New species of *Endoclita* C. and R. Felder, 1874 and first record of *E. salvazi* from Vietnam (Insecta: Lepidoptera: Hepialidae)

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Summary

Discovery of Endoclita vietnamensis sp n. is based on a single specimen (holotype) from Phia Oac-Phia Den National Park, and 21 paratypes collected from Eucalyptus and Acacia plantations. Reared specimens of E. vietnamensis sp. n. were obtained from Acacia mangium. E. urophylla x E. grandis, and A. mangium x A. auriculiformis. E. salvazi was reared from Eucalyptus urophylla x E. grandis. The proposed taxonomic status of E. vietnamensis sp. n. is supported by wing pattern and male genitalia differences compared with five other species in eastern China and Taiwan that have a similar overall appearance. Identification of Vietnamese E. salvazi was made by comparing the male genitalia with the holotype male from northern Laos. The female of E. salvazi is described here for the first time. The probable close relatives of each species are identified, and the biogeographic significance of their respective distributions is briefly considered with respect to the historical role of the Red River strike-slip fault in promoting ancestral divergence.

Zusammenfassung

Die Entdeckung von *Endoclita vietnamensis* **sp. n.** basiert auf einem Exemplar (Holotypus) aus dem Phia Oac-Phia Den National Park, sowie 21 Paratypen, die von Eukalyptus- und Akazienplantagen gesammelt wurden. Gezüchtete Exemplare von *E. vietnamensis* **sp. n.** wurden aus *Acacia mangium* gewonnen. *E. urophylla* x *E. grandis* und *A. mangium* x *A. auriculiformis. E. salvazi* wurde aus *Eucalyptus urophylla* x *E. grandis* gezüchtet. Der vorgeschlagene taxonomische Status von *E. vietnamensis* **sp. n.** wird durch die Unterschiede im Flügelmuster und in den männlichen Genitalien im Vergleich zu fünf anderen Arten aus Ostchina und Taiwan unterstützt, die ein ähnliches Gesamterscheinungsbild haben. Die Bestimmung der vietnamesischen *E. salvazi* erfolgte durch Vergleich der männlichen Genitalien mit dem Holotypus-Männchen aus Nordlaos. Das Weibchen von *E. salvazi* wird hier erstmals beschrieben. Die wahrscheinlichen nahen Verwandten jeder Art werden identifiziert, und die biogeografische Bedeutung ihrer jeweiligen Verbreitung wird kurz in Bezug auf die historische Rolle der Plattenverschiebung des Roten Flusses bei der Förderung der Divergenz betrachtet.

Key words: Acacia, biology, biogeography, forestry, host plants, *Eucalyptus*, taxonomy, Vietnam

Introduction

The distribution of Endoclita extends between India and Sri Lanka in the west, to Far East Russia, Japan, Taiwan, Philippines, and Borneo and the Lesser Sunda of Indonesia in the east (GREHAN 2011, GREHAN & MIELKE 2018, BUCHSBAUM et al. 2018). Larvae of Endoclita are borers of live trees and shrubs in forested habitats, and in exotic species of commercial tree plantations. Currently comprising 71 species, the genus is among the largest in the Hepialidae, exceeded at this time only by Oxycanus with 78 species, and Thitarodes with 80 species (GREHAN et al. in review). Recent descriptions for new Endoclita species in Taiwan (BUCHSBAUM et al. 2018, BUCHSBAUM & GREHAN 2019) and India (GREHAN et al. 2022), indicate that further species remain to be described. Northern Vietnam is not well documented for Endoclita, or other Hepialidae, but the region includes the type locality for E. coomani Viette, 1949, and nearby northern Laos was recently shown to include two previously undescribed species in addition to E. salvazi Tindale, 1958 (GREHAN et al. 2019). The current paper is the result of coincidental interests in Endoclita records from northern Vietnam. In 2021, an insect collection donated to the Erfurt Natural History Museum included collections of Lepidoptera from Vietnam which were transferred to the Zoological State Collection in Munich. Among the Lepidoptera

collections was a female specimen of *Endoclita* that is now the holotype of a new species. Overlapping with this assessment, NMC contacted John Heppner (McGuire Center for Lepidoptera) regarding the taxonomic status of two species occurring in *Eucalyptus* plantations of northern Vietnam. This was brought to the attention of JRG, and agreement was reached to include these specimens in recognition of *E. salvazi* and *E. vietnamensis* **sp. n.** being present in northern Vietnam. Here we describe the new species, and the female of *E. salvazi*, a species previously known from a single male in Laos.

Materials & Methods

The holotype was collected at a 160 W mixed light UV lamp placed in front of a white screen, and operating from dusk about 07:00 pm and midnight. Moths were collected in poison glasses with KCN and were subsequently prepared for transport in paper tubes in plastic boxes. Specimen curation was made at a home laboratory with a standard spreading board. The genitalia dissection was made with standard techniques of maceration, and genitalia were stored in alcohol and later mounted in Euparal. Genitalia photos were made using an Olympus Tough, TG-5. Morphological terminology follows MIELKE & CASAGRANDE (2013) and GREHAN et al. (2021). Wing venation diagrams were drawn over photographic images using InkScape® software. Description of the female only refers to those features that are different from the male. Labels of primary types are given verbatim.

Moths reared from *Eucalyptus* and *Acacia* were obtained by collecting cutting stems with tunnels when the larva is in the last instar or pupated, as indicated by dismantling of the feeding web and blocking the entrance tunnel with a web of silk. Evidence of pupation was seen in October for *E. salvazi* and November-early December for *E. vietnamensis* **sp. n.** Cut stems were placed in a cage with water at the base to help prevent desiccation of the stem and pupae within.

Abbreviations

- CUIC Cornell University Insect Collection, Cornell University, Ithaca, New York, USA
- FPRC Forest Protection Research Centre Collection, Vietnamese Academy of Forest Sciences, Hanoi, Vietnam

Taxonomic section

Endoclita vietnamensis Buchsbaum & Grehan sp. n. Figs. 1a-d, 3a, 4a, 5a-b, 6a-b, 7a-b, 8a-b, 10a-b, 13ac, 14a, 15a-c, 16a-c, 17a-c, 18a-c, 19a-c, d, 21a-b, 22a-g, 28a.

Holotype (verbatim label): $\[Pink]$ N-VIETNAM, Cao Bang Prov., vic. Tinh Tuc, Son Dong [recte Nguyen Binh], Nui Pia Oac Nature Reserve [recte Phia Oac-Phia Den National Park], 9.–15.V.2014, 22 37'55"N, 105 52'98"E, 850–1300 m. leg. A. Weigel (Hotel auf N-Seite) / Gen: 2022–002. Holotype deposited in the Zoologische Staatssammlung München (ZSM)

Paratypes (emergence dates): Tan Lac district, Hoa Binh province, Vietnam: 2& 24, January 2022, 1& 1 16 March 2022 Luc Nam district, Bac Giang province, Vietnam: 1& 1 March 2022, 1& 11 March 2022, 1& 13 March 2022, 2& 3 March 2022, 1& 11 March 2022, 1 13 March 2022, 1& 14 March 2022, 1& 16 March 2022, 2& 17 March 2022, 1& 17 March 2022; Da Bac district, Hoa Binh province, Vietnam: 2& 4 April 2022, 4& 4 April 2022 (see Table 1). Deposited in collection of FPRC, other than FPRC#5 and FPRC#20 deposited with CUIC.

Etymology: Named for the country of Vietnam. Treated as an adjective in the nominative singular standing in apposition to the generic name.

Diagnosis

The smooth costal margin and forewing pattern of *E. vietnamensis* **sp. n.** is shared with *E. sinensis* (Moore, 1877), *E. kosemponis* (Strand, 1916), and *E. meifenga* Buchsbaum & Grehan, 2019 with respect to the triangular shading of the discal cells. The narrow oblique stigma of *E. vietnamensis* **sp. n.** distinguishes the species from the ovoid stigma of *E. meifenga*, and the thick, dark and bold transverse costal lines of *E. vietnamensis* **sp. n.** are distinct from the faint or reduced marking of *E. sinensis* and *E. kosemponis* (as illustrated in BUCHSBAUM et al. 2018 and BUCHSBAUM et al. 2019).

Description

Holotype 9 HT (Fig. 1a, 1d). Wingspan ~140 mm, FW length: 65 mm, width: 26 mm; HW length: 55 mm, width: 23 mm.

Head: Densely covered with short greyish-brown piliform scales, except for pale yellowish-brown fronto-clypeus (Fig. 6a). Eyes globular, prominent (Fig. 3a). Antennae filiform, ~24 annuli sparsely covered with sensilla caetica hairs (Fig. 7a). Labial palps (Fig. 5a) with single, ovoid palpomeres, sub-equal in length to labium, left palpomere shorter than right (opposite in ventral view), Von Rath's organ not observed. Maxillae rudimentary (Fig. 6a).

Thorax: Scales as for head. Prothorax triangular in dorsal view (Fig. 3a). Metathorax with anterior portion of scutum and scutellum free of scales, posterior scutum II with long hairs (Fig. 4a). Forewing: Elongate, sub-triangular with shallow tornus near vein A. Costal margin straight, smooth, then curving from terminus of Sc-R to apex, apex almost right angled. Venation hepialine: Sc1 present; CuP distally fused with A (Fig. 8a); base of forewing with three closed cells (Fig. 10b). Ground color pale grevish brown with faint transverse curved shading in cubital and anal cells (Fig. 14a). Dark brown shading across, and slightly distal to, discal cells other than anterior pale discal zone; dark shading extending in a curved band along M1-Rs4 cell and then oblique to apex; submarginal band slightly darker than ground color, expanding width towards costal margin. Subcostal region between costa and R with five transverse blackish-brown lines, four closely proximate to form pairs; three longitudinal subcostal lines between Scland R, and one anterior to Sc near postdiscal band. Elongate, curved white stigma across outer anterior discal cell reaching M1 basal to M1-Rs4 cross vein; white spot at M1 on distal side of M1-RS4 cross vein; white spot in basal anterior discal cell edged with blackish brown. Major transverse bands of forewing (see MIELKE & CASAGRANDE 2013 for Hepialidae) discernible for a pale postdiscal band, a darker premarginal band, a pale submarginal band extending between costa and M3, and a broad marginal band from subapex to CuA2. Short lamellar scales over entire dorsal surface (Figs. 13a-c). Ventral surface covered basally and anteriorly with long fine hairs, with a distinctive row of long, straight, posteriorly directed hairs along Sc. Costal pocket with longitudinal ridges present (see Fig.12c for E. salvazi). Hindwing: wider than forewing with tornus near A; outer margin more sharply curved at M1. Dorsal ground color pale gray with yellowish or reddish brown margins and faint dorsal ornamentation along outer costa. Ventral

ground color yellowish brown. *Legs* (Fig. 15a): lack epiphysis and arolium).

Pregenital abdomen (Figs. 16a-b, 17a-b, 18a-b): Greyish brown. Tergum II rectangular with almost straight lateral ridge. Tergosternal sclerite with relatively short lateral and dorsal brace, intermediate zone broad. Sternum II subsquare with broad anterior margin, antero-lateral arms with sharply angled lateral ridge not extending to posterior margin. Tergum VIII rectangular, posterior margin apparently medially shallow concavity. Sternum VIII rectangular, posterior margin slightly convex. Spherical black eggs (typical of Hepialidae) present within holotype abdomen.

Genitalia (Fig. 12a-c): External genitalia strongly sclerotized, dorsal plate narrowly fused across median, posterior margin forming inverse U and ventrally edged by shallow, setose, anal papillae; subanal sclerites 'C' shaped, curving laterally. Lamella antevaginalis with broad, lateral surface flexed near junction with dorsal plate; dorsal margin of medial sclerite projecting dorsally, forming an elongate, strongly sclerotized dentate spine; lateral sclerite with shallow posteriorly projecting dorso-medial spine; inner (posterior) surface of antrum sclerotized. Internal genitalia with ductus bursae about twice length of corpus bursae, latter distally wider, sub-ovoid; diverticulum about one third longer than corpus bursae, narrowing distally from junction with corpus bursae. Small sclerotized patch at junction between ductus bursae and diverticulum.

ở Wingspan ~97 mm, FW length: 45 mm, width: 19 mm; HW length: 36 mm, width: 18 mm. *Head*: As for female with following differences: Antenna with shorter and broader apical segment (Fig. 7b). Labium with two sub-ovoid palpomeres (Fig. 5b), distal palpomere emerging medio-laterally from basal palpomere (see discussion). Thorax: As for female with following differences. Hindwing more broadly triangular with single A vein (Fig. 8a). Hindleg with well developed reddish-orange androconial brush (Fig. 15b).

Pregenital abdomen (Figs 16-c, 17-c, 18a-c): Sternum II, including lateral arms (Fig. 16c), narrower than female. Tergum VIII subsquare, posterior margin convex. Sternum VIII subrectangular, posterior margin laterally terminating as an acutely angled point, medially forming a U-shaped concavity (Fig. 18c).

Genitalia: (Fig. 22a-g): Tegumen elongate, subrectangular, dorso-anteriorly narrow with acute angled vertex,



Figs. 1-2. Moths of *Endoclita vietnamensis* sp. n. and *E. salvazi* from northern Vietnam and Laos. Photos by Mei-Yu Chen (Fig. 1a), Nguyen Minh Chi (Figs. 1b-c, 2a, c, e), John Grehan (Fig. 2b), Carlos Mielke (Fig. 2d), and Jason Dombroskie (Fig. 2f).

widening ventro-distally, not fused with pseudotegumen. Saccus V-shaped, with broad curved anterior margin; posterior margin with central posteriorly oriented, triangular projection, margin either side with a shallow concave ridge along apodemal suture. Tergal lobes absent or membranous. Pseudotegumen dorso-medially narrowing to sickle-shaped hook at dorsal suture, not fused across median; anogenital field margin with three prominences, dorsal sub-rectangular blade, central narrow and medially curved, and ventral subrectangular blade with rounded apex; ventro-distally with a narrow W-shaped, 'bridge' fused across the median, central bridge slightly enlarged at junction with fultura inferior. Valva elbowed, distally narrow, digitiform; sacculus broad. Fultura inferior with concave lateral margins forming a narrow anterior-ventral waist, dorso-posteriorly widest at junction with pseudoteguminal bridge. Fultura superior absent or fused with pseudoteguminal bridge.

Description of female Endoclita salvazi Tindale, 1958

Figs. 2a-e, 3b, 4b, 5c-d, 7c, 9a-b, 11a-b, 12, 14b, 15ce, 16d, 17d, 18d, 20a-b

Wingspan ~120 mm; FW length: 60 mm, width: 21 mm (not including cosal lobe).

Head: Antenna pale greyish brown, filiform, ~25 flagellomeres (Fig. 7c). Eyes prominent (Fig. 3b). Labial palpomeres elongate, longer than labium, partially fused basally (Fig. 5c).

Thorax: Dorsal scales of pro- and mesothorax short, piliform, yellowish-brown from head to scutum III; dorso-laterally dark chocolate brown. Metathorax anterior scutum III, dark chocolate brown and lacking scale cover other than near posterior edge with covering of pale greyish-brown piliform scales covering posterior metathorax. Ventral thorax pale greyish-brown. Forewing without distinct tornus near vein A at the margin,



Figs. 3–7. Head and thorax *Endoclita vietnamensis* sp. n. and *E. salvazi* from northern Vietnam and Laos: 3: dorsal head, pro- and mesothorax; 4: dorsal metathorax; 5: labium and palps; 6: maxillae and mandibles after removal of labium; 7: antennae, 7a – *E. vietnamensis* sp. n. female (FPRC#24); 7b, *E. vietnamensis* sp. n. male (FPRC#29); 7c, *E. salvazi* female. Photos 3, 6 by John Grehan, 4a, Mei-Yu Chen, 4b, 7a–c by Nguyen Minh Chi.

apex falcate. Costal margin with costal flange (Fig. 14b). Venation hepialine, Sc1 present, stigma of anterior discal cell at junction of M1. CuP of forewing fused distally with A, base of forewing with three closed cells (Fig. 9b). Hindwing with two anal veins. Forewing: Dorsal ground color pale grevish brown suffused with pale grevish brown transverse patches, particularly between costa and Rs4 basally and medially, and between outer costa and outer margin distal to edge of postdiscal band, and in the anal and cubital cells. Dark brown shading across discal cells other than the anterior discal pale zone, and extending as a narrow band about half the length of the Rs4-M1 cell (Fig. 14b). Two or three white spots clustered basally, one in each discal cell, and around the junction of the Rs4-M1 cross vein (stigma). Scattered white spots of various number and size in the central premarginal and submarginal zone. Scattered dark brown spots anterior to discal cells, and a prominent 'eyespot' as a transverse bilobed black patch between CuA2 and A. Ventral forewing greyish brown, some dorsal maculation visible along costal region; surface covered with lamellar scales, basal region (principally discal cells and adjacent distal cells) also covered with fine hairs; Sc lined with 'comb' of posteriorly oriented hairs. Hindwing: wider than forewing with tornus near A, and outer margin more sharply curved at M1. Dorsally greyish brown with some maculation along costal region. Long hairs at base of wing, shorter over discal and and costal region, and short lamellar scales over most of wing surface. Legs: epiphysis and aerolium absent (Fig. 15e), hindlegs lacking androconia, but with covering of elongate scales concolorous with greyish brown scales of leg (Fig. 15c), tarsi covered with narrow, elongate lamellar scales, especially laterally (Fig. 15d). Pre-genital abdomen (Figs. 16d, 17d, 18d): Covered with dark grevish-black scales. Lightly sclerotized. Tergosternal sclerite (Fig. 17c) with broad lateral and dor-

gosternal sclerite (Fig. 17c) with broad lateral and dorsal brace, dorsal brace fused with anterior ridge of tergum II at medial edge of medial apodemal attachment and between posterior of tergosternal sclerite; central zone recessed. Tergum II rectangular, wider than long, strongly sclerotized anterior ridge and lateral ridges, lateral ridges slightly curved medially (Fig. 16d); Sternum II wider than male (cf. GREHAN et al. 2019), lateral margins with strongly sclerotized lateral ridges along triangular shaped antero-lateral arms. Tergum VIII rectangular, wider than long, longitudinally narrower than other tergites (Fig. 18d). Sternum VIII antero-posteriorly narrow, strongly sclerotized.

Genitalia: Dorsal plate (tergum IX) (Fig. 19) dorso-ventrally tall, forming narrow arch fused across the dorsal median. Anal papillae shallow, setose, subanal plates tall; Lateral lamella antevaginalis extending dorsally as broad digitiform lobes; medial antevaginalis with shallow dorsal spine subequal in height to lateral lobes, narrowing slightly to rounded apex. Ductus bursae broad, striated, corpus bursae not recovered intact. Spermatheca large relative to external genitalia, curved between enlarged bulbous and narrow elongate ends.

Notes on Vietnam male Endoclita salvazi

Head: Labium with single palpomeres, each fused basally, narrower than female (Fig. 5d). Maxillae less developed than female (Fig. 6d).

Thorax: Ground colour for dorsal forewings pale to dark greyish brown (Fig. 9a) with narrow longitudinal band of darker greyish-brown to black extending from base of anterior discal cell to outer discal stigma and mid Rs4-M1 cell (similar to female); dark transverse spot present in cubital cell (as for female). Hindwings greyish-brown with some costal maculation. Hindleg with prominent reddish-orange androconial brush, similar to that of *E. vietnamensis* (see Fig. 15b).

Genitalia (Fig. 23a, b): Lacking medial bridge of *E. vietnamensis* **sp. n.** Base of valva with elongate basal process. Ventro-posterio apex of pseudotegumen with short, strongly sclerotized, black pseudoteguminal arms. Almost identical to holotype (Fig. 23c).

Biology

Holotype of *E. vietnamensis* **sp. n.** was collected from a forest habitat in the Phia Oac-Phia Den National Park (Figs. 26). Paratype specimens of *E. vietnamensis* **sp. n.** and *E. salvazi* were collected from commercial *Eucalyptus* plantations and *Acacia* plantations (Figs. 24–25). (Table 1). Adults of *E. vietnamensis* **sp. n.** in the forest plantation were collected between March 1 and April 4 in Tan Lac, Luc Nam and Da Bac districts, while the holotype was collected between May 9-15th. Moths of *E salvazi* were collected between January 20 and March 25 at Yen Lap and Da Bac districts. The Da Bac district plantation was the only location where both species



Figs. 8-9. Wing venation of Endoclita vietnamensis sp. n. and E. salvazi. Green outline - discal stigma.

were recorded. The emergence records of the two species suggest that the seasonal emergence precedes onset of peak rainfall between May and September (HUNG et al. 2022). This timing would allow time for the eggs, which in Hepialidae are dropped by the female at flight or at rest, to eclose on the ground, and for early instars to develop among dead plant detritus and fungi before excessive surface water is present. The developmental pattern of early plant detritus/fungal feeding is recorded for a closely related species of *Endoclita* from south-eastern China (YANG et al. 2013b [incorrectly named *E. signifer* (Walker, 1856), see Discussion), and



Figs. 10–13. Details of forewing structures. 10–11: Forewing basal venation, 10a (FPRC#5), 10b (FPRC#20), 11a (FPRC#22), 11b (FPRC#20); 12: *E. salvazi* female costal pocket (FPRC#20); 13: *E. vietnamensis* sp. n. holotype female wing scales: 13a, outer discal stigma at cross Rs4-M1 cross vein, 13b white lamellar scales of stigma, 13e, lamellar scale of central forewing. Photos 10–12 by John Grehan, 13 by Mei-Yu Chen.

documented for some other stem boring species of Hepialdiae (cf. GREHAN 1989, KAY et al 202 for *Aenetus*). Early instars of *E. excrescens* feed on live herbaceous stems and leaves before transitioning to woody stems (OCHI 1975), although whether this begins at the first instar has yet to be documented.

As a stem borer of live trees and shrubs, forests constitute the natural habitat of *Endoclita* species. As demonstrated by the records presented here, as well as in China (YANG et al. 2013a, b) and Taiwan (LIANG & LEE 2011), Endoclita species may extend their host preference to include exotic tree species in commercial forests such as those of *Eucalyptus* and *Acacia*. The four *Eucalyptus* plantations inhabited by *E. vietnamensis* **sp. n.** and *E. salvasi* (Table 1) are 1-2 km from the nearest intact forests, a distance that may be within the flight range of gravid females. Alternatively, the *Endoclita* infestation may represent local populations that have survived in scattered trees or shrubs in the immediate vicinity of the plantations from the time they were first established. The native food plant of both *Endoclita* species



Fig. 14. Forewing patterns of *E. vietnamensis* sp. n. (14a) and *E. salvazi* (14b) females. Green outline: discal-apical band; blue dotted lines: approximate boundaries of transverse bands; blue lines: principal veins. AD, MD, PD – anterior, medial, posterior discal cells.

are unknown. The plantation host plants of *E. salvazi* comprise the *Eucalyptus* hybrid *E. urophylla* x *E. grandis* while the hosts of *E. vietnamensis* **sp. n.** are *Acacia* mangium, *E. urophylla* x *E. grandis*, and *A. mangium* x *auriculiforjmi*. Introduced species of both plant genera are known to be hosts of other *Endoclita* species.

The plantation stand with *E. salvazi* comprises 20 monthold saplings that are about 12 m high and with stem diameters (standard height) of 1.8–12 cm. The three plantation stands with *E. vietnamensis* **sp. n.** comprise 10–20 month-old saplings that are about 8–10 m high, and with stem diameters of 6–8 cm. Larval tunnelling in young tree growth is known for various other *Endoclita* species (e.g. BEESON 1941, KALSHOVEN 1965, TINTUMOL et al. 2014), and many species of the wood-boring genus *Aenetus* are known to occupy small diameter trees and shrubs (BEAVER & GREHAN 2018). Larval activity of *Aenetus virescens* (Doubleday, 1843) is usually limited to small diameter trees and shrubs, but in some hosts larvae may inhabit much larger diameters such as 1.5 m trunks of *Vitex lucens* (GREHAN 1988).

The larval tunnels of *E. salvazi* are 18-30 cm long and positioned 20–50 cm above ground, while those of *E. vietnamensis* **sp. n.** are 20–29 long and 29–37 cm above ground. This appears to be a frequent pattern in *Endo*-

clita where at least most larval tunnels in taller trees are relatively close to the ground. This may be a function of larvae climbing up from the ground to establish their tunnel, or bark or other anatomical, physiological, or physical environment characteristics that are less suitable for larval tunnelling and feeding higher up. The tunnels are relatively short (compared, for example, with many wood feeding cerambycid species), which is to be expected since the larvae feed primarily on callus growing around the tunnel entrance under the feeding web (Figs. 24d, 25d). The tunnel comprises a short and curved 'radial' tunnel that extends down to the principle 'longitudinal' tunnel (Figs. 24c, 25c). This shape and size conforms to a frequent pattern in other wood-boring Hepialidae. Some species sometimes construct longer and more distinct radial tunnels with a sharper angle joining the longitudinal tunnel. Larvae of E. excrescens sometimes construct a relatively short longitudinal tunnel extending up as well as down (GREHAN 1988).

At the time of pupation, larvae dismantle the feeding web. This is a common behaviour in callus feeding wood-boring Hepialidae, although some species of *Aenetus* appear to only provide a very small aperture for the mobile pupa to protrude through at emergence (BEAVER & GREHAN 2018). Pre-pupal larvae were observed to construct a thin silk membrane across the



Fig. 15. Thoracic appendages.

tunnel entrance. This structure may be present for the pupal stage of all callus feeding wood borers. Presumably the membrane is effective in preventing access by potential predators, as is the feeding web during larval development and feeding (evidenced by the apparent absence of pupal predation by ants or other predators). The feeding web or chemical characteristics of tunnelling appear to prevent ant or other predation during the larval stage. Dismantling of the web and construction of the silk membrane provides an effective means by which to recognize when larval development is completed and pupation has, or is, about to take place. Larvae consume callus or wound tissue that constantly grows back after larval feeding, and can rapidly expand when feeding ceases at pupation as is evident in Figs. 24d, 25d.

Discussion

The state of systematics and taxonomy of *Endoclita* is only partially explored. There is no comprehensive systematic analysis of species relationships (and even the sister genus is unresolved with respect to a possible

phylogenetic links with other callus feeding Hepialidae as suggested by GREHAN & RAWLINS (2003). Very few species have received detailed taxonomic treatment. These limitations do not, however, preclude confidence in establishing E. vietnamensis sp. n. as a valid taxon. The costal margin in Endoclita has two principal forms, either smooth (as in E. vietnamensis sp. n.) or with a bulge or 'costal flange' (as in E. salvazi). Within the Exporia (Mnesarchaeidae, Hepialidae, and four other hepialoid families), the subcostal flange is uniquely shared only by some species of Endoclita. This structure may, therefore, be phylogenetically informative. The relative size of the costal flange is, however, variable, and in some species the structure is barely discernible. In the absence of other correlated features the phylogenetic significance of the subcostal flange will need to be treated with caution.

While the smooth shape of the costal margin in *E. viet-namensis* **sp. n.** is not informative about species affinities within *Endoclita*, it does reduce the comparative scope necessary to distinguish *E. vietnamensis* **sp. n.**



Fig.16-18. Abdominal sclerites. 16, sternum and tergum II; 17, tergosternal sclerite; 18, sternum and tergum VIII. Photos 16a, 17a, 18a by Mei-Yu Chen, photos 16b-d, 17b-d, 18b-d by Loren Jones.

from other *Endoclita* species. There are only three species that are very similar to *E. vietnamensis* **sp. n.** with respect to a smooth costal margin, dark brown shading across the discal cells, and (with the exception of *E. meifenga*) an oblique narrow distal anterior disc stigma. There is sometimes an oblique curved extension of the dark shading to the apex, but the forewings in some specimens cited here are not in the best condition to make a definitive assessment. These morphological similarities may be indicative of a close phylogenetic affinity. The most similar species in external appearance appears is *E. sinensis* (Moore, 1877) (Fig. 28b), known with certainty for a single male and female collected from Shanghai, China (MOORE 1877). While the type genitalia have not been described, an illustration of genitalia presented as *E. sinensis* (Fig. 30b) by CHU &



Figs. 19-20. Female genitalia. *Endoclita vietnamensis* sp. n.: 19a-b oblique lateral, 19c posterior, 19d lateral habitus; *E. Salvazi*: 20a posterior, 20b spermatheca. Photo 19a-c by Mei-Yu Chen, 120a-b by Loren Jones, 19d by John Grehan.

WANG (1985) shows no direct similarity to *E. vietnam*ensis **sp. n.** Similarly, a male specimen of 'sinensis' from Taiwan (Fig. 28c) has structurally distinct genitalia (Fig. 30c), as is also the case for *E.* 'sinensis' of Japan (Fig. 28d-e) where the male genitalia (Fig. 30d, h-i) lack the medial prominence of *E. vietnamensis* **sp.** **n.** (see also UEDA 1978: fig. 9), and the female genitalia (Fig. 30j) have a broad medial spine while the lateral spines are absent (see also UEDA 1980: fig. 13).

The Taiwanese *E. kosemponis* (Fig. 28d) shares with *E. vietnamensis* **sp. n.** the presence of a curved medial



Fig. 21. Endoclita vietnamensis sp. n. bursa copulatrix. Photo 21a by Mei-Yu Chen, 21b by Loren Jones.

prominence and a rounded ventral prominence in the male genitalia, but the medial prominence is narrower and the ventral prominence is not lobate (Fig. 30e). The third similar species is *E. meifenga* Buchsbaum & Grehan, 2019 from Taiwan (Fig. 28g) which has an olive-brown color and distinct genitalia (Fig. 30f). An additional species from China, *Endoclita jianglingensis* (Zeng & Zhao, 1991) has a smooth costal margin but is not illustrated for wing pattern (ZENG & ZHAO 1991). The written description may indicate some similarities with *E. vietnamensis* **sp. n.**, but the genitalic illustration (Fig. 30g) shows absence of the medial spine and other

structural differences (ZENG & ZHAO 1991). Several biological studies of *Endoclita* feeding on *Eucalyptus* in southeastern China illustrate a moth that is very similar in appearance to *E. vietnamensis* **sp. n.** The species was referred to as *E. signifer* (YANG et al. 2013a: Fig. 1b, 2013b: Fig. 2h-k; Hu et al. 2022: Fig. 1a), but the moths have a smooth costal margin whereas the lectotype of *E. signifer* from northern Bangladesh has a costal flange (GREHAN et al. in press). Future comparative dissection will be necessary to assess the species status of the southeastern Chinese moths with respect to *E. vietnamensis* **sp. n.**



Figs. 22-23. Male genitalia. 22a-f E. vientamensis paratype FPRC#5; 23a-c E. salvazi. Photos 22a-e, 23a-b by Loren Jones, 23c by Kyhl Austin (from GREHAN et al. 2019), 22f-g by John Grehan.

The male genitalia of the Vietnamese *E. salvazi* shows no distinctive difference from that of the holotype that could not conceivably fall within species variation (Fig. 23a-b). The forewing shape and pattern of *E. salvazi* is similar to several other species that share presence of a costal flange and central transverse cubital spot such as *E. gmelina* Tindale, 1941 from Myanmar (Fig. 29b); *E. warawita* Tindale, 1958 (Tindale 1958, fig. 21), *E. paraja* Tindale, 1958 (Fig. 29d) and *E. hosei* Tindale, 1958 (TINDALE 1958: pl. 22, fig. 3) of Borneo; *E. taramu* (TINDALE 1958: pl. 22, fig. 2) of Sumatra; *E. tosa* Tindale, 1958 (TINDALE 1958: pl. 19, fig. 4) and *E. aikasama* Tindale, 1958 (TINDALE 1958: pl. 17, fig. 2) of Java; and *E. raapi* Tindale, 1958 (TINDALE 1958: pl. 19, fig. 3) from Palau Nias. In addition, there is an undetermined species recorded from Malaysia (Fig. 29e). The transverse cubital spot represents a derived feature within the Hepialidae (as with the costal flange, the spot is absent from the other hepialoid families and the Mnesarchaeidae). These two structures suggest that these species are closely related and may form a clade.

The distribution ranges of the two *Endoclita* groups is of biogeographic interest. The *vietnamensis-sinensis*



Figs. 24–26. E. vietnamensis sp. n. habitat and tunnels: 24 – Bac Giang province, (a, b) plantation at ten months; (c) longitudinal view of larval tunnel; (d) larval tunnel entrance with remnants of feeding web. 25 – Phu Tho province, (a, b) plantation at twenty months; (c) longitudinal view of tunnel; (d) larval tunnel entrance with remnants of feeding web. 26a–c – Phia Den National Park, habitat and collecting site of holotype. Photos by Nguyen Minh Chi (Bac Giang, Phu Tho), and André Skale (Phia Den).

morphology has a range extending to northeastern China Korea, Japan, and Taiwan while the range of the *salvazi* morphology ranges between northern Vietnam and southeast Asia (Fig. 32). This distributional difference may be an artifact of limited collecting, but if future collecting corroborates the current pattern, its biogeographic origin may be associated with the geological history of the Red River Fault that crosses the intersection of the two distribution ranges. This fault is a major intraplate strike-slip belt between northern Vietnam and to the north of the Himalayas that originated in the Mesozoic, and was active in the Oligocene-Miocene time when Southeast Asia was displaced 500 km southeastward with respect to China. This tectonic disruption may have contributed to the differentiation of each of the two *Endoclita* groups, and has been implicated in the differentiation of some allopatric primate and amphibian clades (HEADS 2012).

Fig. 27. Distribution records for Endoclita species. Map symbols: locality 1 - Laos, E. salvazi (holotype), Locality 2 - Tan Lac District, E. vietnamensis sp. n. (FPRC#17, 18, 24, 27), locality 3 - Da Bac district, E. vietnamensis sp. n. (FPRC#19. 26. 28. 29. 30. 31); E. salvazi (FPRC#20, 21, 22, 23, 25), locality 4 - Yen Lap district, E. salvazi (FPRC#1-4), locality 5 - Luc Nam district, E. vietnamensis sp. n.(FPRC#5, 6, 7, 8, 10-16), locality 6 - Phia Oac-Phia Den National Park, E. vietnamensis sp. n. (holotype).



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Figs. 28-29. Endoclita species comparisons. Fig. 28 similar species to E. vietnamensis sp. n.: 28a E. vietnamensis sp. n. (FPRC#20), 28b E. sinensis holotype (NHMUK, China, Shanghai), photo by David Lees, 28c E. 'sinensis' [status inconclusive], photo by Mei-Yu Chen; 28d E. kosemponis, photo by Mei-Yu Chen; 7ig.29, similar species to E. salvazi: 29a E. salvazi: 29b E. gmelina; 29c E. warawita (NHMUK), 29d E. paraja (NHMUK), 29e Endoclita sp., photo by Joseph Thompson, inaturalist.org observation No. 135182198.

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Figs. 30-31. 30. Male genitalia and posterior sternite comparisons for similar species: (a) *E. vietnamensis* sp. n.; (b) *E. sinensis* from China (CHU & WANG 1985); (c) male *E. 'sinensis*' [status inconclusive] from Taiwan [TN] (photo by Mei-Yu Chen); (d, h-j) *E. 'sinensis'* from Japan (photo by Nikolai Ignatev); (e) *E. kosemponis* (photo by Mei-Yu Chen); (f) *E. meifenga* (photo by Mei-Yu Chen); (g) *E. jianglingensis* (from ZENG & ZHAO 1991); 31. Male sternite VIII for similar species. Photos by Mei-Yu Chen (31b, d, e) and Nikolai Ignatev (31c).

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Fig. 32. Conceptual illustration of northern (vietnamensis-sinensis morph) species (blue outline), and southern (salvazi morph) species (green outline) with respect to the Red River Fault (red line). Extent of distribution ranges highly generalized and require future corroboration. Model suggests that the Red River Fault may have contributed to differentiation of each ancestral group, but does not imply that these two morphs are sister taxa.



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	indoclita species at two forest plantations in Vietnam
Anhang	Table 1. Sampling of

Code	Sex	Site	Host	Planta-tion age	Ø at 1.3m (cm)	Height (m)	Lat/Long	Distance to natural forest	Sample date	Emer-gence	Length of tunnel (cm)	Height from ground (cm)
Endoclita salvazi												
FPRC 1	EL,	Yen Lap	E. wophylla x E.	20 months	8.1 ± 0.4	12±0.3	21.341061,	1.9-2.3 km	December 25, 2021	January 21, 2022	27-30	25-40
FPRC 2	н	district – Phu Tho movince	grandis				105.069758					
FPRC 3	ы											
FPRC 4	EL,											
FPRC 20	H	Da Bac	E. wophylla x E.	20 months	7.9±0.2	11.8 ± 0.2	20.866709,	1.8-2.5 km	March 25, 2022	March 25, 2022	18-30	27-50
FPRC 21	H	district - Hoa Binh province	grandis				105.164935					
FPRC 22	Μ											
FPRC 23	щ											
FPRC 25	ы								January 20, 2022	March 24, 2022		
Endoclita												
vietnamensis												
FPRC 17	Μ	Tan Lac	A. mangium	18 months	7.5±0.2	9.5± 0.3	20.648077,	2.1-2.5 km	January 24, 2022	March 20, 2022	20-21	33-35
FPRC 18	Μ	district – Hoa Binh province					105.207260					
FPRC 24	H	Source inter							March 16, 2022	March 29, 2022		
FPRC 27	Μ											
FPRC 5	Μ	Luc Nam	E. wophylla x E.	10 months	5.8 ± 0.3	8.5±0.2	21.408624,	1.0-1.3 km	December 28, 2021	March 1, 2022	20-24	31-33
FPRC 10	H	district –	grandis				106.432852		March 11, 2022	March 14, 2022		
FPRC 11	ы	province								March 13, 2022		
FPRC 12	Μ									March 13, 2022		
FPRC 13	ſĽ,									March 16, 2022		
FPRC 14	F									March 17, 2022		
FPRC 15	ы									March 17, 2022		
FPRC 16	н									March 18, 2022		
FPRC 6	Ŀ4		A. mangium	20 months	7.9±0.3	9.8± 0.4	21.409223,	1.1-1.5 km	December 23, 2021	March 3, 2022	21-23	29-30
FPRC 7	щ		xA. auriculiformic				106.435524					
FPRC 8	H		un remponino							March 11, 2022		
FPRC 26	EL,	Da Bac	A. mangium	16 months	7.5±0.3	9.1 ± 0.4	20.866709,	1.8-2.1 km	March 25, 2022	April 4, 2022	21-29	33-37
FPRC 19	ы	district – Hoa Binh province	E. urophylla	16 months	8.0±0.4	9.9± 0.5	105.164935					
FPRC 28	F		x E. grandis									
FPRC 29	Μ											
FPRC 30	Ľ4											
FPRC 31	Μ											

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