broader at base, 0.8 times the length of S10, triangular in lateral view, pointed; paraprocts reduced, rounded black, less than half the length of cerci; dorsal half of valve of ovipositor dark brown, ventral half black, terebra brown, triangular, slightly longer than cerci; ovipositor brown, ending in a long black styles reaching beyond cerci and valve. Measurements: abdomen + caudal appendages = 30.9, FW = 21.3–21.4, HW = 20.1–20.4, cerci = 0.25.

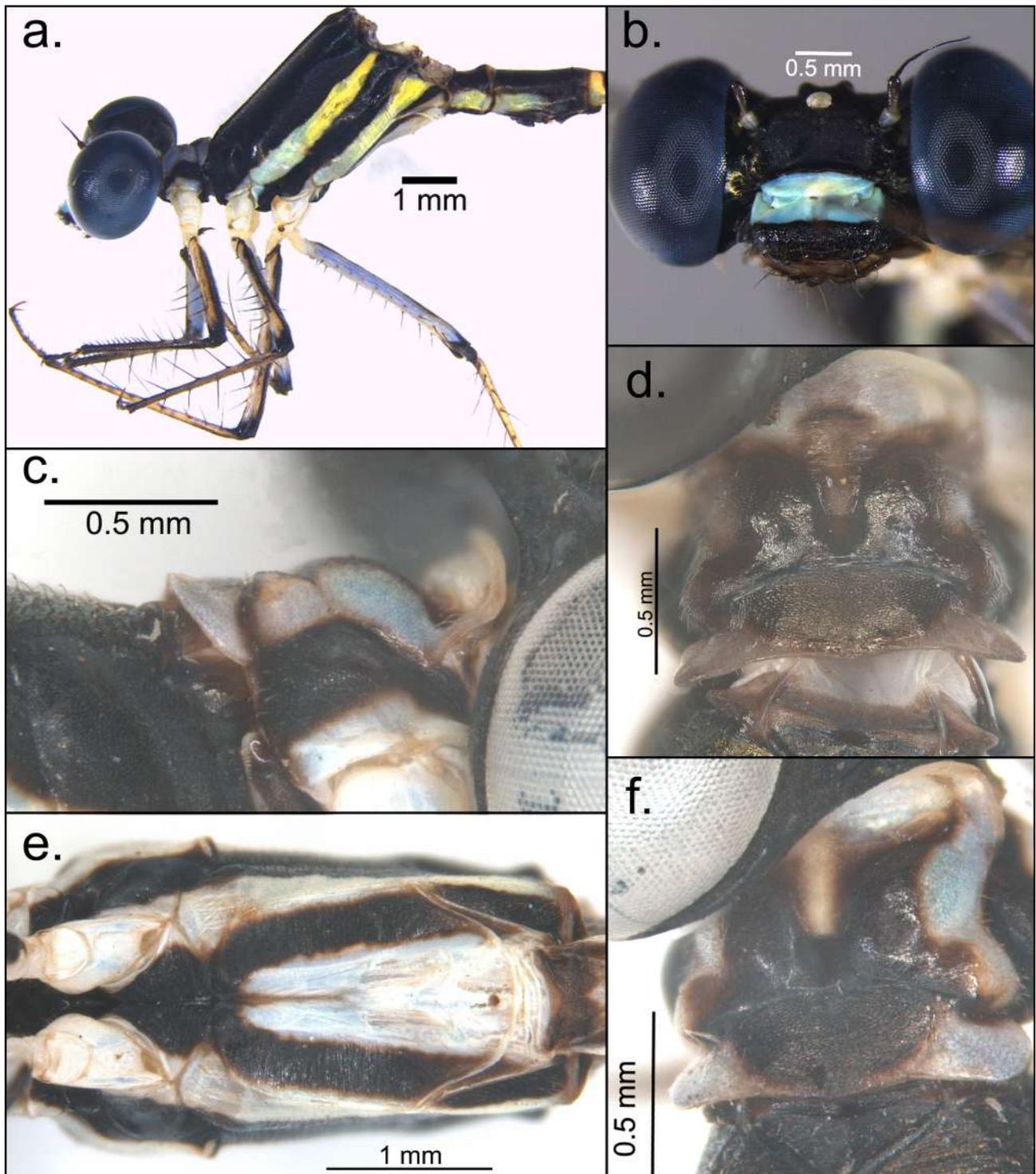
**Variation in females.** One cell between junction of  $RP_1$ - $RP_2$  and origin of  $IR_1$  in FW and HW of specimens I/OD/ 2212, 2214–2217. Two cells in right hindwing of I/OD/2213.

**Diagnosis.** Male of this species is at once distinguished from all other *Protosticta* spp. of the Western Ghats by its bright-blue coloration (Figs. 3a, 12a) of facial markings, eyes, prothoracic markings, and femora. Three additional characters to differentiate it from similar species are: a) lateral lobes of middle lobe and central portion of posterior lobe of prothorax black dorsally, propleuron with blue and black bands (Figs. 1g, 3c–d,f); b) shape of apical fork of cerci: not flattened, inner arm beak-like, & outer arm longer with round apices; c) marking on S8 triangular, broader at base, tapering posteriorly in lateral view, not connected dorsally; S9 black (Fig. 1e–f). Female of this species can be diagnosed from congeneric species by: a) blue eyes (Fig. 12b), b) color of prothorax, especially the black marking present on middle lobes and posterior lobe (Fig. 5e), and c) extent and shape of bright markings on S3–9 (Fig. 5b).

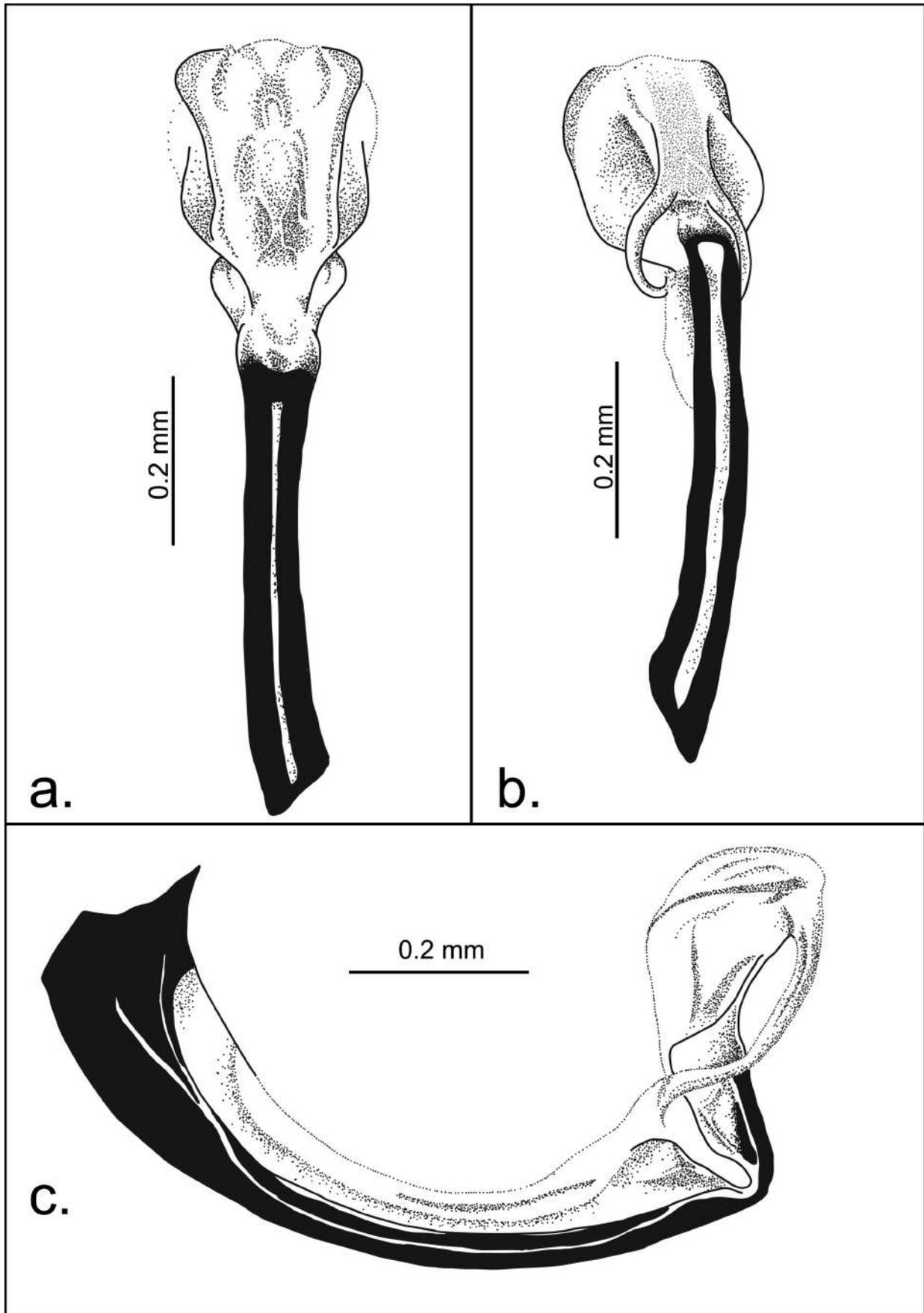
**Habitat and Ecology.** This species was first observed at Pandimotta, Shendurney Wildlife Sanctuary, Kerala, India at the elevation of ~1,200 m. Pandimotta is covered with a mosaic of shola (stunted patches of evergreen forests in the valleys) and tropical evergreen forest patches (Fig. 18a). This species was observed resting on shrubs and undergrowth along the banks of small hill streams in tropical evergreen forest patches sympatrically with *P. graveleyi*, *P. davenporti*, and *P. sanguinostigma*. In 2019, specimens of *P. cyanofemora* were collected from two localities at similar elevation in Kalakkad Mundanthurai Tiger Reserve, Tirunelveli, Tamil Nadu; one locality is a riparian evergreen forest and the other is a forest patch bordering tea garden. These localities are about 15–20 kilometers away from the type locality (Fig. 23a).



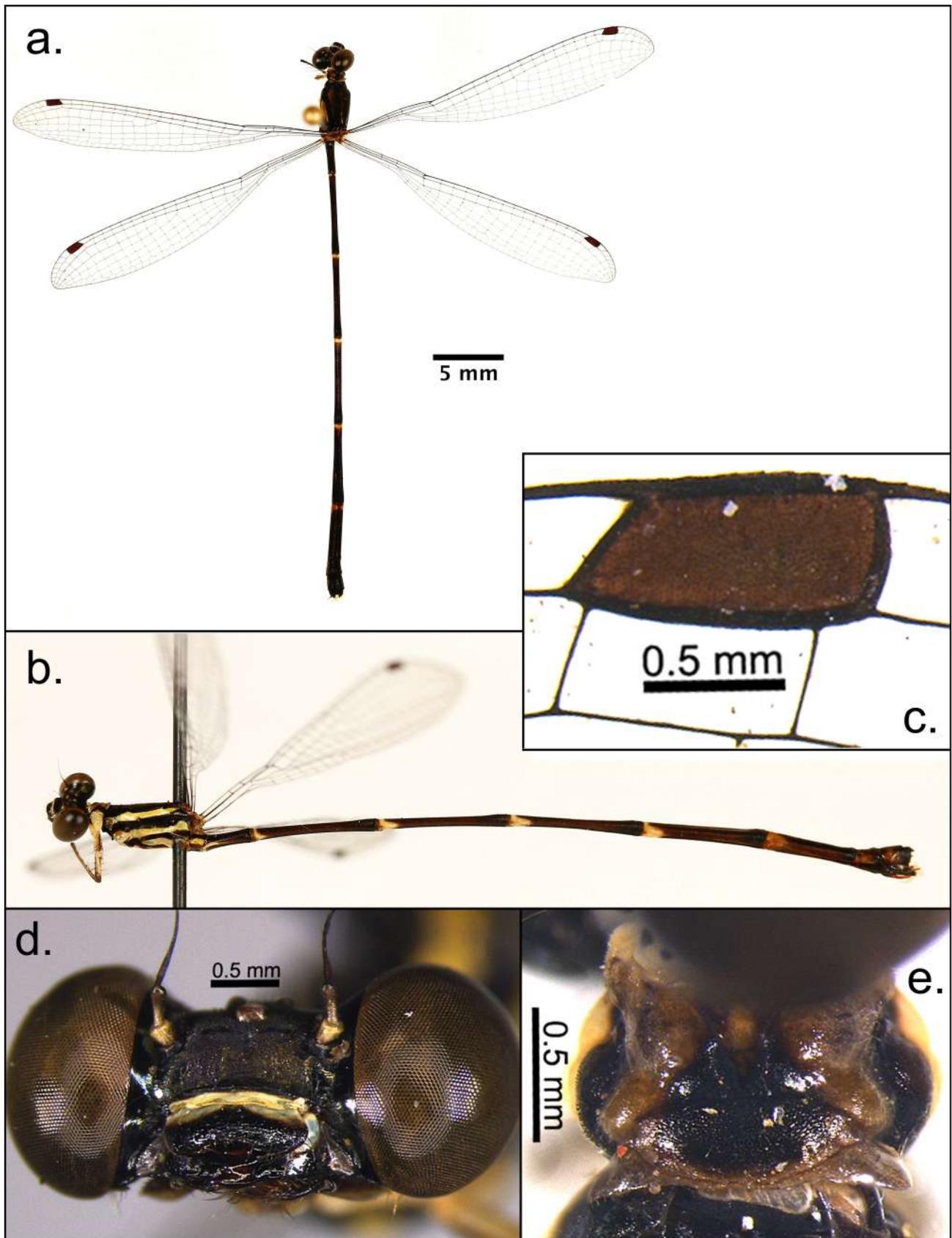
**FIGURE 2.** Caudal appendages of *Protosticta cyanofemora* sp. nov. (a–c) Holotype male [NCBS-BK825]: (a) dorsal view; (b) dorso-lateral view; (c) left lateral view; (d–f) Paratype male: (d) dorso-lateral view [NCBS-QA011]; (e) dorsal view [ZSI-SRC I/OD/2222]; (f) right lateral view [ZSI-SRC I/OD/2222].



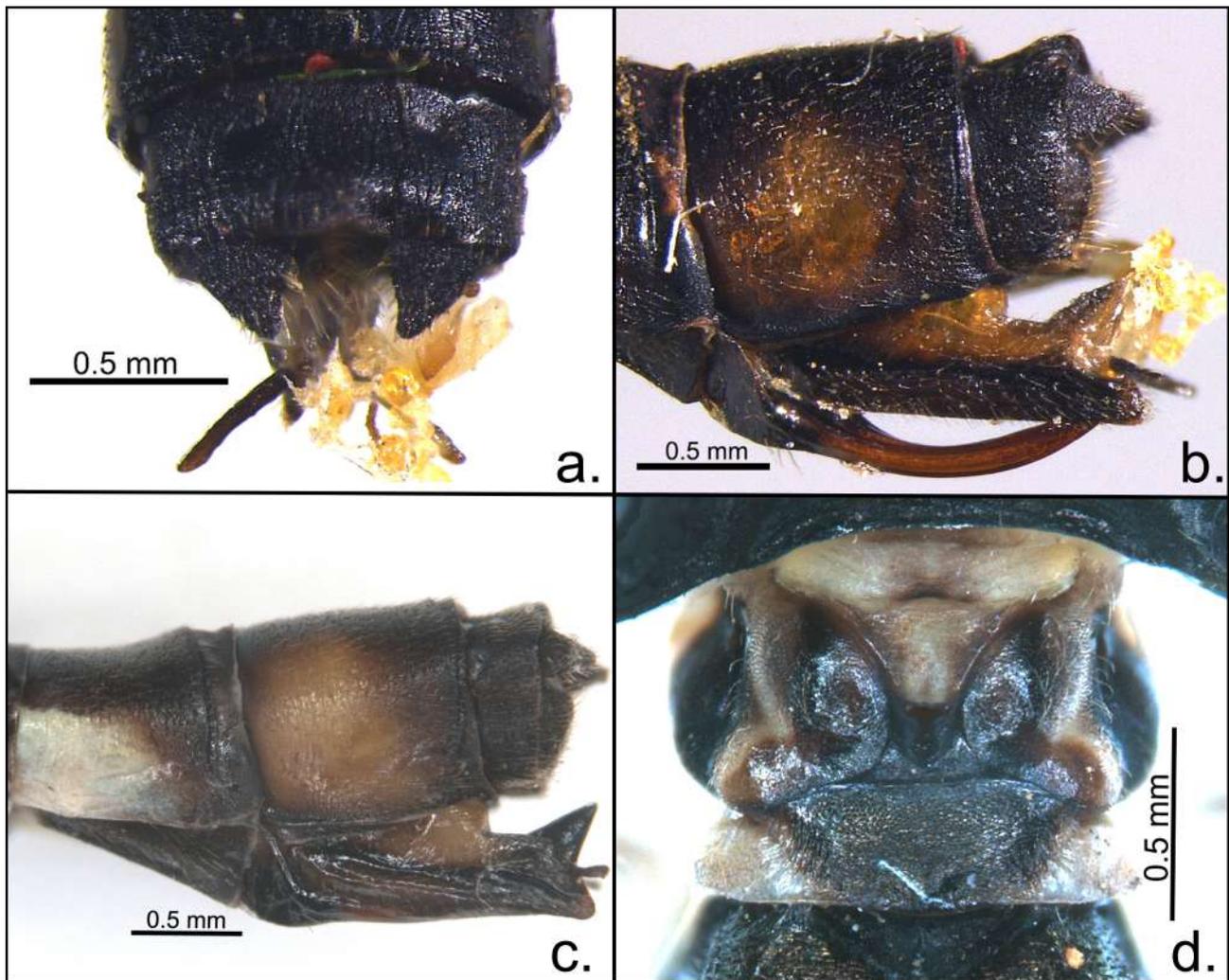
**FIGURE 3.** *Protosticta cyanofemora* sp. nov. Paratype males (a–b) NCBS-QA009: (a) head, thorax & legs; (b) face; (c, e–f) ZSI-SRC I/OD/2220, (d) ZSI-SRC I/OD/2222: (c) prothorax, right lateral view; (d) prothorax, dorsal view; (e) pterothorax, ventral view; (f) prothorax dorsal view.



**FIGURE 4.** Genital ligula of *Protosticta cyanofemora* sp. nov. based on NCBS-QA009 & ZSI-SRC I/OD/2220: (a) dorsal view; (b) ventral view; (c) left lateral view.



**FIGURE 5.** *Protosticta cyanofemora* sp. nov. Paratype female [NCBS-BK826]: (a) habitus, dorsal view; (b) habitus, lateral view; (c) pterostigma, right FW; (d) face; (e) prothorax, dorsal view.



**FIGURE 6.** *Protosticta cyanofemora* sp. nov. Paratype females: (a–b) caudal appendages [NCBS-BK826]: (a) dorsal view; (b) lateral view; (c–d) caudal appendages and prothorax [ZSI-SRC I/OD/2212]: (c) caudal appendages, lateral view; (d) prothorax, dorsal view.

***Protosticta myristicaensis* spec. nov.**

**Joshi & Kunte**

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(Figs. 7–11, 12c–d)

**Holotype.** ♂ (NCBS-BH110), Kathlekan, Shivamogga, Karnataka, India (14.2743 N, 74.7479 E; Alt: 560 m), 16.iv.2019, Krushnamegh Kunte leg.

**Paratypes.** 2 ♀♀ (NCBS-BH111 & NCBS-BH112), location, date of collection, and collector same as holotype. 3 ♂♂, 1 ♀ (NCBS-BM654–BM657), same locality as holotype, 23.xi.2019, Krushnamegh Kunte leg.

**Etymology.** The specific name is given after ‘*Myristica* swamps’, a unique, biodiverse forest swamp habitat endemic to the Western Ghats, where the type series was observed and collected.

**Description of holotype (Figs. 7, 9).** *Head* (Fig. 7b). Labrum, anteclypeus, postclypeus bright blue in live condition, pinkish white in preserved individual; lower 1/3rd of labrum, mandibles and labium brown; antefrons, postfrons black; vertex and postocular lobes black with metallic green sheen; eyes pastel blue in situ, pale pinkish brown post-mortem; both sides of the occipital ridge with a small rounded protuberance; base of antenna white, filament black.

*Thorax.* Prothorax (Fig. 7c) dorsally bright turquoise blue, brown laterally, dorsal carina pale yellow. Pterothorax (Fig. 7a) black, with copper colored sheen, marked with white: dorsal carina, across mesepimeron occupying

dorsal 1/3<sup>rd</sup>, connected to white metacoxae, and across metepimeron connecting to the white metacoxae laterally, metinfraepisternum slightly white at ventral border adjacent to metacoxae; ventrum of metathorax black. *Legs* including coxae white, femur faintly marked black on the posterior face, tarsus dark at apices, tarsal claws yellow.

*Wings* (Fig. 7a,d). Basal wing venation white; Pt dark brown bordered with yellow; two cells between junction of RP<sub>1</sub>-RP<sub>2</sub> and origin of IR<sub>1</sub> in FW and right HW, three in left HW; Ab absent; Ax: 2 in all wings; Px: FW = 11, HW = 9–10.

*Abdomen* (Fig. 7a). Marked with black and white: anterior half of S1 white laterally, S2 with a slanting white marking laterally reaching 2/3<sup>rd</sup> of its length; S3–7 with white annules at anterior border and black annules at the posterior border, white markings reduced on S3, more prominent on subsequent segments; S8 with a broad white basal ring occupying about 3/4<sup>th</sup> of the segment, continued ventro-laterally till posterior margin; S9–10 black. Anterior hamuli small, ovoid, dark brown, covered with thick brown hair at apices. Posterior hamuli saddle-shaped, broader at base curved anteriorly at a 45° angle, base covered with sparse hair, apex covered by a plume of hair.

*Genital ligula* (Fig. 9). Ventral half of first and second segments black, dorsally dark brown; first segment thicker at base, thinner midway and thick at the juncture with second segment; second and third segments attached; third segment complex; dorsally with two inwardly curved ridges on apices; these two ridges connecting at the apices; laterally third segment with conical protuberances on both sides, apices tapering, elongated reaching till the first segment.

*Caudal appendages* (Fig. 7e–f). Cerci black, about 3.5 times of S10 in length, curving inwards at apices; cerci with a basal spine, bifurcated at the apices into two arms; inner, ventral arm thick at its base, curved, with bluntly pointed apices, expanded at base and curved downwards, at the base of inner arm a small blunt spine pointing posteriorly; outer dorsal arm much thinner than inner, slightly thinner at base, thicker medially and with blunt thin apices; paraprocts brown, curved ventro-laterally inwards and upwards towards apices, a small inwardly curved basal spine present, broader at base, apices rounded.

Measurements: abdomen + caudal appendages = 19.2, FW & HW = 12, cerci = 0.7, paraprocts = 0.6.

**Variation in males (Fig. 8).** In NCBS-BM654, bright markings on S2–7 fainter; marking on S8 slightly irregular on left lateral area, but of same length as holotype; yellow border of pterostigma less extensive; two cells between junction of RP<sub>1</sub>-RP<sub>2</sub> and origin of IR<sub>1</sub> in FW, three in the HW. In NCBS-BM655, border of anteclypeus and postclypeus bluish, postclypeus brown; three cells between junction of RP<sub>1</sub>-RP<sub>2</sub> and origin of IR<sub>1</sub> in all wings. In NCBS-BM656, three cells between junction of RP<sub>1</sub>-RP<sub>2</sub> and origin of IR<sub>1</sub> in all wings, except left HW with four cells. Immature males have white pterostigma.

Px: HW = 9–10, FW = 10–11.

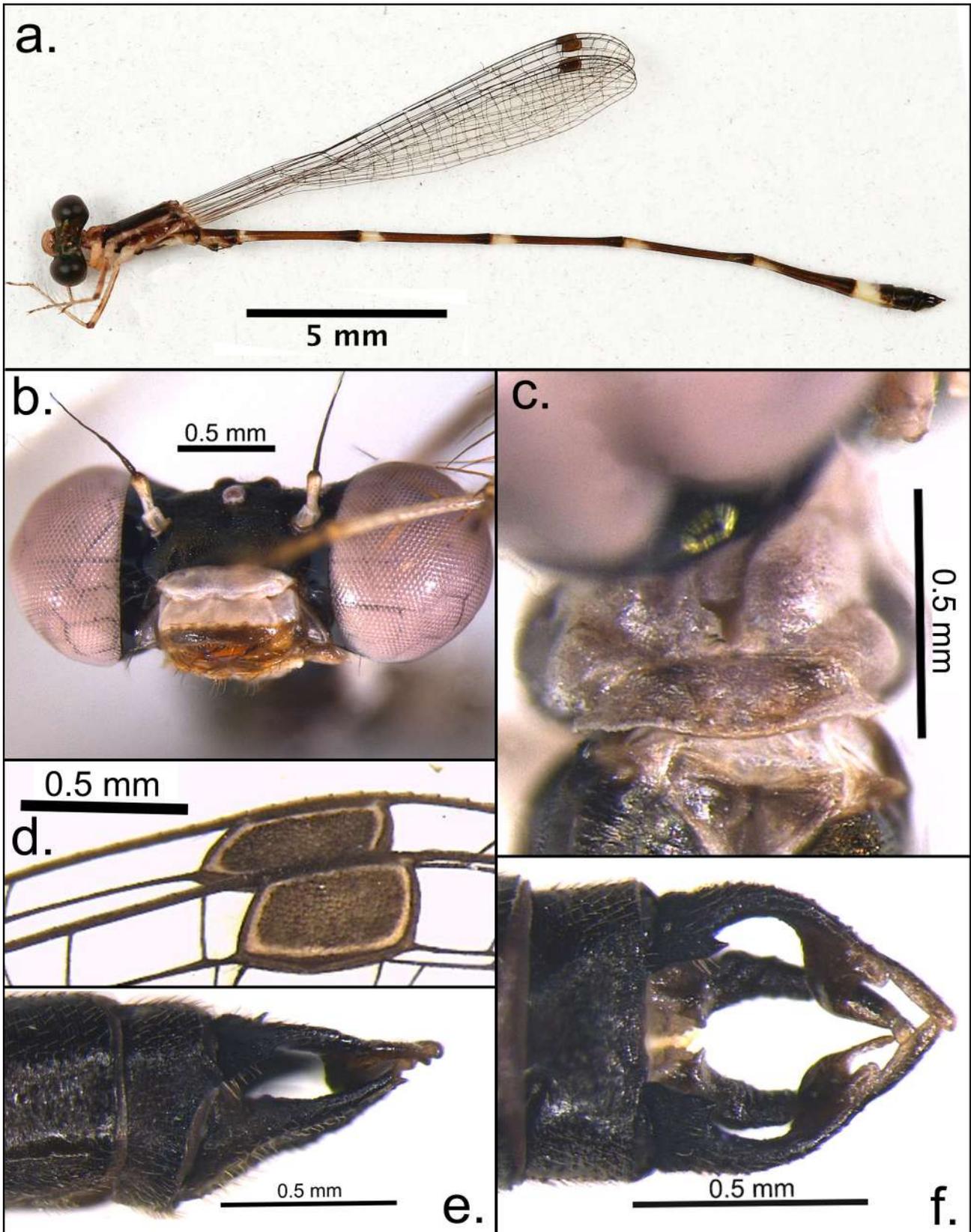
**Description of female (NCBS-BH111) (Fig. 10).**

*Head* (Fig. 10b). Labrum, anteclypeus, bright blue; lower half of labrum, mandibles and labium dark brown; postclypeus, frons, vertex and postocular space black with metallic green sheen; both sides of the occipital ridge with a small rounded protuberance; base of antennae white, rest dark brown; eyes brown centrally largely pale blue.

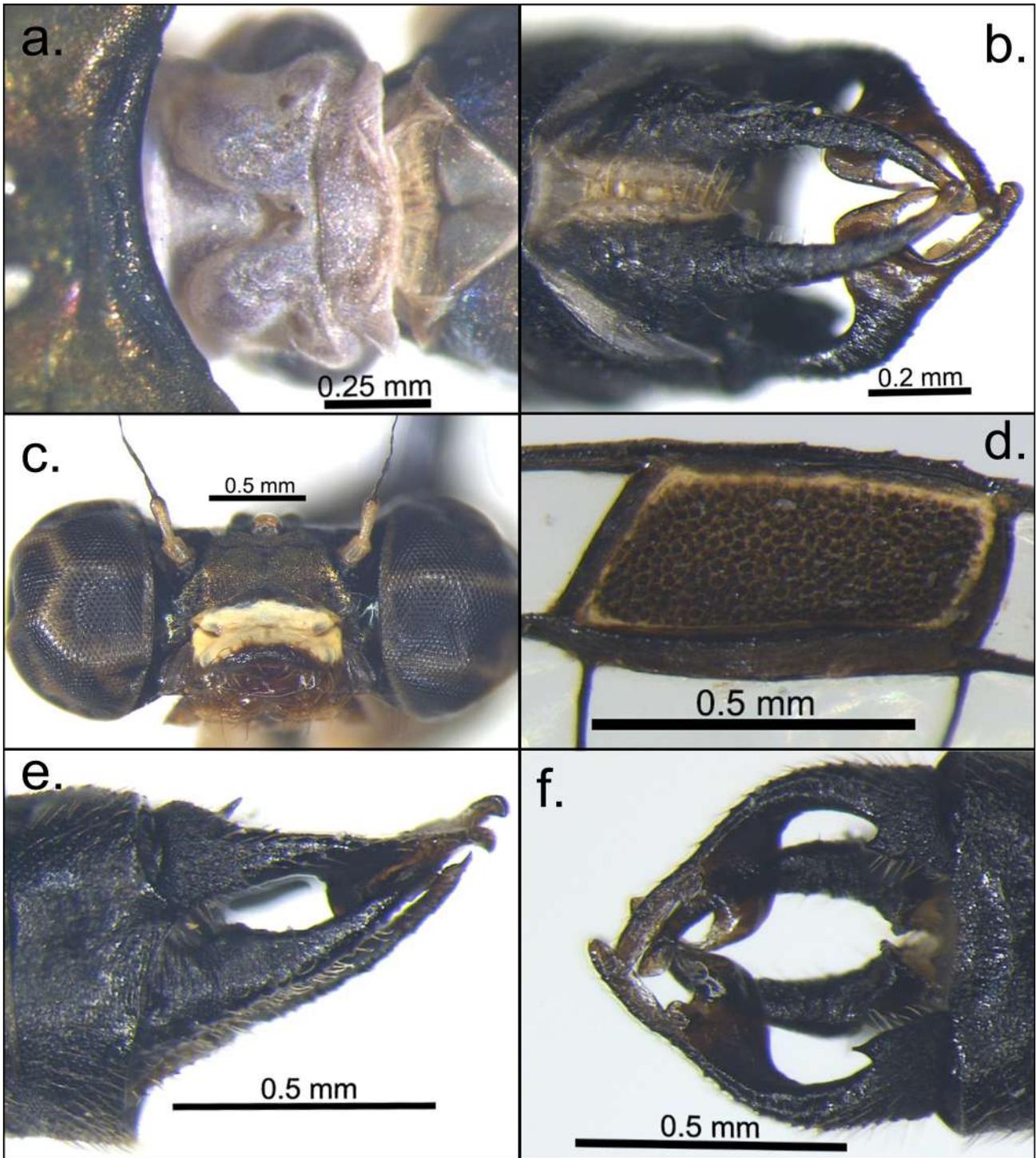
*Thorax*. Prothorax (Fig. 10d–e) bright blue in situ, laterally median and posterior lobes faint purple, propleuron brown; anterior margin of anterior lobe raised; posterior lobe depressed medially. Pterothorax (Fig. 10a). Dorsal carina white, mesepisternum brown with purplish sheen at some viewing angles, dorsal carina pale yellow, mesepimeron brown with a faint metallic blue band adjacent to the ventral border; white band across upper half of metepisternum connecting to mesocoxae; mesinfraepisternum largely brown, white at lower border adjacent to coxa; metepimeron with lower half white; brown marking on lower half of metepisternum and upper half of metepimeron connecting, expanded medially, tapering posteriorly, anteriorly continued on metinfraepisternum; venter of metathorax black with a medial broad white band continuing on S1. *Legs* including coxae white, junction of femur and tibia black.

*Wings* (Fig. 10a,c). Basal membranules white, venation black; Pt brown post-mortem, slightly longer than one cell; three cells between junction of RP<sub>1</sub>-RP<sub>2</sub> and origin of IR<sub>1</sub> in all wings; Ab absent; Ax: 2 in all wings; Px: FW: left = 10, right = 11, HW = 10.

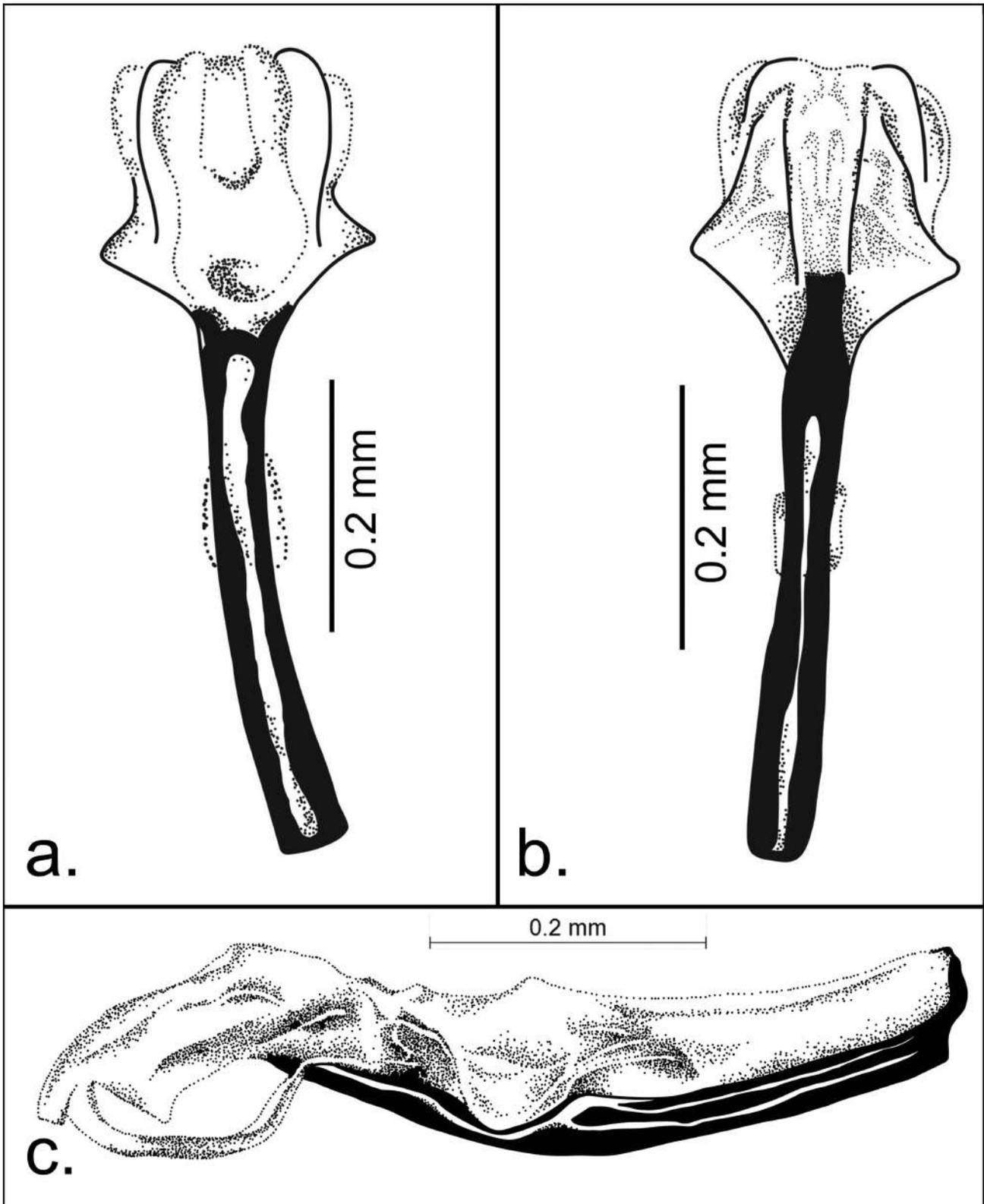
*Abdomen* (Fig. 10a). Anterior half of S1 laterally white; S2–8 with white annules at the anterior border, more extensive laterally and ventrally; dorsal markings reduced on S2; white marking at the anterior border of S8 not connected dorsally, continuing laterally about 1/2 the length of the segment; S9 white laterally but not connected dorsally; S10 brown; S2–7 darker at posterior border.



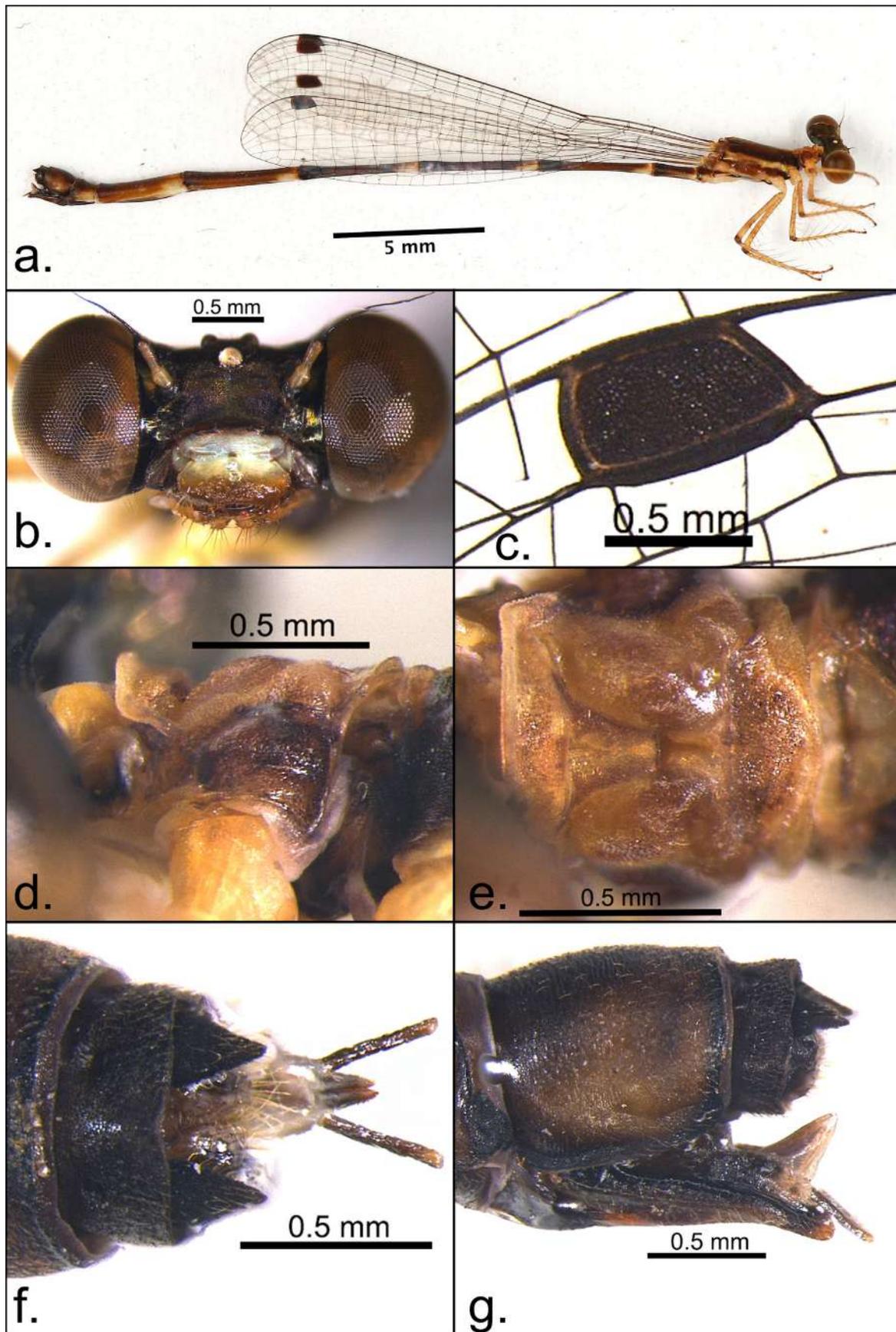
**FIGURE 7.** *Protosticta myristicaensis* **sp. nov.** Holotype male [NCBS-BH110]: (a) habitus, lateral view; (b) face; (c) prothorax, dorsal view; (d) pterostigma of right HW & FW; (e) caudal appendages, lateral view; (f) caudal appendages, dorsal view.



**FIGURE 8.** *Protosticta myristicaensis* **sp. nov.** Paratype males: (a–b) NCBS-BM655, (c–f) NCBS-BM654: (a) prothorax, dorsal view; (b) caudal appendages, ventral view; (c) face; (d) pterostigma of right FW; (e) caudal appendages, lateral view; (f) caudal appendages, dorsal view.



**FIGURE 9.** Genital ligula of *Protosticta myristicaensis* sp. nov. [based on NCBS-BH110 & NCBS-BM656]: (a) dorsal view; (b) ventral view; (c) left lateral view.

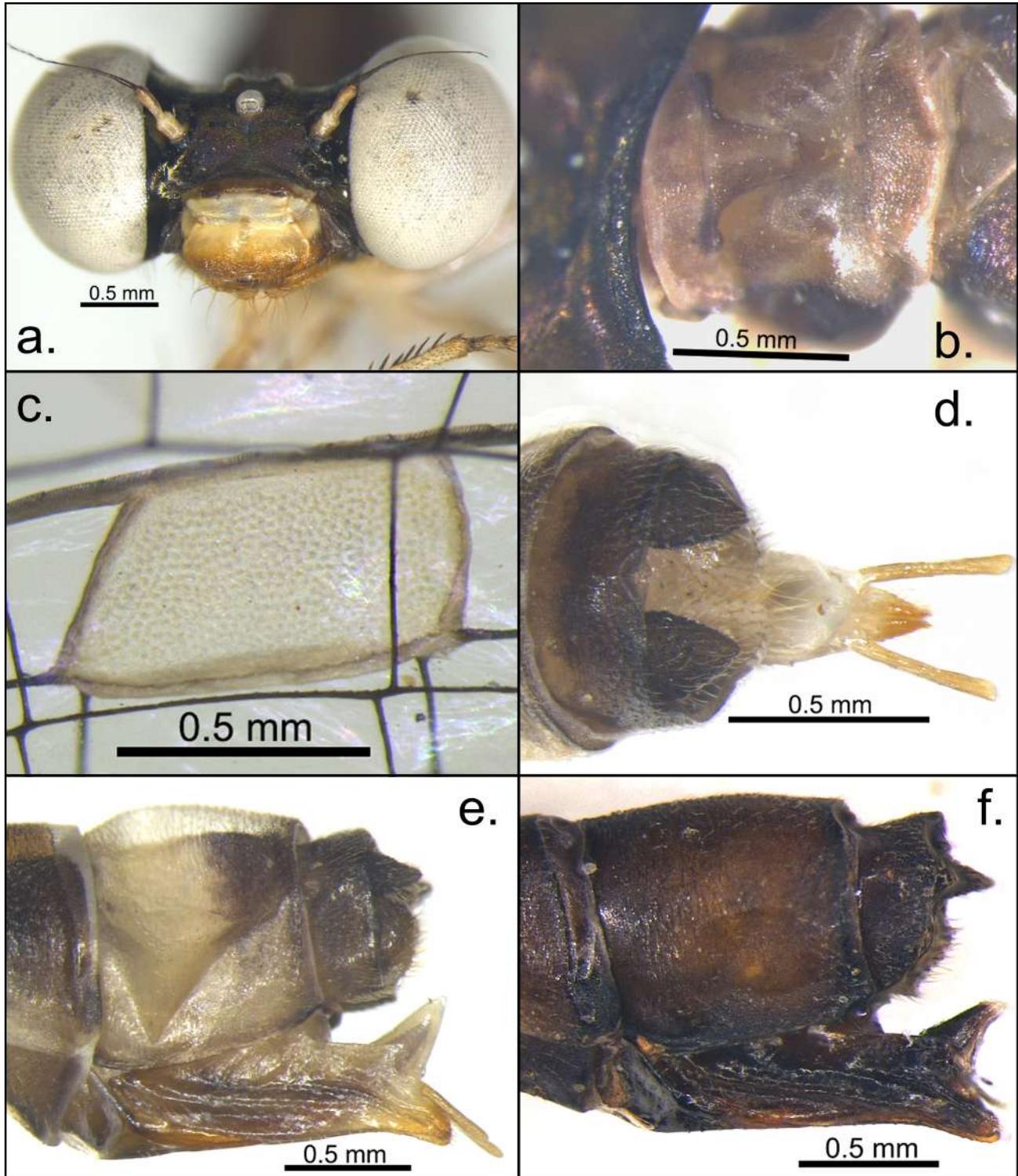


**FIGURE 10.** *Protosticta myristicaensis* sp. nov. Paratype female [NCBS-BH111]: (a) habitus, lateral view; (b) face; (c) pterostigma of right FW; (d) prothorax, left lateral view; (e) prothorax, dorsal view; (f) caudal appendages, dorsal view; (g) caudal appendages, lateral view.

*Caudal appendages* (Fig. 10f–g). Cerci black, conical, pointed at apices, approximately same length as S10; paraprocts black, rounded, half the length of cerci; ovipositor and valve of ovipositor black, ventrally dark brown, terebra large, about twice the length of cerci, grey-brown; ovipositor dark brown and sharply pointed at apices, ending in long dark brown styles extending well beyond cerci.

Measurements: abdomen + caudal appendages = 20.4, FW & HW = 14, cerci = 0.27.

**Variation in females (Fig. 11).** Wings enfumed brown and basal membranules yellow in NCBS-BH112. Immature females (e.g. NCBS-BM657, Fig. 11a–e) have white pterostigma and basal membranules, venation brown.



**FIGURE 11.** *Protosticta myristicaensis* sp. nov. Paratype females: (a–e) NCBS-BM657, (f) NCBS-BH112: (a) face; (b) prothorax, dorsal view; (c) pterostigma of right FW; (d) caudal appendages, dorsal view; (e–f) caudal appendages, lateral view.



**FIGURE 12.** Field images of: (a–b) *Protosticta cyanofemora* sp. nov. (a) male; (b) female; (c–d) *P. myristicaensis* sp. nov. (c) male; (d) female. Photos: (a, c–d) SJ, & (b) KAS.

In NCBS-BM657, three cells between junction of  $RP_1$ - $RP_2$  and origin of  $IR_1$  in left FW and both HW and two cells in right FW.

Px: FW = 12, HW: 10–11.

**Diagnosis.** This species is clearly the smallest Indian *Protosticta*. Apart from its small size, males can be distinguished from all other species by the shape of cerci, specifically the small tubercle at the base of the apical fork (Figs. 7f, 8b,f). It can be further distinguished from congeneric species by the color of eyes (blue, Fig. 12c), uniform coloration of prothorax (purple in live condition) (Figs. 7c, 8a), and bright marking on S8 (anterior 3/4<sup>th</sup> of the segment white, Fig. 7a).

Female of this species can be differentiated from other species in Western Ghats by its small size, color of prothorax (purple in live condition), and the extent and shape of bright markings on S8–9. Both males & females can be distinguished by the broad white dorsal carina.

**Habitat and Ecology.** Myristica swamps are freshwater swamps characterized by trees with stilt roots (Fig. 18b). These are relict habitats thought to have existed over large areas but have become highly fragmented, and now occupy less than 200 hectares (Kumaran *et al.* 2013, Limaye *et al.* 2016). These unique ecosystems are highly threatened from various factors such as land-use changes like conversion into agricultural fields and plantations (Chandran & Mesta 2001), and excessive water withdrawal (Ganesan 2002). We also observed this at the type locality of *P. myristicaensis* where on one side of the road Myristica swamps have been converted into areca nut plantations. Of the recorded wildlife in Myristica swamps 16.3% are endemic to Western Ghats (Jose *et al.* 2007), and many new species exclusive to Myristica swamps have been discovered in recent years such as the monotypic ‘Myristica Swamp tree frog’, *Mercurana myristicapalustris* Abraham, Pyron, Ansil, Zachariah & Zachariah, 2013.

*Protosticta myristicaensis* was observed exclusively in Myristica swamp patch, along the Bengaluru-Honnar road at Kathlekan, Karnataka (Fig. 23a). This site was surveyed twice (April and November 2019) and both times the species was observed (April: four males and two females; November: three males and two females). This species was observed alongside *P. gravelyi*, *Heliocypha bisignata* Hagen in Selys, 1853, *Tholymis tillarga* (Fabricius, 1798), *Mortonagrion varralli* Fraser, 1920 and *Phylloneura westermanii* (Hagen in Selys, 1860) (a species endemic to Myristica swamps). Unlike other Indian *Protosticta* spp., this species has the unique behavior of perching very low (not flying above the height of 20–30 cm) among roots of trees such as *Myristica fatua* Houtt. var. *magnifica* (Bedd.), *Gymnacranthera canarica* (King) Warb., *Semecarpus kathalekanensis* Dasappa & Swaminath (all three species endemic to Myristica swamps), *Knema attenuata* (Hook. Fil. & Thomas.) Warb., *Lophopetalum wrightianum* Arn. and *Hopea ponga* (Dennst.) Mabberley (Fig. 18b).

### ***Protosticta sholai* spec. nov.**

**Subramanian & Babu**

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(Figs. 13–17)

**Holotype:** ♂ (ZSI-SRC I/OD/2223), Upper Manalar, Near Suruli colony, Meghamalai Wildlife Sanctuary, Theni, Tamil Nadu, India (9.5889 N, 77.3416 E; Alt: 1,536 m), 17.ix.2016, R. Babu & K.A. Subramanian leg.

**Paratypes.** 2 ♂♂, 1 ♀ (ZSI-SRC I/OD/2224-2226), Downstream of Iravangalar Dam, Meghamalai Wildlife Sanctuary, Theni, Tamil Nadu, India (9.6079 N, 77.2996 E; Alt: 1,464 m), 17.ix.2016, R. Babu & K.A. Subramanian leg.

**Etymology.** The specific name *sholai* indicate the habitat of the species, i.e., montane evergreen forests of southern Western Ghats, known as *Sholai* (L. Tamil) or *Shola* (L. Malayalam).

**Description of holotype (Figs. 13, 14a–d).** [Note: markings described as yellow especially for the thorax, abdomen and legs change to light yellow to dull white and black changes to dark brown post-mortem]

**Head** (Fig. 13b). Central and lateral lobes of labium yellow at base and gradually changing into dark brown anteriorly; genae and mandibles black; dorsal half of labrum bright blue and ventrally black; anteclypeus and postclypeus bright blue, base of antennae yellow, gradually fading into brown; median and lateral ocellus black; median ocellus encircled by a light brown ring; eyes turquoise blue with a dorsal dark region and light blue ventrally; rest of the head black.

**Thorax.** Prothorax (Fig. 13d–e): Anterior lobe pale yellow; anterior half of middle lobe dark purple, posterior half brown; posterior lobes black with a bronze sheen medially bordered by small brown patches on both sides

at posterior border, purple laterally; the posterior margin of prothorax is concave medially and convex laterally, expanded into two flaps; propleuron yellow. Pterothorax (Fig. 13a,f): mesepisternum and metepisternum black, dorsum of mesepisternum and dorsal carina with bronze sheen, metepimeron and mesepimeron yellow; ventrally yellow with black “Y” shaped mark, stem of “Y” is directed anteriorly. *Legs*: coxae and trochanter yellow; femur anteriorly yellow, posteriorly black; segmental joints of femur and tibia black; tibia yellow anteriorly and black posteriorly; tarsal segments brown; claws brown.

*Wings* (Fig. 13a,c) hyaline, Pt dark brown, occupying about 1 cell; one cell between junction of RP<sub>1</sub>-RP<sub>2</sub> and origin of IR<sub>1</sub> in FW and HW; Ab absent; Ax: 2 in all wings; Px: FW = 13, HW = 12.

*Abdomen* (Figs. 13a, 14a). Black marked with yellow. S1 with lateral yellow semicircular spot, dorsally black; S2 with basal backwardly directed narrow yellow triangular spot, rest of the segment black; S3–7 black with basal yellow ring which is contiguous with backwardly directed lateral narrow yellow triangular spot; S8 with broad yellow lateral triangle which is continuous as broad basal yellow ring; S9 with broad lateral yellow spot, ventral part of S8–9 yellow; S10 black.

*Genital ligula* (Fig. 15). Brown, broad at base, tapering and thinner at junction with second segment; third segment expanded laterally at the juncture with second segment; apical surface curved ending in two long curved filaments, which are broad medially and taper apically. Ligula vesicle brown and club shaped. Anterior hamuli small, brown, oval with downwardly directed thick golden hairs. Posterior hamuli brown, saddle-shaped, paler brown at base; expanded ventrally, knob-like at apex.

*Caudal appendages* (Fig. 14b–d). Black, apices dark brown, about three times longer than S10; cerci with a laterally curved basal spine at inner margin, situated closer to the base and less than 1/3<sup>rd</sup> of total length of cerci. Cerci bifid at apex, curved inwards, outer and inner arm broad and spatulate, inner arm shorter than the outer and ends in a sharp thumb like projection; paraprocts shorter than cerci, thicker at base, apices thin, strongly curved inwards and backwards, ending with a spoon shaped dorso-ventrally flattened apex.

Measurements: abdomen + caudal appendages = 42.1, FW = 24, HW = 24.8, cerci = 2.4, paraprocts = 1.62

**Variation in paratype males (ZSI-SRCI/OD/2224 & 2225).** Similar to holotype in coloration of body parts. Px 12 in right and left FW; 12 and 11 in right and left HW, respectively (I/OD/2224) and 14 in right and left FW; 13 in right and left HW (I/OD/2225).

**Description of female (Fig. 16).** Coloration of head, thorax and abdomen similar to male. However, the yellow markings in terminal abdominal segments are duller.

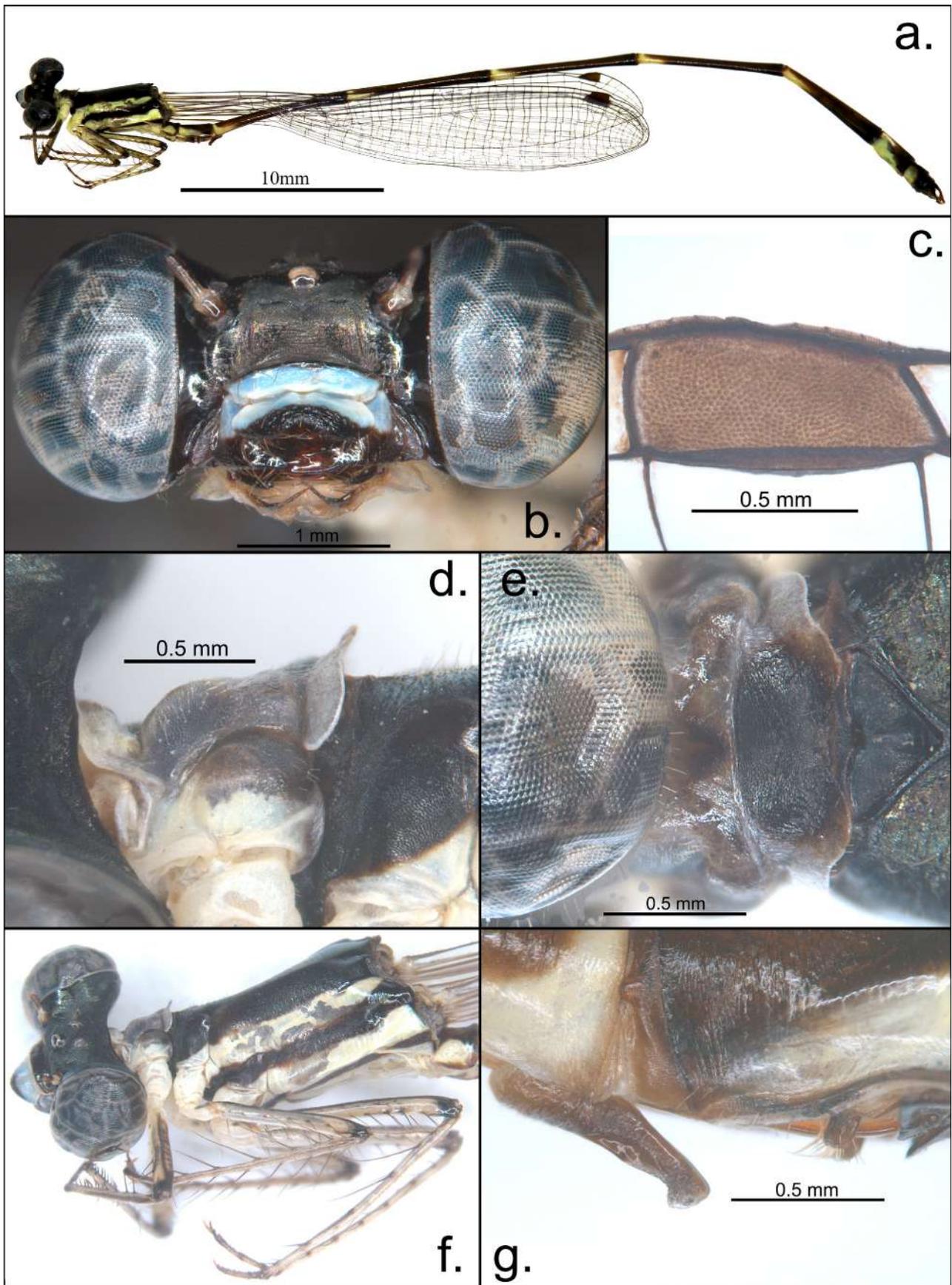
*Head* (Fig. 16c). Labium brown; dorsal 1/4<sup>th</sup> of labrum blue, rest dark brown; anteclypeus and postclypeus blue; rest of the face black; postfrons with a rounded brown marking medially at the ventral border; base of antennae pale yellow, brown at apices, filaments broken.

*Thorax*. Prothorax (Fig. 16d–e): anterior border of anterior lobe pale yellow, rest of the anterior lobe pale purple with two faint brown stripes medially; anterior lobe of prothorax with a pair of lateral downwardly directed small finger like projections at ventral border, the base of the fingers black and apices yellow (Fig. 16d); central lobe of the middle lobe brown, lateral lobes dark purple; posterior lobe black medially, lateral borders purple-brown; posterior lobe winged, expanded laterally, bilobed; ventral half of propleuron pale yellow, dorsal half black. Pterothorax (Fig. 16a–b): black, marked with pale yellow as follows: broad stripe at dorsal border of metepisternum slightly tapering at posterior border, another strip across metepimeron occupying the ventral half of it, expanded at posterior border; coxae and trochanter pale yellow, trochanter with small lateral black spots on inner and outer side on mid and hind legs; femur and tibia pale yellow on anterior front, black posteriorly, covered with brown long setae on tibia; tarsus dark brown.

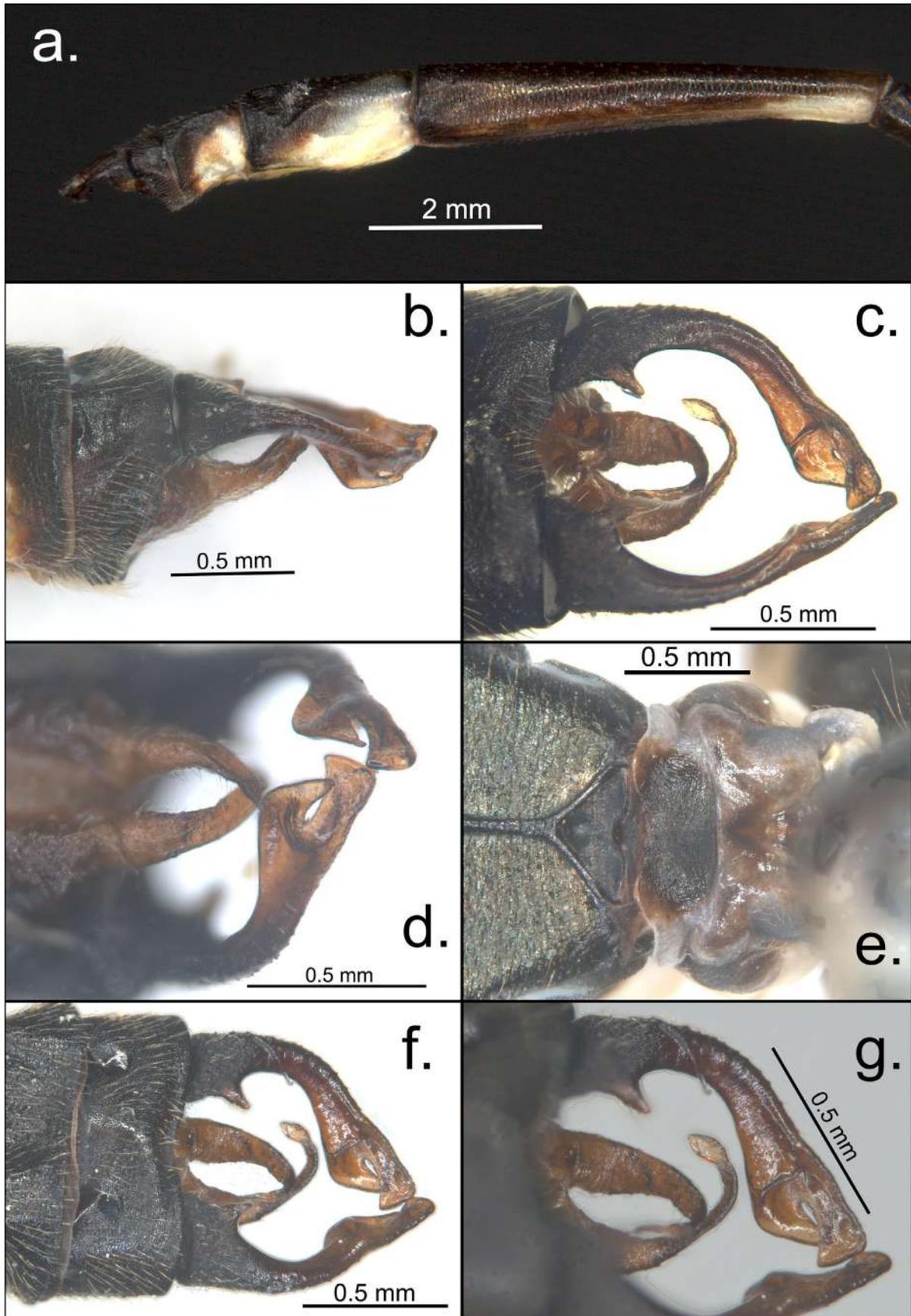
*Wings* (Fig. 16a,i) hyaline, veins black; Pt dark brown, occupying 1 cell; one cell between junction of RP<sub>1</sub>-RP<sub>2</sub> and origin of IR<sub>1</sub> in FW and HW; Ab absent; Ax: 2 in all wings; Px: FW = 13, HW = 12.

*Abdomen* (Fig. 16a,h). Black marked with yellow as follows: S1 with lateral yellow semicircular spot, dorsally black; S2 with basal backwardly directed narrow yellow triangular spot, rest of the segment black; S3–7 black with basal yellow ring which is contiguous with backwardly directed lateral narrow yellow triangular spot; black and yellow markings in S7–10 are duller; S8 with broad dull yellow lateral triangle which continuous as broad basal dull yellow ring; S9 with broad lateral dull yellow spot, ventral part of S8–9 dull yellow; S10 brownish black.

*Caudal appendages* (Fig. 16f–g). Cerci dark brown, broader at base, 0.8 times the length of S10, triangular in dorsal and lateral view, pointed; paraprocts reduced, rounded, dark brown, less than half the length of cerci; dorsal half of the valve of ovipositor light brown, ventral half brown, terebra brown, triangular, slightly longer than cerci; ovipositor brown, ending in a long brown styles reaching beyond cerci and valve.



**FIGURE 13.** *Protosticta sholai* sp. nov. Holotype male [ZSI-SRC I/OD/2223]: (a) habitus, lateral view; (b) face; (c) pterostigma of right FW; (d) prothorax, left lateral view; (e) prothorax, dorsal view; (f) pterothorax; (g) hamuli, right lateral view.



**FIGURE 14.** *Protosticta sholai* sp. nov. Holotype male [ZSI-SRC I/OD/2223] (a–d), and paratype male [ZSI-SRC I/OD/2224] (e–f): (a) lateral view of S7–10; (b) caudal appendages, right lateral view; (c) caudal appendages, dorsal view; (d) caudal appendages, ventral view; (e) prothorax, dorsal view; (f) caudal appendages, dorsal view; (g) dorsal close-up of left cercus.

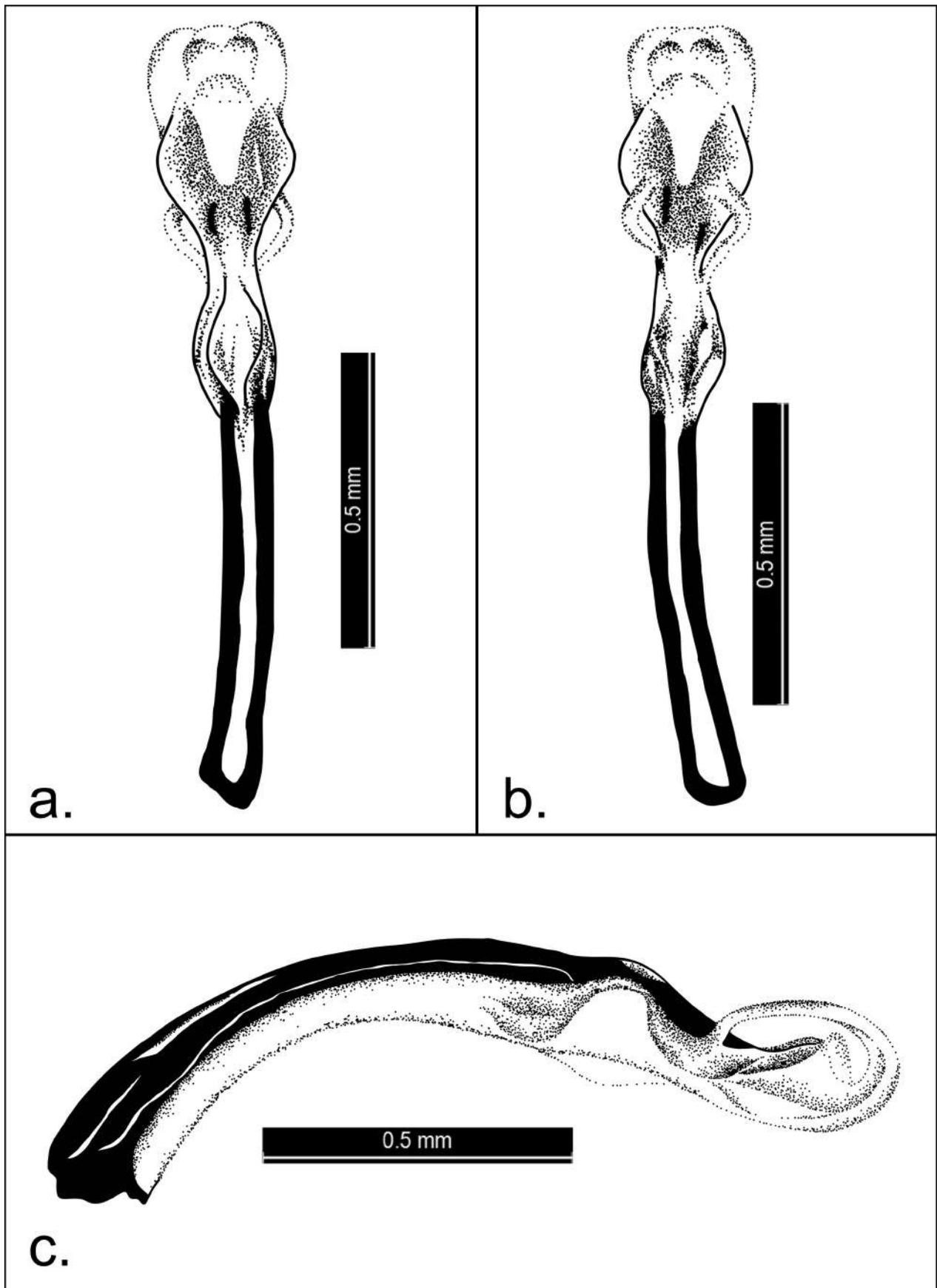
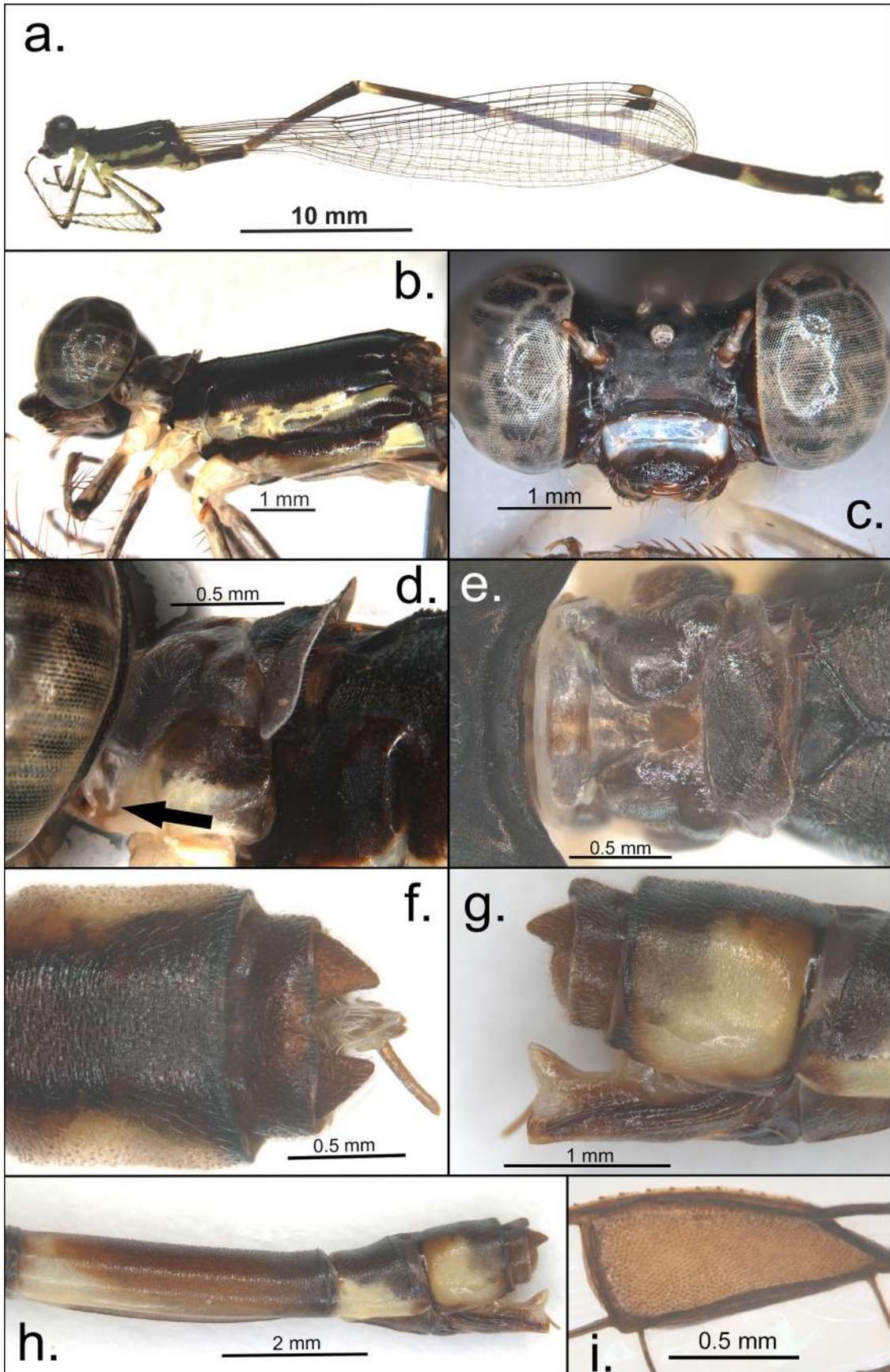
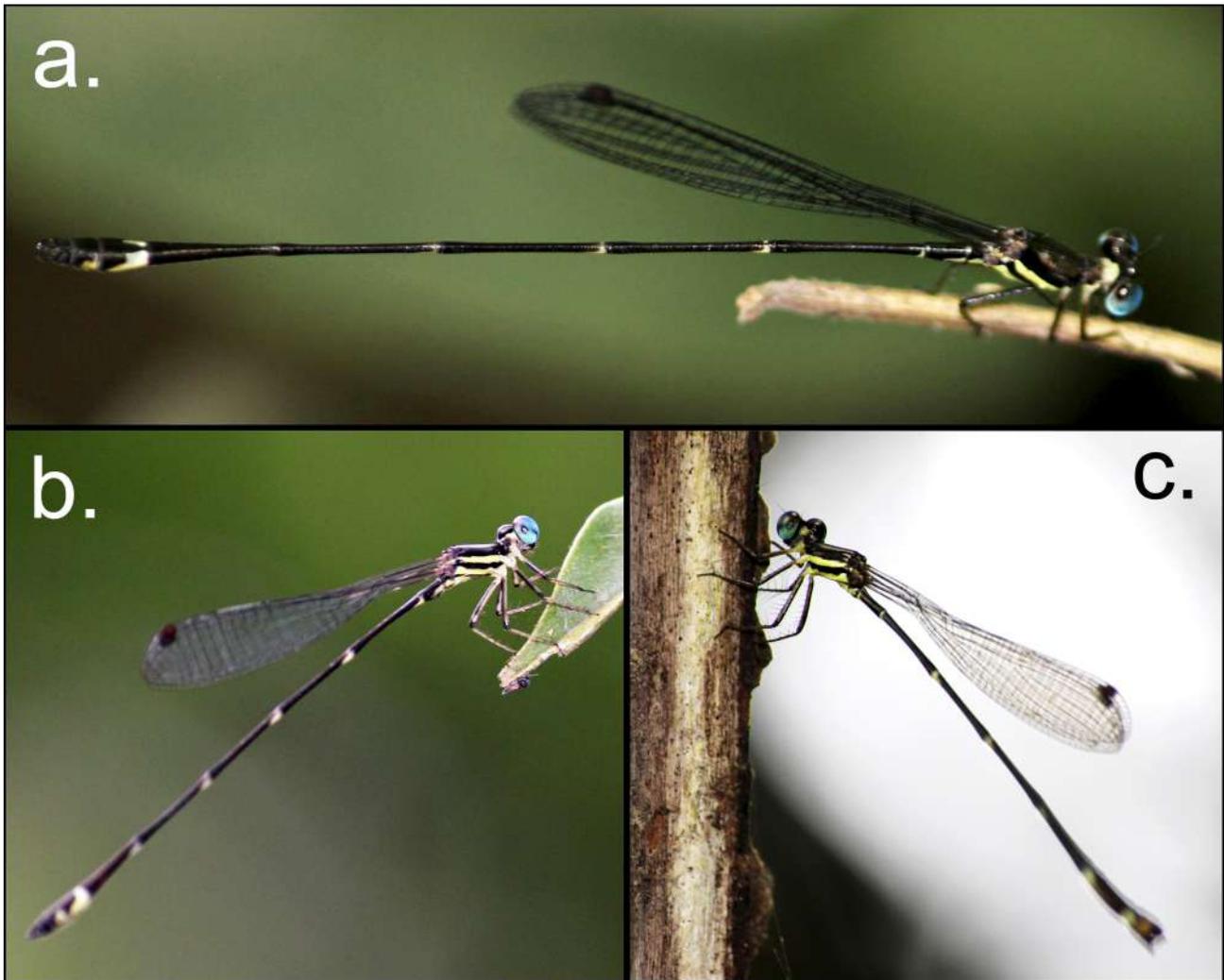


FIGURE 15. Genital ligula of *Protosticta sholai* sp. nov. Holotype male [ZSI-SRC I/OD/2223]: (a) ventral view; (b) dorsal view; (c) right lateral view.



**FIGURE 16.** *Protosticta sholai* sp. nov. Paratype female [ZSI-SRC I/OD/2226]: (a) habitus, lateral view; (b) pterothorax; (c) face; (d) prothorax, lateral view [arrow indicates the finger-like projections]; (e) prothorax, dorsal view; (f) caudal appendages, dorsal view; (g) caudal appendages, lateral view; (h) lateral view of S7–10; (i) pterostigma of left FW.



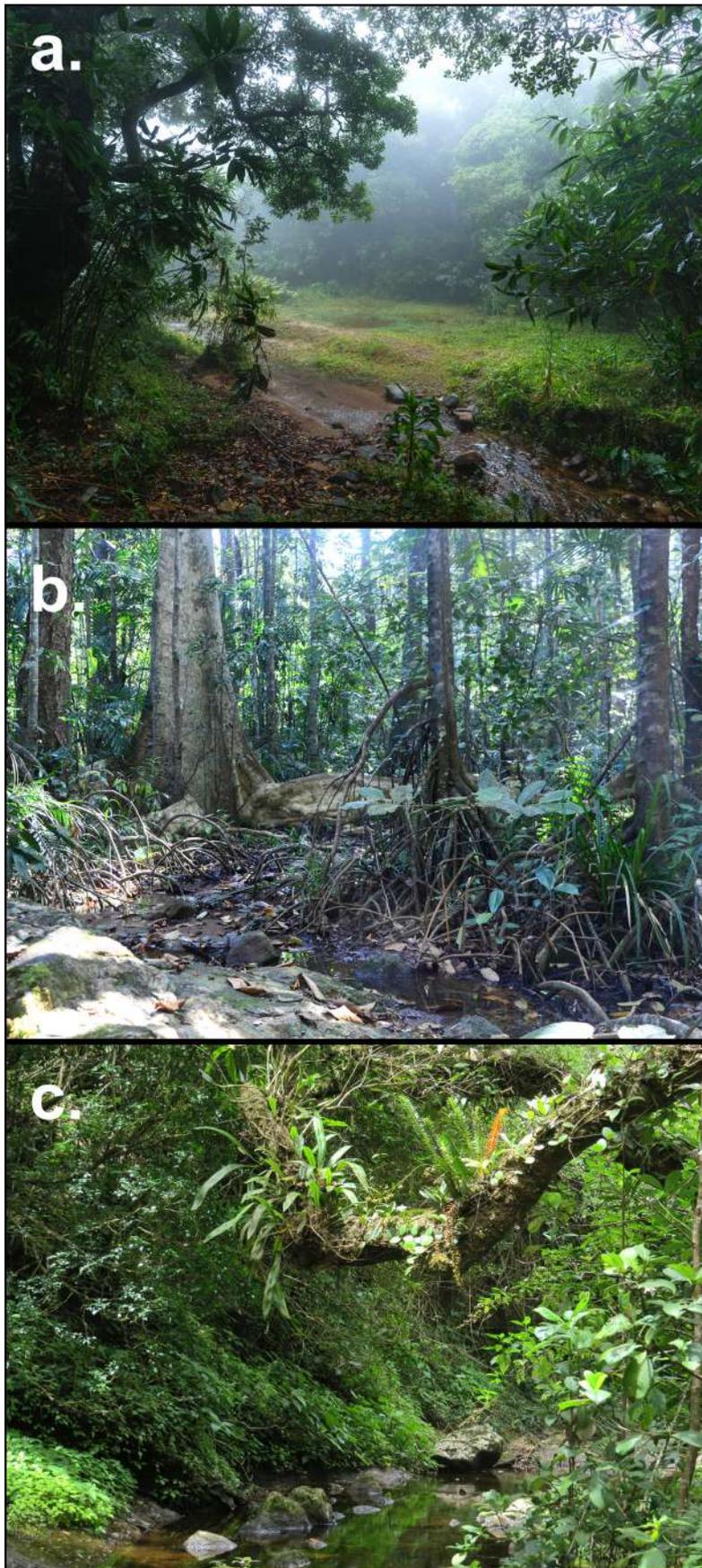
**FIGURE 17.** Field images of *Protosticta sholai* sp. nov. (a) male, dorso-lateral view; (b) male, lateral view; (c) female, lateral view. Photos: (a–b) KAS, & (c) Senraj.

Measurements: abdomen + caudal appendages = 41.9, FW = 30.4, HW = 30.3, cerci = 0.24.

**Diagnosis.** Male of this species is differentiated from all *Protosticta* spp. from Western Ghats by a combination of: shape of posterior margin of prothorax, distinct bright blue eyes, as well as shape of cerci and peculiar shape of paraprocts. Additionally, it can be distinguished from *P. monticola* which occupies similar altitudinal zone in the Western Ghats, by presence of extensive yellow markings on S8–9 (dorsum of S8–9 metallic black in *P. monticola*); shape of posterior margin of prothorax and eye coloration (grayish-black above, pale bluish-green at sides and below in *P. monticola*).

The female of this species is characterized by: a) presence of pair of lateral downwardly directed small finger like projections in the anterior lobe of prothorax, b) an extended posterior lobe of prothorax, posterior border with two extended lateral flaps, c) extent of yellow markings on S7–9, d) coloration of eyes, and e) black spot on trochanters of mid and hind legs.

**Habitat and Ecology.** *Protosticta sholai* was first observed in a small stream running through a shola adjoining a tea garden in Upper Manalar, Meghamalai Wildlife Sanctuary (Fig. 23a). The male was perching six to seven feet above the ground on a tree trunk densely covered with moss and lichens (Fig. 18c). When disturbed, they tend to fly higher and perch on leaf and branch tips. Female continuously wags abdomen at rest. Paratypes were collected from a similar habitat in Iravangalar within the same landscape.

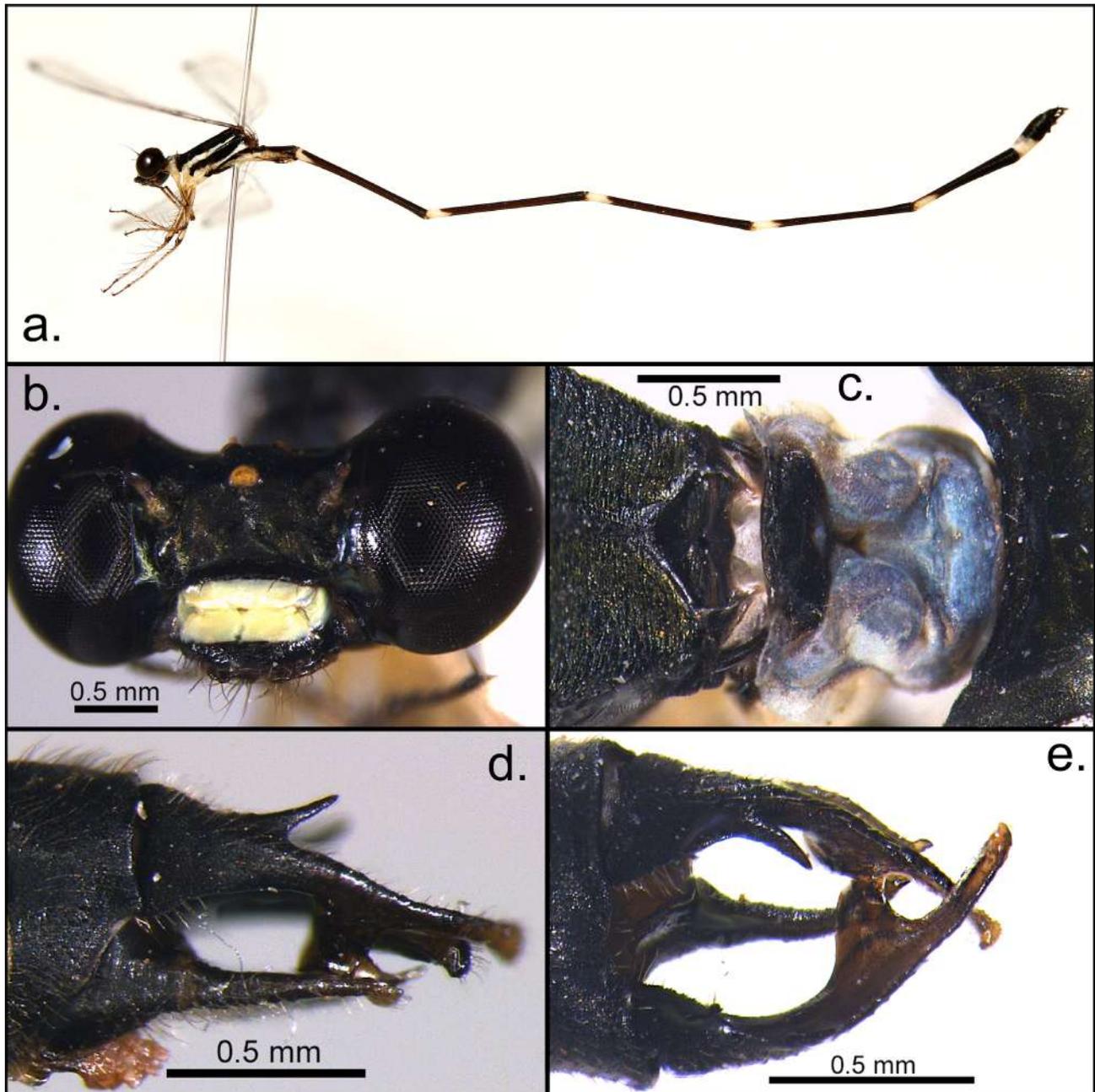


**FIGURE 18.** Habitats of (a) *Protosticta cyanofemora* **sp. nov.**; (b) *P. myristicaensis* **sp. nov.**; (c) *P. sholai* **sp. nov.** Photos: (a) Raghu Ram, (b) SJ, & (c) KAS.

## Taxonomic validity of *Protosticta mortoni* Fraser, 1924

**Material examined.** 2♂♂ (NCBS-AX588 & AX589): Kadumane Tea Estate, Hassan, Karnataka, India (12.91932 N, 75.66013 E; Alt: 1,075 m), 5.v.2017, K. Marathe, G. Kumar & A. Sanyal leg.

*Protosticta mortoni* was described by Fraser (1924) based on collections made at Sampaji Ghat, Coorg (now Kodagu), Karnataka, India (Fig. 23c). This species is distinguished from other congeners by blue prothorax with black posterior lobe, and shape of male caudal appendages. Subsequently, Fraser (1931) reported on the occurrence of species from “Malabar”, Kerala (exact locality unknown) and Fraser (1933) recorded it from Salsette Island (now Mumbai), Maharashtra based on collections by Prater. Fraser (1933) commented that the female of *P. graveleyi* described by Laidlaw (1915) collected from Talewadi, Castle Rock, Karnataka as that of *P. mortoni*.



**FIGURE 19.** *Protosticta mortoni* Fraser, 1924 [NCBS-AX589]: (a) habitus, lateral view; (b) face; (c) prothorax, dorsal view; (d) caudal appendages, lateral view; (e) caudal appendages, dorsal view.

Few decades later, Davis & Tobin (1984) listed *P. mortoni* as a synonym of *P. gravelyi*. This view was followed by Subramanian & Babu (2017) and Paulson & Schorr (2020) but not by Emiliyamma *et al.* (2007) who reported four males of *P. mortoni* from the foothills of Banasura, Wayanad, Kerala. These specimens were not available for the current study.

Two male specimens of *Protosticta* were collected which have been compared to other *Protosticta* spp. They were found to conform to the description of *P. mortoni*, with consistent differences from *P. gravelyi*. Based on this new material and morphological comparison with other *Protosticta* species of the Western Ghats as well as images of the types deposited at NHM, London and available online (Natural History Museum 2014; also see Kimmins 1966), *P. mortoni* is established as a valid species and this view has also been recently followed by Kalkman *et al.* (2020).

There are no reliable recent records of this species, we provide a supplementary information to the description of the male which will aid in identification of this species.

### Supplementary notes on the morphology of male (NCBS-AX589)

(Fig. 19)

**Head** (Fig. 19b). Lateral and middle lobe of labium, anteclypeus and postclypeus bright yellow with a tinge of blue; frons and vertex with a metallic sheen; rest of the head black.

**Thorax.** Prothorax (Fig. 19c). Anterior and middle lobe and lateral area of posterior lobe sky blue, central portion of posterior lobe black, posterior margin of posterior lobe rounded. Pterothorax (Fig. 19a): black, marked with two white stripes; one across lower edge of mesepimeron not touching the posterior border, broader anteriorly; other on lower part of metepimeron, thinner medially, touching the base of the wings; coxae white. **Legs:** femur and tibia pale brown covered with long dark brown setae, tarsus brown with few small brown setae; femur brown at junction with tibia; tarsal claws brown.

**Wings** hyaline, veins black, basal venation and membranules brown; Pt dark brown, occupying slightly more than one cell underneath; two cells between junction of  $RP_1$ - $RP_2$  and origin of  $IR_1$  in left HW, one cell in other three wings; Ab absent; Ax: 2 in all wings; Px: FW = 14, HW = 13.

**Abdomen** (Fig. 19a). Black, marked with white as follows: ventral half of S1–2, marking broader at anterior border of S2, tapering posteriorly; S3–8 with a white annule at the anterior border, not connected dorsally only on S3, broader on subsequent segments, more extended laterally; broadest on S8 covering about 3/4<sup>th</sup> of its length.

**Caudal appendages** (Fig. 19e–f). Cerci and paraprocts black, apical fork of cerci dark brown; cerci broader at base, thinner medially with a robust black spine 0.3 times the length of cerci pointed upwards and laterally inwards; cerci ending in a finger-thumb process, thumb process shorter, pointed at apices, the outer fork longer, at apices obtuse, and slightly thicker; paraprocts broader at base with inwardly pointed spine, apices curved inward gently.

Measurements: abdomen + caudal appendages = 38.6, FW = 19.8, HW = 19.5, cerci = 1.1, paraprocts = 0.8.

### Rediscovery of *Protosticta rufostigma* Kimmins, 1958

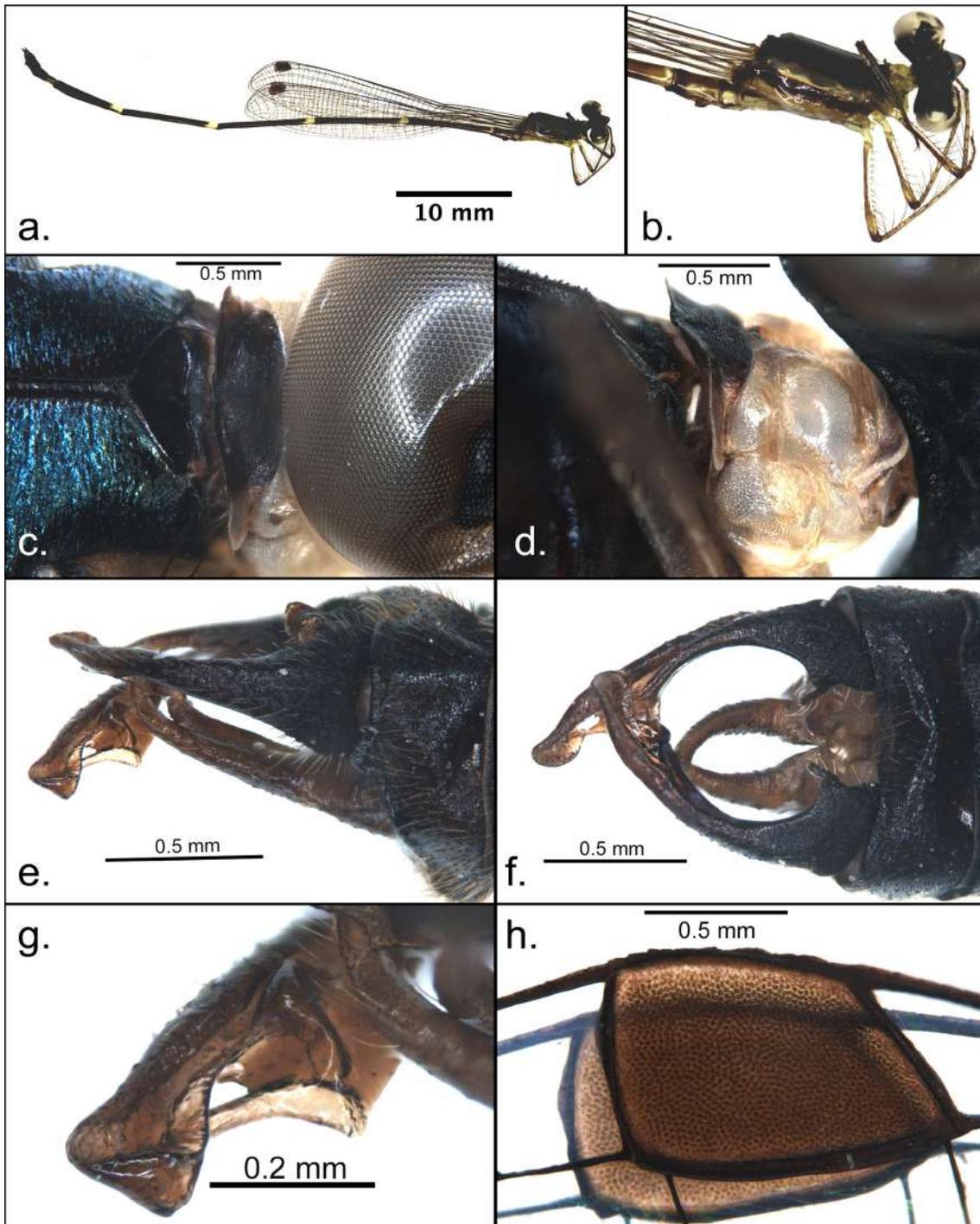
(Fig. 20)

**Material examined.** 1 ♂ (ZSI-SRC I/OD/2227): Velachithodu, Kaliyal Beat, Kanyakumari Wildlife Sanctuary, Tamil Nadu, India (8.53833 N, 77.31174 E; Alt. 482 m), 04.iv.2017, R. Venkitesan leg.

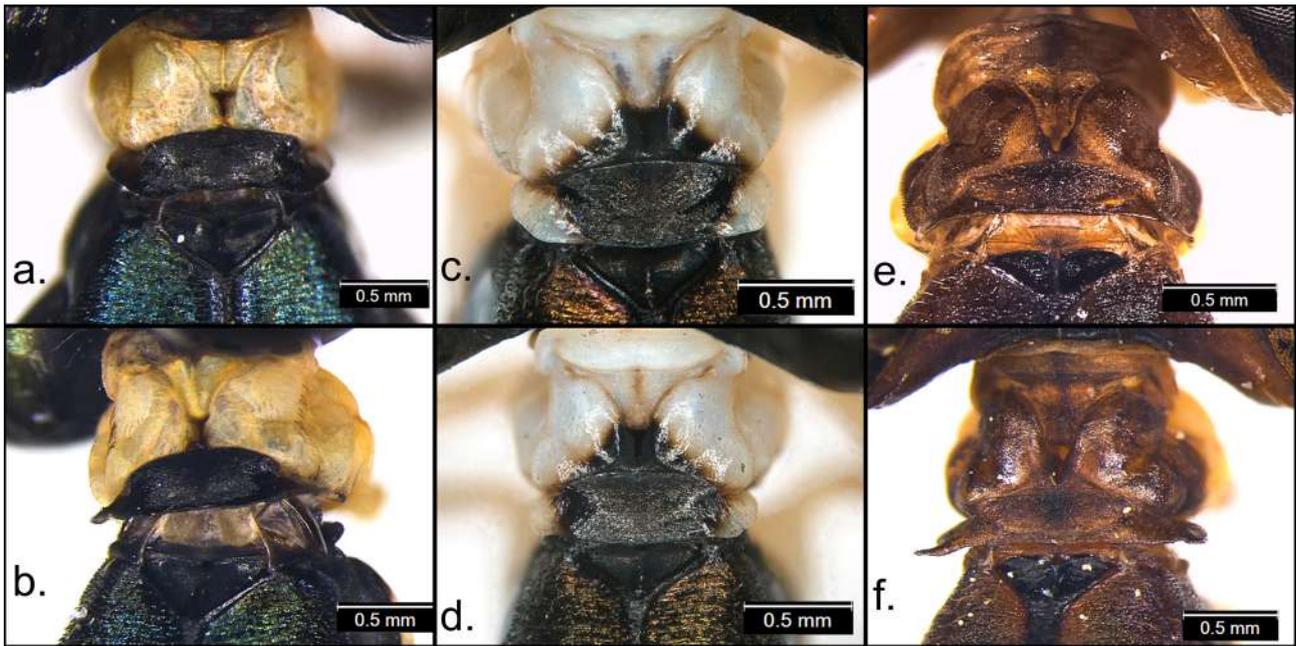
Kimmins (1958) described *Protosticta rufostigma* from the Odonata collections of the British Museum of Natural History. The specimens (1 ♂ and 2 ♀♀) used in the description were collected from Naraikadu, Tirunelveli (= Tinnevely), Tamil Nadu (South India) during the month of September 1938 by G.M. Henry. Recently, the Zoological Survey of India, Southern Regional Centre has been surveying the Western Ghats of Tamil Nadu to document the odonate fauna of Kanyakumari Wildlife Sanctuary, Kanyakumari (Fig. 23b). While studying the collections, we identified a specimen as belonging to *P. rufostigma*, which has not been recorded since the species description. This species is distinguished from its close relative *P. davenporti*, by a combination of following characters: a) central portion of posterior lobe of prothorax black (Fig. 20c–d), sides brown (posterior lobe fully black in *P. davenporti*, Fig. 21a–b); b) larger pterostigma (Fig. 20h); c) outer fork of cerci less than twice the length of inner fork (more than twice the length in *P. davenporti*); and d) outer fork of cerci squared at apices (Fig 20 e–g; rounded in *P. davenporti*, see Fig. 22).

Nodal index: 14 in all wings.

Measurements: abdomen + caudal appendages = 44.4, FW = 24.2, HW = 24, cerci = 1.2, paraprocts = 0.8.



**FIGURE 20.** *Protosticta rufostigma* Kimmins, 1958 [ZSI-SRC I/OD/2227]: (a) habitus, lateral view; (b) pterothorax, lateral view; (c) prothorax, dorsal view; (d) prothorax, lateral view; (e) caudal appendages, lateral view; (f) caudal appendages, dorsal view; (g) close-up of apical fork of right cercus; (h) pterostigma of right FW (in front).

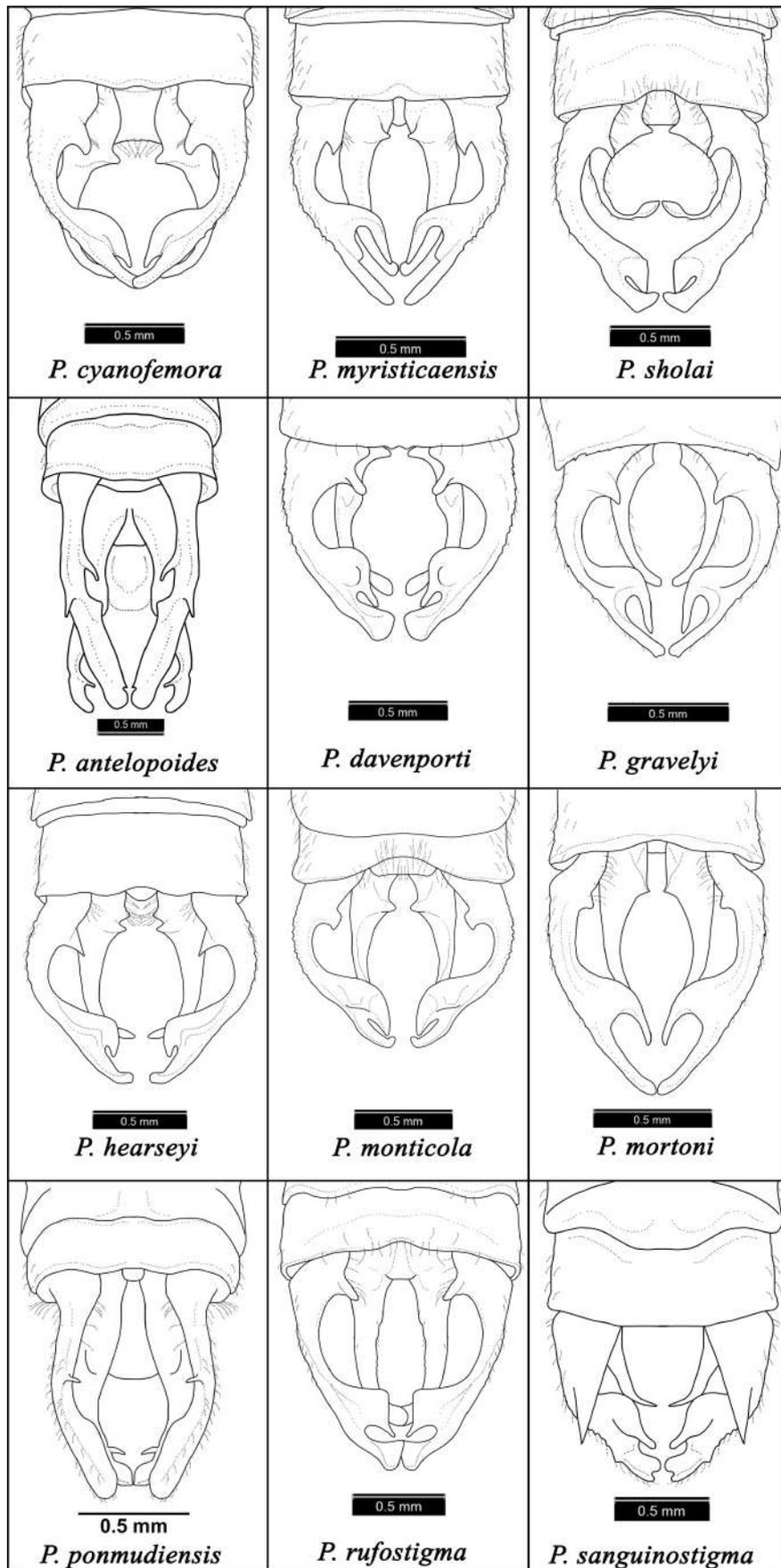


**FIGURE 21.** Comparison of prothorax of *Protosticta* spp.: (a) *P. davenporti* male [NCBS-PW759], Ponmudi, Thiruvananthapuram, Kerala, India, v.2013, S. Kalesh & C.G. Kiran leg.; (b) *P. davenporti* male [NCBS-QA007], Pandimotta, Shendurney WLS, Kollam, Kerala, 4.v.2014, SJ leg.; (c) *P. gravelyi* male [NCBS-QA020], Katilapara, Shendurney WLS, Kollam, Kerala, 9.v.2014, SJ leg.; (d) *P. gravelyi* female [ZSI-SRC I/OD/2228], Gouthalaiaru, Kalakkad Mundanthurai Tiger Reserve, Tirunelveli, Tamil Nadu, 18.viii.2019, RB & KAS leg.; (e) *P. sanguinostigma* male [NCBS-PZ975] Kallar, Thiruvananthapuram, Kerala, 29.iv.2014, SJ leg.; (f) *P. sanguinostigma* female [NCBS-QA008], Pandimotta, Shendurney WLS, Kollam, Kerala, 4.v.2014, SJ leg.

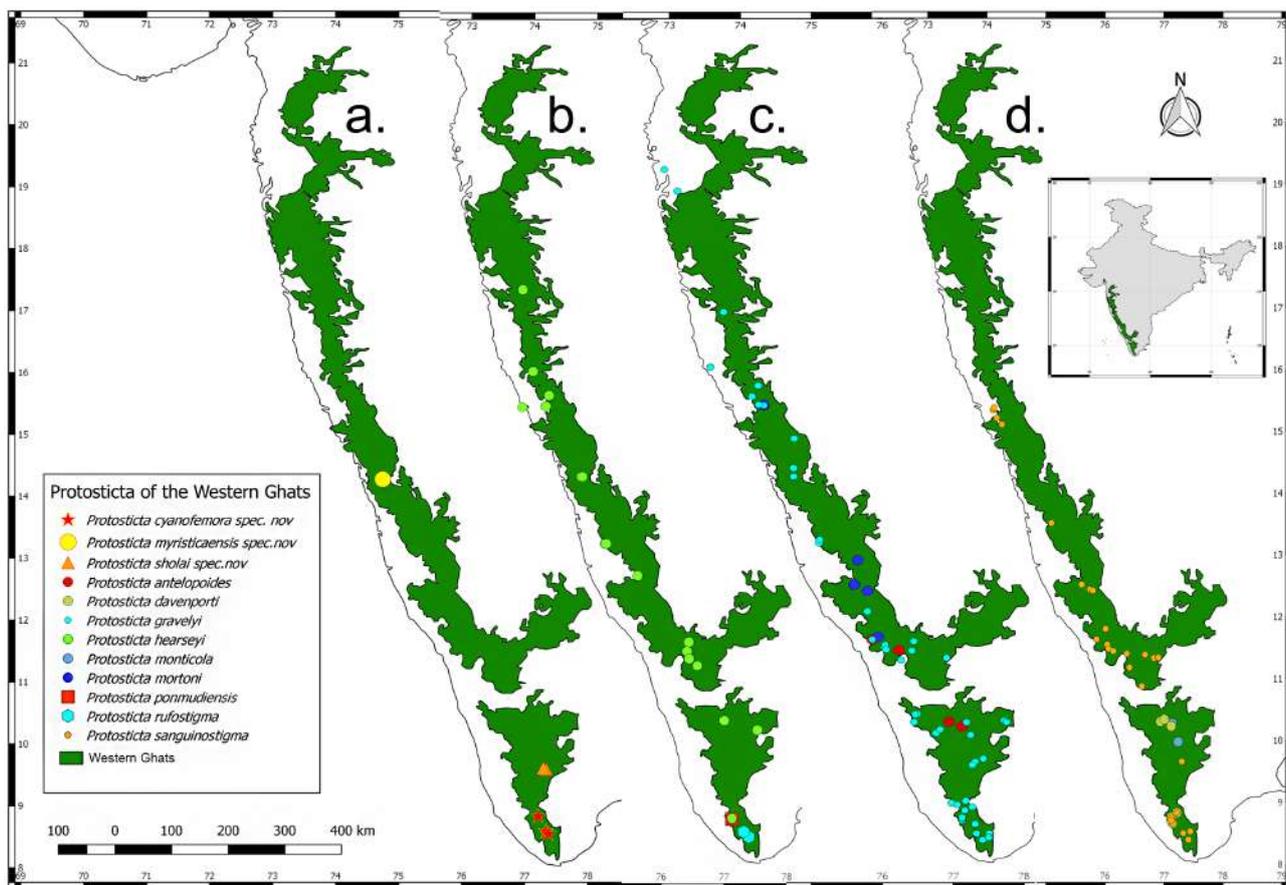
### Distribution of *Protosticta* species in the Western Ghats

(Table 3, Fig. 23)

Our recent field surveys and inspection of museum specimens have shed light on the distribution of *Protosticta* in the Western Ghats, as detailed below (all unpublished observations). All the Western Ghats (8–21.5°N) *Protosticta* are endemic to the wet evergreen forests. Within the Western Ghats, they are found in regions with 950–5000 mm of average annual rainfall, 9–35°C of average annual temperature, and altitude ranging from 24–2,300 m. *Protosticta gravelyi*, *P. hearseyi*, and *P. sanguinostigma* are found from low to high elevation (24–2,315 m); *P. monticola*, *P. sholai* and *P. cyanofemora* occur only above 1,200 m; *P. mortoni*, *P. rufostigma*, *P. ponmudiensis* Kiran, Kalesh & Kunte, 2016 and *P. myristicaensis* occur only between 500–1,000 m; and *P. antelopoides* and *P. davenporti* occur between 150–2,000 m. *Protosticta sanguinostigma* is found in central (12–16°N) and southern Western Ghats (8–12°N). High species diversity of *Protosticta* is observed in southern Western Ghats, especially south of the Palghat Gap, which is a natural geological demarcation in the Western Ghats. *Protosticta gravelyi*, *P. hearseyi*, and *P. sanguinostigma* have been reported in the northern Western Ghats. However, based on our review of available museum material and literature, we believe that some of the earlier records of *P. hearseyi* (e.g., Koparde *et al.* 2014) from the northern Western Ghats may be based on misidentifications, and they need to be reviewed properly, especially if any fresh specimens were collected. *Protosticta monticola* and *P. ponmudiensis* that were described recently are known only from their type localities. *Protosticta davenporti* and *P. mortoni* are known only from the south and north of the Palghat Gap, respectively. Discovery of five new species of *Protosticta*, of which four originate from the southern Western Ghats indicate high local level species diversification and narrow endemism in the region especially in the high altitude forests. These observations indicate that a detailed study of the distributional ranges, habitat use, and phylogenetic relationships of the Western Ghats *Protosticta* may reveal interesting ecological patterns of diversification and specialization in this super-diverse mountain range.



**FIGURE 22.** Comparison of caudal appendages of *Protosticta* spp. from the Western Ghats of India (scale: 0.5 mm, dorsal view).



**FIGURE 23.** Maps depicting the known distribution of *Protosticta* spp. in Western Ghats of India. (a) *P. cyanofemora* sp. nov., *P. myristicaensis* sp. nov., *P. sholai* sp. nov.; (b) *P. hearseyi*, *P. ponmudiensis*, *P. rufostigma*; (c) *P. antelopoides*, *P. gravelyi*, *P. mortoni*; (d) *P. davenporti*, *P. monticola*, *P. sanguinostigma*.

**TABLE 3.** Bioclimatic distribution and region of occurrence of *Protosticta* of Western Ghats. Bioclimatic variable include minimum and maximum values for temperature, altitude and precipitation. WG: Western Ghats (8–21.5°N), SWG: Southern Western Ghats (8–12°N), and CWG: Central Western Ghats (12–16°N).

Sl. No.	Species	Temp. Min. (°C)	Temp. Max. (°C)	Alt. Min. (m)	Alt. Max. (m)	Prec. Min. (mm)	Prec. Max. (mm)	Region
1	<i>P. antelopoides</i>	12	34	246	2,016	1,980	3,591	SWG
2	<i>P. cyanofemora</i>	17	29	1,231	1,264	1,439	1,920	SWG
3	<i>P. davenporti</i>	12	32	169	2,016	1,510	2,379	SWG
4	<i>P. gravelyi</i>	15	35	37	1,507	949	4,880	WG
5	<i>P. hearseyi</i>	9	35	24	2,315	988	5,047	WG
6	<i>P. monticola</i>	16	27	1,275	1,307	1,908	2,062	SWG
7	<i>P. mortoni</i>	17	34	534	988	1,969	4,180	SWG
8	<i>P. myristicaensis</i>	21	33	560	560	4,111	4,111	CWG
9	<i>P. ponmudiensis</i>	20	29	681	681	1,701	1,701	SWG
10	<i>P. rufostigma</i>	21	31	501	516	1,239	1,342	SWG
11	<i>P. sanguinostigma</i>	9	35	40	2,210	954	5,041	WG
12	<i>P. sholai</i>	15	25	1,574	1,621	2,119	2,151	SWG

## Key to the males of *Protosticta* spp. from the Western Ghats

[Note: Caution is needed in using the key in immature animals in which colors are not fully developed; please also refer to Fig. 22 which depicts caudal appendages of all species included in the key]

1. Posterior lobe of prothorax with spines ..... 2  
- Posterior lobe of prothorax without spines. .... 3
2. Posterior lobe of prothorax furnished with a pair of long, divaricate horn like spines; S7 faintly marked at base or unmarked; paraprocts bifid at apex ..... *P. antelopoides*  
- Posterior lobe of prothorax furnished with a pair of short lateral spines and internally two medial spines; S7 with extensive blue markings; paraprocts twisted and curved inwards, not bifid at apex ..... *P. ponmudiensis*
3. Anterior 1/3<sup>rd</sup> or more of S8 marked with bright turquoise-blue, the markings connected dorsally ..... 4  
- Anterior 1/3<sup>rd</sup> of S8 yellow or blue colored, the marking not connected dorsally ..... 9
4. Apical fork of cerci deeply incised more than 1/3<sup>rd</sup> of the total length ..... 5  
- Apical fork of cerci shallow, much less than 1/3<sup>rd</sup> of total length ..... 7
5. Cerci with a small tubercle at middle of the apical fork; length of abdomen + caudal appendages < 25 mm. ....  
..... *P. myristicaensis*  
- Apical fork of cerci without a tubercle at its center; length of abdomen + caudal appendages > 25 mm ..... 6
6. Prothorax with a hexagonal black marking covering central portion of posterior lobe and small portion of middle lobe; cerci with a prominent laterally pointed basal spine; paraprocts furnished with an inner stout spine at base ..... *P. gravelyi*  
- Anterior and middle lobes of prothorax blue; cerci with a small laterally pointed basal spine; paraprocts without an inner stout spine at base ..... *P. mortoni*
7. Prothorax completely blue; length of abdomen + caudal appendages < 30 mm; inner fork of cerci very short, outer fork not expanded. .... *P. hearseyi*  
- Anterior and middle lobes of prothorax pale yellow, posterior lobe partially or completely black; length of abdomen + caudal appendages > 30 mm; inner fork of cerci more than 1/3<sup>rd</sup> length of outer fork, outer fork expanded ..... 8
8. Dorsum of middle portion of posterior lobe of prothorax completely black extending as two points to the dorsum of middle lobe; inner fork of cerci thin and small, outer fork rounded at apices and more than twice the length of inner fork .....  
..... *P. davenporti*  
- Dorsum of posterior lobe of prothorax black, laterally brown; middle lobe of prothorax with a small dorsal faint black spot; inner fork of cerci thick, outer fork ending in a quadrangle, less than twice the length of inner fork. .... *P. rufostigma*
9. S9 completely black or marked only at ventral border; posterior border of prothorax not expanded; paraprocts not lobed at apices ..... 10  
- S9 laterally marked with a large yellow at anterior border, reaching more than 2/3<sup>rd</sup> of the segment, not connected apically in both sexes; posterior border of prothorax expanded; paraprocts thin, long and lobed at apices ..... *P. sholai*
10. Pterostigma red; S3–4 with longitudinal white markings laterally at 2/3<sup>rd</sup> of its length; cerci with a robust basal spine; outer fork of the cerci bi-lobed ..... *P. sanguinostigma*  
- Pterostigma black or brown; no medial bright markings on S3–4, except basal annules; cerci with only one small basal protuberance not sharp at apices, inwardly pointed; outer fork of cerci not bi-lobed ..... 11
11. Eyes dark grey above, bluish green below; femur pale yellow; S8 black dorsally, ventro-laterally 1/4<sup>th</sup> yellow; outer fork of cerci curved at apices ..... *P. monticola*  
- Eyes blue; femur bright blue internally; S8 with a bright blue annule extended laterally 2/3<sup>rd</sup> of its length; outer fork of cerci straight ..... *P. cyanofemora*

## Discussion

In this study we describe three new species of *Protosticta* from the Western Ghats. The type localities of these species are well known for their high endemism and potential for species discovery.

The southern Western Ghats, south of Kodagu, Karnataka is as one of the most diverse regions in terms of odonate fauna, and is home to six endemic *Protosticta* species: *P. mortoni*, *P. antelopoides*, *P. davenporti*, *P. rufostigma*, *P. ponmudiensis* and *P. monticola* (Subramanian *et al.* 2018). Our newly described *P. cyanofemora* and *P. sholai*, bring the total number of *Protosticta* species endemic to southern Western Ghats to eight, while 10 out of 12 (excludes *P. mortoni* & *P. myristicaensis*, which are known only from central Western Ghats) species known from Western Ghats occur in this small region.

The recent surge in discoveries of odonates from the Western Ghats, affirms that many areas of this region remain underexplored in terms of odonates. The rise in number of described platystictid species worldwide has been noteworthy. Bedjanič *et al.* (2016) noted that 37% (94 of 250) belonging to the family had been described after the year 2000. This proportion has now increased to 44% with 121 out of the 275 named species having been described after the start of this millennium (based on Paulson & Schorr 2020). Among *Protosticta* spp., 25 out of the 51 (47%)

known so far (including the three species described above) have been described since 2000. In Western Ghats of India, five of the 12 species (42%) of *Protosticta* have been described within last five years indicating high regional potential for species discovery in this genus. The information on adult *Protosticta* distribution in the Western Ghats was recently summarized in Subramanian *et al.* (2018), however very little is known about the larval stages, ecology, biology and seasonality from the Western Ghats. In last 100 years, only the larvae of *P. gravelyi* and *P. mortoni* have been described (Fraser 1919, 1943) and larval stages of other platystictids from south Asia are unknown (Kalkman *et al.* (2020). There is an urgent need to fill this information gap using molecular tools to hasten the process of identification and description of platystictid larvae from the region. The phylogenetic affinities of *Protosticta* of the Western Ghats with congeners in the Himalaya and south east Asia and other platystictids across the globe need to be worked out using tools in molecular systematic to understand the evolution and diversification of this ancient damselfly lineage in the Western Ghats.

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**<https://www.indianodonata.org/tx-58-Protosticta> of the Odonata of India website (Joshi *et al.* 2020).**