Neurostigma Enderlein, 1990: new records, update diagnosis, description, redescription, description increment of females and a new synonymy (Psocodea: "Psocoptera": Epipsocidae)

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Abstract. In this paper, we treat three species of *Neurostigma*. For the first, *N. roesleri* New, 1980 we provide illustrations of the holotype, a revised diagnosis, the female redescription, including the first description of the spermatheca and a distribution map of the species considering *N. garcialdretei* Mendivil Nieto, Gonzalez Obando & Carrejo Gironza, 2020 **syn. nov.** For the second species, *N. enderleini* New, we redescribe the male, describe and illustrate the unknown female, and provide a revised diagnosis and new records for the Brazilian states of Amapá and Rondônia. For the third species, *N. xanthopterum* New, 1980, we include the first description and illustration of the spermatheca.

Keywords. Non-parasitic lice; Biodiversity; Neotropical Region; Spermatheca.

INTRODUCTION

Neurostigma Enderlein, 1900, is one of the least diverse genera of Epipsocidae, currently with 15 described species, of which 11 are known exclusively from males, two are only from females, and two from both sexes (Reategui *et al.*, 2022a, b). The species range from Southern Mexico to southeastern Brazil (Silva-Neto & García Aldrete, 2020; González-Obando *et al.*, 2021). The Neurostigma species are presently placed in two species group based on the *areola postica*. Group I with *areola postica* fused to vein M and group II not fused to vein M (Mendivil Nieto *et al.*, 2020).

Brazil is the richest country for *Neurostigma* species with seven species, most belonging to species group II, distributed in 10 Brazilian states (Table 1) (Silva-Neto & Garcia Aldrete, 2020; Reategui *et al.*, 2022b). However, the description of females is only documented for three species: *Neurostigma dispositum* Roesler, 1940; *Neurostigma roesleri* New, 1980 and *Neurostigma xanthopterum* New, 1980 (Table 1) (Reategui *et al.*, 2022a).

For the state of Amazonas, New (1980) described *N. enderleini, Neurostigma paucivenosum,*

Pap. Avulsos Zool., 2024; v.64: e202464009 https://doi.org/10.11606/1807-0205/2024.64.009 https://www.revistas.usp.br/paz https://www.scielo.br/paz Edited by: Carlos José Einicker Lamas Received: 19/09/2023 Accepted: 18/12/2023 Published: 05/02/2024 *N. roesleri* and *N. xanthopterum*, collected in the Reserva Florestal Adolpho Ducke (RFAD), Manaus, Amazonas, Brazil. Among these, only *N. roesleri* was described based on female specimens, the holotype and one paratype. The female genital characteristics, crucial for recognition of the species, were not described.

The female of *N. xanthopterum* was recently described by Reategui *et al.* (2022a); however, the authors did not describe or illustrated the spermatheca, one of the structures of the female genitalia, which, together with other structures, can become an important taxonomic character for the genus. *Neurostigma enderleini* was described based on a male specimen collected in a Malaise trap in the RFAD; however, this species has little taxonomic information, needs a clear diagnosis and description, and this taxonomic scenario has mad new identifications and individual records difficult for over 40 years.

This paper aims to redescribe the female of *N. roesleri* and to describe the variation of the forewing venation in this species. Also for the first time, the spermatheca of *N. roesleri* and *N. xanthopterum* are described and illustrated. It also aims

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Table 1. Known species of Neurostigma, species group, sexes known, general distribution and distribution in Brazilian states (between parenthese).

Species	Species group	Sexes known	Distribution
N. chaetocephalum Enderlein, 1900	Species group I	Male	Peru
N. dispositum Roesler, 1940	Species group II	Both	Brazil (Mato Grosso, Santa Catarina, São Paulo), México, Peru
N. enderleini New, 1980	Species group I	Male	Brazil (Amazonas, Amapá, Rondônia)
N. paucivenosum New, 1980	Species group II	Male	Brazil (Amazonas)
N. roesleri New, 1980	Species group II	Both	Brazil (Amazonas, Amapá), Colombia
N. xanthopterum New, 1980	Species group I	Both	Brasil (Amazonas, Acre, Amapá), Colombia
N. radiatum Mockford, 1991	Species group II	Male	Brazil (Roraima)
N. atlanticum Reategui, Rafael & Silva-Neto, 2022	Species group I	Male	Brazil (Minas Gerais)
N. furcivenula Badonnel, 1986	Species group II	Female	Colombia
N. lienhardi González-Obando, Carrejo-Gironza, Mendivil-Nieto & Garcia Aldrete, 2021	Species group II	Male	Colombia
N. mockfordi González-Obando, Carrejo-Gironza, Mendivil-Nieto & Garcia Aldrete, 2021	Species group II	Male	Colombia
N. newi González-Obando, Carrejo-Gironza, Mendivil-Nieto & Garcia Aldrete, 2021	Species group II	Male	Colombia
N. thorntoni González-Obando, Carrejo-Gironza, Mendivil-Nieto & Garcia Aldrete, 2021	Species group II	Male	Colombia
N. valderramae González-Obando, Carrejo-Gironza, Mendivil-Nieto & Garcia Aldrete, 2021	Species group II	Male	Colombia

to redescribe the male of *N. enderleini* and to describe and illustrate the female of *N. enderleini*. Additionally, we include new records, illustrate the holotype of the *N. enderleini* and *N. roesleri* with photos, and present an updated diagnosis of these two species with female characteristics included. Furthermore, *N. garcialdretei* is synonymized under *N. roesleri*, and a distribution map of *N. roesleri* and *N. enderleini* specimens is provided.

MATERIAL AND METHODS

We access the type material of *N. enderleini* and *N. roesleri*, which had been deposited in the Invertebrates Collection of the Instituto Nacional de Pesquisas da Amazônia (INPA), to conduct this study. Additionally, we utilized common material from *N. enderleini*, consisting of one female and 20 males, and from *N. roesleri*, with nine females and seven males, and two females of *N. xanthopterum*.

The remnants of the *N. roesleri* holotype were made up of the head and thorax, including the left, fore and hind wings. Dissecting the mouthparts was not viable, as the process could lead to their destruction due to the material being preserved in alcohol for an extended period. Only the left fore-hindiwing was dissected and mounted on a slide. Regarding the paratype, the right and left forewings were dissected and mounted on a slide.

The remaining structures of the *N. enderleini* holotype encompassed the head and thorax, with the left, anterior, and posterior wings, alongside the left, anterior, medial, and posterior legs. Both wings and legs were dissected and mounted on slides. The thorax of the *N. enderleini* and *N. roesleri* type material was stored in separate micro-vials with ethanol.

The non-type specimens were dissected in 80% ethanol. Their parts were mounted on permanent slides in Canada balsam: head, right antenna with distal flagellomeres and mouthparts (right and left lacinia, right maxillary palp, right mandible, left mandible, labium and labrum), and right legs, right and left wings, and genitals. Before dissecting, the specimen was placed in 80% ethanol under a dissecting microscope, illuminated with cold, white light, and observed at 50X to record color. Standard measurements (in μ m), were taken with a filar micrometer. Abbreviations of parts measured are as follows: FW and HW: right fore- and hindwing lengths, F, T, t1 and t2: lengths of femur, tibia and tarsomeres 1, 2 and 3 of right hind leg, f1...fn: lengths of flagellomeres 1...n of right antenna, Mx1-Mx4: lengths of segments of right maxillary palpus, IO: minimum distance between compound eyes in dorsal view of head, D, and d: antero-posterior and transverse diameter, respectively, of right compound eye in dorsal view of head, PO: d/D.

The specimens were stored in "CD boxes," as described in Silva-Neto *et al.* (2016). Except for the holotype, the *N. roesleri* and *N. enderleini* specimens were named Male (M1...Mn) and Female (F1...Fn). Photographs of parts of the specimens were taken with a Leica DFC500 digital camera attached to a Leica M205C stereomicroscope, connected to a computer with the Leica Application Suite LAS V3.6 software, which includes an Auto-Montage module (Syncroscopy software). The map of the species locality was made with SimpleMappr (Shorthouse, 2010). All examined specimens of *N. roesleri*, *N. enderleini* and *N. xanthopterum* were deposited at the Invertebrate Collection of the Instituto Nacional de Pesquisas da Amazônia (INPA).

RESULTS

Neurostigma enderleini New, 1980 (Figs. 1-11)

Neurostigma enderleini New, 1980: 192; Rafael et al., 1983: 915 (deposit of types); Liennhard & Smithers, 2002: 122 (catalogue); Casasola Gonzalez, 2006: 16-32 (phylogeny); García Aldrete & Mockford, 2009: 667 (species list). Silva-Neto & García Aldrete, 2020: 3 (species list); Mendivil Nieto et al., 2020: 133 (taxonomy); González-Obando et al., 2021: 95-97 (taxonomy); Reategui et al., 2022b: 40 (taxonomy).



Figure 1. Neurostigma enderleini (Holotype male): (A) Front view of head; (B) Right forewing; (C) Left forewing; (D) Right antenna; (E) Pterostigma of right forewing; (F) Pterostigma of left forewing; (G) Right hindwing; (H) Epiprocto and Paraprocto; (I) Hypandrium; (J) Phallosome. Scales in mm.



Figure 2. Neurostigma enderleini (Holotype male): (A) Right front leg; (B) Right medial leg; (C) Right hind leg. Scales in mm.



Figure 3. Neurostigma enderleini (male I): (A) Lateral view; (B) Zoom of lateral view of head; (C) Head in lateral view. Scales in mm.



Figure 4. Neurostigma enderleini (male I): (A) Front view of head; (B) Right forewing; (C) Right hindwing; (D) Pterostigma of right forewing; (E) Pterostigma of left forewing; (F) hypandrium; (G) Epiprocto and Paraprocto; (H) Phallosome. Scales in mm.



Figure 5. Neurostigma enderleini (male I): (A) Labrum; (B) Labium; (C) Right mandible; (D) Left mandibles; (E) Right lacinia; (F) Left lacinia. Scales in mm.



Figure 6. Neurostigma enderleini (female): (A) Lateral view; (B) Thorax in lateral view; (C) Head in lateral view. Scales in mm.



Figure 7. Neurostigma enderleini (female): (A) Front view of head; (B) Right forewing; (C) Right hindwing; (D) Pterostigma of right forewing; (E) Pterostigma of left forewing; (F) Subgenital plate; (G) Epiprocto and Paraprocto; (H) Ninth sternum. Scales in mm.





Update diagnosis: Frons of the head with homogeneously dark spots from the middle of the lobes to the postclypeus (Figs. 4A, 7A). Fore and hindwings with the proximal half homogeneously pigmented, basally with a rounded-shaped hyaline área between vein CuA and vein CuP and between vein CuP and wing margin (Figs. 1B-C, 1G, 4B-C, 6A, 7B-C). Phallosome with posterior process of subquadrate aedeagal arch (Figs. 1J, 4H); membranous endophallus, with a transverse and elongated central stem, with denticles pronounced (Figs. 1J, 4H). Ninth sternum formed by two sclerites, curved inwards, posterioly with median recess, anteriorly separated by a narrow membranous area (Fig. 7H).

Redescription of the male based on the holotype and common specimens

Color: Frons of the head with homogeneously dark spots from the middle of the lobed to the postclypeus (Figs. 1A, 4A, 7A), lateral areas of head entirely light brown (Fig. 3A-C). Compound eyes black, ocelli hyaline with ochre centripetal crescents (Figs. 1A, 3, 4A). Scape, pedicel, and flagelomeres light brown (Fig. 1D). Clypeus brown (Fig. 4A); labrum light brown, with dark brown labral sclerites (Fig. 5A), labium with light brown prementum, with palps, paraglossas and glossa light brown (Fig. 5B). Mandibles light brown with and brownish ends

(Fig. 5C-D). Brown laciniae with light brown distal region (Fig. 5E-F). Tergal lobes of meso and metathorax brown; thoracic pleura brown (3A-B). Fore-hindwing with the proximal half homogeneously pigmented, with brownish veins (Figs. 1B-C, 1G, 4B-C). Legs with coxae, trochanters, femurs, tibiae brown, tarsomeres 1 and 2 light brown (Fig. 2A-C). Light brown abdomen with dark abdominal segments (Fig. 3A).

Morphology: Head with abundant macrosetae more concentrated on the vertex (Figs. 1A, 3, 4A), large compound eyes (Figs. 1A, 3, 4A), laterally rounded (Fig. 3B-C), vertex convex, bilobed, with above upper border of compound eyes (Figs. 1A, 4A). Labium with prementum narrow, labial palpus with round shape, paraglossas with round shape, slender glossa (Fig. 5B). Mandibles asymmetrical, elongate and with outer margin angled (Fig. 5C-D), outer cusp of lacinial tip short, with eight to nine denticles (Fig. 5E-F). Lobes tergal with many setae (Fig. 3A-B). Forewing pterostigma triangular (Figs. 1B-C, 4B, 9, 10, 11) with shape and number of crossveins, varying from four to ten crossveins (Figs. 9-11); R₂₊₃ almost straight (Figs. 1B-C, 4B); M vein before its first bifurcation, abruptly concave, V-shaped (Figs. 1B-C, 4B). Hindwing R₂₊₃ slightly sinuous and R₄₊₅ straight, M sinuous (Figs. 1G, 4C). Hypandrium distally concave, with sides sclerosed (Figs. 1I; 4F). Phallosome open basally; side struts straight, somewhat wide ba-

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sally and gently curved outwards, aedeagal arch robust, with posterior processo of subquadrate aedeagal arch (Figs. 1J, 4H); membranous endophallus, with a trans-

A B 0.5 С D 0.5 E 0.5 0.5 0.5 K 0.5 M 0.5 P 0.5

Figure 9. Pterostigma of the Neurostigma enderleini (male I...male VIII): (A) PRF of MI; (B) PLF of MI; (C) PRF of MII; (D) PLF of MII; (E) PRF of MIII; (F) PLF of MIII; (G) PRF of MIV; (H) PLF of MIV; (I) PRF of MV; (J) PLF of MV; (K) PRF of MVI; (L) PLF of MVI; (M) PRF of MVII; (N) PLF of MVII; (O) PRF of MVIII; (P) PLF of MVIII. Abbreviations: PRF = pterostigma of right forewing, PLF = pterostigma of left forewing, M = male. Scales in mm.



verse and elongated central stem, with denticles, more pronounced (Figs. 1J, 4H). Epiproct rounded with a field

of setae in the distal region (Figs. 1H, 4G). Paraproct dis-



tally subrounded with a field of microsetae in the distal region, sensory fields with 37-44 tricobothria on basal rosettes (Figs. 1H, 4G).

Measurements of holotype (in microns): FW: 4122, HW: 2625, Mx2: 112, Mx4: 237, F: 929, T: 1727, t1: 579, t2: 170, IO: 617, D: 312, d: 275, PO: 0.881.

Description of female

Color: As in male.

Morphology: Head with abundant macrosetae, more concentrated on the vertex (Figs. 6A-C, 7A), small compound eyes, widely separated and laterally rounded (Figs. 6A-C, 7A), vertex convex, bilobed, with above upper border of compound eyes (Figs. 6A-C, 7A). Labium with prementum narrow, rounded palps labial, subquadrate paraglossas, slender glossa (Fig. 8B). Mandibles asymmetrical, elongated and with outer margin angled (Fig. 8C-D), outer cusp of lacinial tip short, with nine or ten denticles (Fig. 8E-F). Lobes tergal with many setae (6A-B). Forewing pterostigma triangular (Fig. 7B, D-E), right forewing pterostigma with even

crossveins, with crossvein vein PT₅ forked (Fig. 7E); R₂₊₃ veins almost straight; M vein before its first bifurcation, abruptly concave, V-shaped (Fig. 7B). Hindwings elongate; M simple, unbranched, R₂₊₃ vein slightly curved at the base and R₄₊₅ vein almost straight (Fig. 7C). Subgenital plate broad with abundant setae, distally concave (Fig. 7F). Ninth sternum formed by two scleritos, curved inwards, posterioly with median recess, anteriorly separated by a broad membranous area (Fig. 7H). Epiproct rounded with a field of setae in the distal region (Fig. 7G). Paraproct distally subrounded with a field of microsetae in the distal region, sensory fields with 38-40 tricobothria on basal rosettes (Fig. 7G).

Measurements (in microns): FW: 4027, HW: 2990, F: 1011, T: 1856, t1: 650, t2: 173, IO: 662, D: 301, d: 254, PO: 0,843.

Material examined: Holotype, male (Figs. 1A-J): Brazil, Amazonas, Manaus, Reserva Florestal Adolpho Duck, 02°57'48.0"S, 59°55'22.2"W. 14.ii.1978. Malaise trap. J. Arias & N.D. Penny. (Deposited in INPA).

Other examined material: 1 female (INPA) Brazil, Rondônia, Morro três irmãos, Estrada Agrovila, Linha 17,



Figure 10. Pterostigma of the *Neurostigma enderleini* (male IX...male XIII): (A) PRF of MIX; (B) PLF of MIX; (C) PRF of MX; (D) PLF of MX; (E) PRF of MXI; (F) PLF of MXI; (G) PRF of MXII; (I) PLF of MXII; (J) PLF of MXIII. Abbreviations: PRF = pterostigma of right forewing, PLF = pterostigma of left forewing, M = male. Scales in mm.

09°00'9"S, 64°52"W. 20-21.viii.2015. CDC 1 m Rw Hutchings & DDD Carmo. Code Rbia-0029; **4 males** (males I-IV) (INPA) Brazil, Amazonas, Reserva Florestal Adolpho Duck. Portion L1. 02°57'50.0"S, 59°56'17.6"W. 01-15.x.2014. Malaise trap. Silva-Neto, A.M. & Mendes, D.M; **13 Males** (males V-XVII) (INPA) Brazil, Amazonas, Manaus, Reserva Biológica de Cueiras, km 14, 02°35'21"S, 60°06'55"W. 18.viii-01.viii.2016. J.A. Rafael-Rede BIA.; **2 males** (males XVIII-XIX) (INPA) Brazil, Rondônia, Morro Três Irmãos, Estrada Agrovila, Linha 17, 09°00'9"S, 64°52"W. 20-21.viii.2015. CDC 1 m Rw Hutchings & DDD Carmo. Code Rbia-0029; **1 male** (male XX) (INPA) Brazil, Amapá, Oiapoque BR-156, 03°39'35"N, 51°46'17"W, km 25, 05-17. xii.2019. Malaise. J.A. Rafael, S. Lima, F.F. Xavier.



Figure 11. Pterostigma of the *Neurostigma enderleini* (male XIV...male XX): (A) PRF of MXIV; (B) PLF of MXIV; (C) PRF of MXV; (D) PLF of MXV; (E) PRF of MXVI; (F) PLF of MXVI; (G) PRF of MXVI; (H) PLF of MXVII; (I) PRF of MXVII; (J) PLF of MXVII; (K) PRF of MXIX; (L) PLF of MXIX; (M) PRF of MXX; (N) PLF of MXX. Abbreviations: PRF = pterostigma of right forewing, PLF = pterostigma of left forewing, M = male. Scales in mm.



Figure 12. *Neurostigma roesleri* (Holotype female): (A) Front view of head; (B) Right forewing; (C) Right hindwing; (D) Pterostigma of right forewing; (E) Pterostigma of left forewing; (F) Clunium (Epiprocto, paraprocto, gonapophyses and ninth sternum); (G) Ninth sternum; (H) Subgenital plate; (I) Right gonapophyses. Scales in mm.

Neurostigma roesleri New, 1980 (Figs. 12-22)

- Neurostigma roesleri New, 1980: 194; Rafael et al., 1983: 915 (type deposit); Liennhard & Smithers, 2002: 122 (catalog); García Aldrete & Mockford, 2009: 667 (catalog). Silva-Neto & García Aldrete, 2020: 3 (list of species).
- *N. garcialdretei* Mendivil Nieto *et al.,* 2020: 132 (taxonomy); González-Obando *et al.,* 2021: 95-97 (taxonomy); Reategui *et al.,* 2022b: 40 (taxonomy). **syn. nov.**

Update diagnosis based on the holotype and common

specimens: Areola postica with light brown spot around Cua1 and Cua2, giving the shape of a halo (Figs. 12B, 13A-B, 14A, 15B, 18B). Posterior process of the edeagal arch long and narrow with slight indentation of outer margin; endophallus with sharp spines directed antero-mesally, with long spicules on outer margin and dense field of short spines and spicules latero-posteriorly (Fig. 18H). Ninth sternum almost circular (Figs. 12G, 15J), without pigmented areas, with invagination in the center (Figs. 12F-G, 15I-J). Gonapophyses long and slender, acuminate distally, with V2 strongly sclerotized with six microsetae on the outer lobe; V3 weakly sclerotized, thin, and elongated (Figs. 12I, 15G).

Male: As described by Mendivil Nieto et al. (2020).

Redescription of female

Color: Essentially as in male.

Morphology: Head with abundant macrosetae more concentrated on the vertex (Figs. 14A-C, 15A), compound eyes small, widely separated, and laterally elliptical (Fig. 14A-C); vertex convex, clearly above upper border of the compound eyes (Figs. 12A, 14B, 15A). Short and wide labium with rounded sides of the prementum, short labial palps directed downwards, almost square paraglossas, robust glossa (Fig. 16B). Mandibles asymmetrical, elongate, and with outer margin angled (Fig. 16D-E).

Outer cusp of lacinial tip broad, with four or five denticles, one of the denticles is acuminate (Fig. 16F-G). Lobes tergal with many setae (Fig. 14A-C). Forewings with narrow pterostigma, extending distally, with number and shape of transverse veins varying (Figs. 12D-E, 13, 15B, 20, 21, see also discussion of variations of Pterostigma); R₂₊₃ forked in the paratype (Fig. 13B), in the holotype and in the other observed specimens R2+3 and R4+5 are sinuous; M vein before its first bifurcation, gently concave, U-shaped; M with three branches (Fig. 12A, 13A-B, 15B); areola postica wide basally, slightly slanted posteriorly, apically rounded, with Cua1 touching the wing margin at a parallel point, after the first bifurcation of the M vein (Figs. 12B, 13A-B, 15B) (see below in anomalies bifurcated areola postica in common specimens (Fig. 20F-H)). Hindwings R_{2+3} and R₄₊₅ slightly sinuous, M sinuous (Figs. 12C, 15C). Subgenital plate with abundant setae, U-shaped, no pigmented area (Figs. 12H, 15H). Ninth sternum almost circular, without pigmented areas, with invagination in the center (Figs. 12F-G, 15I-J). Spermateca oval, anteriorly striated in the origin of spermathecal duct, posteriorly sclerotized (Fig. 15I, K). Gonapophyses long and slender, acuminate distally, with V2 heavily sclerotized with six setae on the outer lobe; V3 weakly sclerotized, thin, and elongated (Figs. 12F, I, 15G). Eggs almost elliptical (Fig. 14D-E). Epiproct basally wide, distally rounded with a field of microsetae in the medial and distal region (Figs. 12F, 15F). Paraproct rounded, sensory fields with 20-23 trichobothria on basal rosettes; setae as illustrated (Figs. 12F, 15F).

Measurements of holotype (in microns): FW: 3471, HW: 2528, F: 773, T: 1202, t1: 415, t2: 146, MX2: 128, MX4: 185, IO: 484, D: 177, d: 144, PO: 0,813.

Anomalies in the forewing veins

Type 1: Forewing with R₁ forked as in the holotype and paratype (Figs. 12A, 13A-B, 20F); *areola postica* with a vein that reaches the wing margin, dividing it into two areas (Fig. 20F).

Figure 13. Neurostigma roesleri (Paratype female): (A) Right forewing; (B) Left forewing; (C) Pterostigma of right forewing; (D) Pterostigma of left forewing. Scales in mm.

Figure 14. Neurostigma roesleri (female): (A) Lateral view; (B) Zoom of lateral view of head; (C) Zoom of dorsal view of head; (D) Eggs; (E) Zoom of egg. Scales in mm.

Figure 15. Neurostigma roesleri (female): (A) Front view of head; (B) Right forewing; (C) Right hindwing; (D) Pterostigma of right forewing; (E) Pterostigma of left forewing; (F) Clunium, epiprocto and paraprocto; (G) Gonaphophyses; (H) Subgenital plate; (I) Spermatheca connected to the ninth sternum via the spermathecacal duct. (J) Ninth sternum; (K) Spermatheca. Scales in mm.

Figure 16. Neurostigma roesleri (female): (A) Labrum; (B) Labium; (C) Right maxillary palp; (D) Right mandible; (E) Left mandibles; (F) Right lacinia; (G) Left lacinia. Scales in mm.

Figure 17. Neurostigma roesleri (male): (A) Lateral view; (B) Zoom of lateral view of head; (C) Zoom of dorsal view of head. Scales in mm.

Figure 18. Neurostigma roesleri (male): (A) Front view of head; (B) Right forewing; (C) Right hindwing; (D) Pterostigma of right forewing; (E) Pterostigma of left forewing; (F) Hypandrium; (G) Clunium, epiprocto and right paraprocto; (H) Phallosome. Scales in mm.

Figure 19. Neurostigma roesleri (male): (A) Labrum; (B) Labium; (C) Right maxillary palp; (D) Right mandible; (E) Left mandibles; (F) Right lacinia; (G) Left lacinia. Scales in mm.

Type 2: Forewing with R₁ forked; with a spurious vein in the *areola postica* (Fig. 20G-H).

Material examined: Holotype, female (Figs. 12A-I): Brazil, Amazonas, Manaus, Reserva Florestal Adolpho Ducke, 02°57′48.0″S, 59°55′22.2″W. 20.xii.1977. light trap. J. Arias & N.D. Penny. (Deposited in INPA).

Other examined material: 9 females (females I-IX) (INPA) Brazil, Amazonas, Manaus, Reserva Biológica de Cueiras, km 14, 02°35′21″S, 60°06′55″W. 18.viii-01. viii.2016. J.A. Rafael-Rede BIA; **7 males** (males I-VII) (INPA) Brazil, Amazonas, Manaus, Reserva Biológica de Cueiras, km 14, 02°35′21″S, 60°06′55″W. 18.viii-01.viii.2016. J.A. Rafael-Rede BIA; **1 male** (male VII) (INPA) Brazil, Amapá, Oiapoque, BR-156, km 25, 3°39′35″N, 51°46′17″W, 16.i.2020, Malaise trap, J.A. Rafael, S. Lima, F.F. Xavier (formerly registered as *N. garcialdretei*).

Neurostigma xanthopterum New, 1980 (Figs. 23A-F)

Neurostigma xanthoptera New, 1980: 194; Rafael et al., 1983: 916 (Catalogue); New, 1984: 3 (Ecology); Lienhard & Smithers, 2002: 122 (Catalogue); García Aldrete & Mockford, 2009: 667 (species list); Mendivil Nieto *et al.*, 2020: 132 (taxonomy); Silva-Neto & García Aldrete, 2020: 3 (species list); González-Obando *et al.*, 2021: 83 (taxonomy); Reategui *et al.*, 2022a: 15 (taxonomy).

Diagnosis: Head with vertex narrowed, bilobed, raised and distinctly emarginate medially (See figs. 1, 2A, 3B, 4A in Reategui et al., 2022b). Forewings with their proximal part half yellowish to brown, basally with a large clubshaped hyaline area between vein R and vein M+CuA; with large irregular dark brown spots from base of Pterostigma to CuP (See figs. 10A-B, 10D-G in Reategui et al., 2022b) or present only from M+CuA to CuP. A small dark brown spot at the base of the Pterostigma and this one with its transverse veins pigmented along its entire length (See figs. 2B-C, 7-9 in Reategui et al., 2022b). Hindwings with their proximal part half yellowish to brown, with two hyaline areas almost elliptic (See figs. 2G, 4C, 11 in Reategui et al., 2022b). Phallosomal arch narrow and widening at the ends, anteriorly with a U-shaped area, then with a small transverse part, almost straight, posteriorly elongated vertically, ending in an almost elliptical area, with convex inner margin and blunt outer margin (See fig. 2J in Reategui et al., 2022b). Endophallus heartshaped, radular sclerites with small denticles, more pro-

Figure 20. Pterostigma of the *Neurostigma roesleri* (female 1...female VI): (A) PRF of FI; (B) PLF of FI; (C) PRF of FII; (D) PLF of FII; (E) PRF of FIII; (F) PLF of FIII; (G) PRF of FIV; (H) PLF of FIV; (I) PRF of FV; (J) PLF of FV; (L) PLF of FVI. Abbreviations: PRF = pterostigma of right forewing, PLF = pterostigma of left forewing, M = male. Scales in mm.

Figure 21. Pterostigma of the *Neurostigma roesleri* (female VII...female IX): (A) PRF of MVII; (B) PLF of MVII; (C) PRF of MVIII; (D) PLF of MVIII; (E) PRF of MIX; (F) PLF of MIX. Abbreviations: PRF = pterostigma of right forewing, PLF = pterostigma of left forewing, M = male. Scales in mm.

nounced in midline (See fig. 2J in Reategui *et al.*, 2022b). Hypandrium U-shaped, more sclerotized on the sides (See fig. 2I in Reategui *et al.*, 2022b). Ninth sternum with a v-shaped recess in the middle of the posterior margin and a deep recess in the anterior region, giving rise to two similar areas, almost elliptical and anteriorly open ending in a membranous area (See fig. 4E in Reategui *et al.*, 2022b). Gonapophyses with short, blunt ended heel, distally culminated, with v2 heavily sclerotized, with three setae on outer lobe; V3 weakly sclerotized, swollen and elongated (See fig. 4G in Reategui *et al.*, 2022b).

Male: As described by New (1980).

Female: As described by Reategui *et al.,* 2022b, adding: Spermatheca striated bag-shaped, slightly sclerotized anteriorly, distally rounded (Fig. 23D-F).

Material examined: 2 females (INPA) Brazil, Amapá, BR-156, km 25, 03°39'35"N, 51°46'17"W. 17-30.i.2020. J.A.R, S. Lima, F. Xavier.

Comments: Reategui *et al.* (2022b) recorded nine eggs present in the described female, but here, 14 eggs were found in the analyzed female. Perhaps not all eggs were developed in the female described by Reategui *et al.* (2022b), or there is a wide variation in the number of eggs in this species.

DISCUSSION

Since 1980, only the holotype of *N. enderleini* described by New (1980), has been known. However, with the numerous specimens of additional material collected in Amazonas, Amapá, and Rondônia, it was possible to update the diagnosis and additional information

about variations on the crossveins of the pterostigma of this species. *Neurostigma enderleini* has variations in shape and the number of pterostigma crossveins, ranging from six to ten crossveins (Figs. 9-11 and Table 2), and the combinations of these characters are never repeated in any specimen, thus corroborating the previous work of Reategui *et al.* (2022a), in which the authors believe that the crossveins in the pterostigma are like a type of wing fingerpint.

The new records for *N. enderleini* expand our knowledge about the current geographic distribution of this species, which is no longer known only by the type-lo-

Table 2. The number of pterostigma crossveins the forewing of specimens of *N. enderleini* New.

Specimens of <i>N. enderleini</i>	Number of pterostigma crossveins of right forewing	Number of pterostigma crossveins of left forewing
Male I	8 (Fig. 9A)	8 (Fig. 9B)
Male II	9 (Fig. 9C)	9 (Fig. 9D)
Male III	8 (Fig. 9E)	9 (Fig. 9F)
Male IV	8 (Fig. 9G)	8 (Fig. 9H)
Male V	10 (Fig. 9I)	9 (Fig. 9J)
Male VI	9 (Fig. 9K)	8 (Fig. 9L)
Male VII	6 (Fig. 9M)	7 (Fig. 9N)
Male VIII	7 (Fig. 90)	8 (Fig. 9P)
Male IX	9 (Fig. 10A)	9 (Fig. 10B)
Male X	7 (Fig. 10C)	7 (Fig. 10D)
Male XI	10 (Fig. 10E)	9 (Fig. 10F)
Male XII	8 (Fig. 10G)	6 (Fig. 10H)
Male XIII	10 (Fig. 10I)	9 (Fig. 10J)
Male XIV	8 (Fig. 11A)	9 (Fig. 11B)
Male XV	9 (Fig. 11C)	9 (Fig. 11D)
Male XVI	6 (Fig. 11E)	8 (Fig. 11F)
Male XVII	7 (Fig. 11G)	8 (Fig. 11H)
Male XVIII	8 (Fig. 11I)	6 (Fig. 11J)
Male XIX	4 (Fig. 11K)	5 (Fig. 11L)
Male XX	9 (Fig. 11M)	8 (Fig. 11N)

cality (Fig. 24). Additionally, the unknown female of *N. enderleini* was described, which can be easily distinguished from other known females of this genus by having the proximal half of the forewings and hindwings homogeneously pigmented. In contrast, all other *Neurostigma* species with known females have hyaline

wings, except *N. xanthopterum,* which has a uniformly unpigmented brown forewing (see fig. 59 in New, 1980, fig. 41 in Roesler, 1940, fig. 56 in New, 1980 and fig. 70, Badonnel, 1986).

Unfortunately, we did not compare the gonapophyses of *N. enderleini* with other females, as it was lost

Figure 22. Pterostigma of the *Neurostigma roesleri* (male 1...male VI): (A) PRF of MI; (B) PLF of MI; (C) PRF of MII; (D) PLF of MII; (E) PRF of MIII; (F) PLF of MIII; (G) PRF of MIV; (H) PLF of MIV; (I) PRF of MV; (J) PLF of MV; (K) PRF of MVI; (L) PLF of MVI. Abbreviations: PRF = pterostigma of right forewing, PLF = pterostigma of left forewing, M = male. Scales in mm.

during dissecting of the female genitalia. We are currently adapting a new methodology for dissecting the female genitalia, allowing safe dissection of the spermatheca, ninth sternum, and the gonapophyses of females of this genus. According to the information above, N. enderleini appears closer to the female of N. xanthopterum since the proximal region of the wing is pigmented. However, N. enderleini differs from N. xanthopterum due to its characteristics mentioned above and its diagnosis. Furthermore, we can differentiate them by the structure of the ninth sternum. In N. enderleini, the ninth sternum is formed by two sclerites, curved inwards, and posteriorly with a median recess, separated anteriorly by a narrow membranous area (Fig. 7H). On the other hand, in N. xanthopterum, the ninth sternum is formed by only one shield-shaped sclerite with an invagination in the center (Fig. 23D-F). With the description of the female of N. enderleini, in the present study, the number of known females of this genus will increase to four species (Table 1).

Neurostigma roesleri was published without a diagnosis, with only a comment and brief description for the female. The structures of the female genitalia illustrated and described by New (1980) were the subgenital plate and the gonapophysis with six microsetae (See fig. 58 in New, 1980). However, it is impossible to identify the delimitations of the second and third ovipositor valves in this illustration. The other structures that constitute the female genitalia, such as the ninth sternum and the spermatheca, have not been described or illustrated. After analyzing the slide mounted by New (1980), it was possible to verify that he had mounted the ninth sternum (Fig. 12F). However, perhaps due to a lack of knowledge about the taxonomic importance of this structure to separate the species in Neurostigma, New (1980) did not describe or illustrate the ninth sternum (See figs. 56-58 in New, 1980). Here, we describe and illustrate the ninth sternum and the spermatheca of N. roesleri for the first time.

Previously, N. roesleri was known only from the type locality (Fig. 12). But after 40 years, this species was mistakenly described as a new species by Mendivil Nieto et al. (2020) (Neurostigma garcialdretei Mendivil Nieto, Gonzalez Obando & Carrejo Gironza) from three localities in southeastern Colombia (Vaupés-Mosiro-Itajura, Amazonas-Leticia, Amazonas-Amacayacu). It was also recorded for Amapá by Reategui et al. (2022b) as N. garcialdretei. The latter authors, a few months after the publication of the new record, examined new material from Reserva Biológica de Cueiras-ZF2, Amazonas, Brazil, and found female specimens of N. roesleri, along with male specimens identical to N. garcialadretei. At this point, it was realized that N. garcialdretei was, in fact, the unknown male of N. roesleri, as they shared conspecific morphological characteristics. Of the observed specimens, nine were females, and six were males. The cross veins of the pterostigma in females varied between five and eight veins (Figs. 20-21). In contrast, in males, these varied between four and seven veins (Fig. 22) (Table 3), thereby consolidating the proposal of Reategui et al. **Table 3.** The number of pterostigma crossveins the forewing of specimens of *N. roesleri* New.

Specimens of <i>N. roesleri</i>	Number of pterostigma crossveins of right forewing	Number of pterostigma crossveins of left forewing
Male I	6 (Fig. 22A)	6 (Fig. 22B)
Male II	8 (Fig. 22C)	8 (Fig. 22D)
Male III	6 (Fig. 22E)	5 (Fig. 22F)
Male IV	6 (Fig. 22G)	6 (Fig. 22H)
Male V	7 (Fig. 22I)	6 (Fig. 22J)
Male VI	6 (Fig. 22K)	7 (Fig. 22L)
Female I	8 (Fig. 20A)	9 (Fig. 20B)
Female II	7 (Fig. 20C)	7 (Fig. 20D)
Female III	7 (Fig. 20E)	6 (Fig. 20F)
Female IV	6 (Fig. 20G)	6 (Fig. 20H)
Female V	7 (Fig. 20I)	8 (Fig. 20J)
Female VI	7 (Fig. 20K)	6 (Fig. 20L)
Female VII	7 (Fig. 21A)	7 (Fig. 21B)
Female VIII	6 (Fig. 21C)	7 (Fig. 21D)
Female IX	7 (Fig. 21E)	7 (Fig. 21F)

(2022a) that the cross veins in the pterostigma are like a type of wing fingerprint.

All females were dissected, and we confirmed that they were all N. roesleri, eliminating the possibility of cryptic species, as the gonapophyses were the same as described and illustrated by New (1980). Males were also dissected and found to have the genitalia of N. garcialdretei (Fig. 18F-H). Therefore, we looked for more morphological characters that both shared and verified that both have a dark brown spot in the pleural region of the thorax (Figs. 14A-B, 17A-B), spots surrounding the posterior region of the compound eyes (Figs. 14B, 17B), spots present on the labium (Figs. 16B, 19B), spots surrounding the first segment of the maxillary palp (Fig. 16C, 19C), one of the denticles of both sexes acuminate (Figs. 16F-G, 19F-G), and the pattern of wing venation (Figs. 12B, 13A-B, 15B, 20F-H, 18B). These observed characters allowed us to infer that N. garcialdretei is the male specimen of N. roesleri. According to the new characters and described diagnosis, it is necessary to synonymize N. garcialdretei as a junior synonym of N. roesleri.

The female of N. xanthopterum was described, but its spermatheca was neither illustrated nor described by Reategui et al. (2022a). In this paper, we illustrate and describe the spermatheca of two female Neurostigma species (N. xanthopterum and N. roesleri) for the first time. Neurostigma xanthopterum and N. roesleri belong to different groups according to the classification proposed by Mendivil Nieto et al., 2020 (Table 1). They have different characters that distinguish them. Furthermore, it is possible to separate them by the characters of the ninth sternum, the ovipositor valves, and the spermathecae (Figs. 15A-K; 23D-F). We are convinced that in the future, with more studies on female specimens of Neurostigma, we will be able to use the spermatheca together with the gonapophyses and the ninth sternum as structures of taxonomic importance for Neurostigma.

Figure 23. Neurostigma xanthopterum (female): (A) Lateral view; (B) Eggs; (C) Zoom of an egg; (D) Spermatheca dorsal view; (E) Spermatheca ventral view; (F) Spermatheca lateral view. Scales in mm.

Figure 24. Geographic records of Neurostigma enderleini and Neurostigma roesleri.

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REFERENCES

- Badonnel, A. 1986. Psocoptères de Colombie (Insecta: Psocoptera). Missions écologiques du Professeur Sturm (1956 a 1978). Spixiana, 9(2): 179-223.
- Casasola González, J.A. 2006. Phylogenetic relationships of the genera of Epipsocetae (Psocoptera: Psocomorpha). *Zootaxa*, 1194: 1-32. <u>https:// doi.org/10.11646/zootaxa.1194.1.1</u>.
- Enderlein, G. 1900. Die Psocidenfauna Perus. Zoologische Jahrbücher Abteilung Systematik, 14: 133-139.
- García Aldrete, A.N.; Mockford, E.L. 2009. A list of Psocoptera (Insecta:Psocodea) from Brazil. *Revista Mexicana de Biodiversidad*, 80(3): 665-673. https://doi.org/10.22201/ib.20078706e.2009.003.163.
- González-Obando, R.; Carrero-Gironza, N.; Mendivil-Nieto, J. & Garcia Aldrete, A.N. 2021. *Neurostigma* (Psocodea: Psocomorpha: Epipsocidae) from Colombia: new species and an identification key. *Acta Entomologica Musei Bational Pragae*, 61(1): 83-98. <u>https://doi.org/10.37520/ aemnp.2021.005</u>.

- Lienhard, C. & Smithers, C.N. 2002. Psocoptera (Insecta). World Catalogue and bibliography. Muséum d'histoire naturelle, Genève. 745p. (Instrumenta Biodiversitatis V)
- Mendivil Nieto, J.A.; González Obando, R. & Carrero Gironza, N.S. 2020. New species of *Neurostigma* Enderlein, 1901 (Insecta: Psocodea: Epipsocidae) from Colombia. *Dugesiana*, 27(2): 131-135. <u>https://doi.org/10.32870/ dugesiana.v27i2.7113</u>.
- New, T.R. 1980. Epipsocetae (Psocoptera) from the Reserva Ducke, Amazonas. Acta Amazonica, 10(1): 179-206. <u>https://doi.org/10.1590/1809-43921980101179</u>.
- Rafael, J.A.; Penny, N.D. & Harada, A.Y. 1983. Relação dos tipos de invertebrados depositados na Coleção em Entomologia Sistematica do IN-PA-Manaus, até dezembro de 1982. *Acta Amazonica*, 13(5-6): 911-926. <u>https://doi.org/10.1590/1809-439219831356911</u>.
- Reategui, N.S.; Silva-Neto, A.M. & Rafael, J.A. 2022a. Neurostigma xanthopterum New, 1980 (Psocodea: Psocoptera: Epipsocidae): updated diagnosis, description of a female specimen, morphological variations and a checklist of all known species of the genus. Papéis Avulsos de Zoologia, 62(52):1-15, e202262052. <u>https://doi.org/10.11606/1807-0205/2022.62.052</u>.
- Reategui, N.S.; Rafael, J.A.; Cordeiro, D.P.; Silva-Neto, A.M. 2022b. Neurostigma Enderlein, 1900 (Psocodea, 'Psocoptera', Epipsocidae): a new species of Brazilian Atlantic Rainforest, and new records for Brazil. Journal of Insect Biodiversity, 34(2): 033-041. <u>https://doi.org/10.12976/jib/2022.34.2.2</u>.
- Roesler, R. 1940. Neue und wenigbekannte Copeognathengattungen. I. Zoologischer Anzeiger, 129(9/10): 225-243.
- Shorthouse, D.P. 2010. SimpleMappr, an online tool to produce publication-quality point maps. Available: <u>http://www.simplemappr.net</u>. Access: 27/10/2023.
- Silva-Neto, A.M. & Garcia-Aldrete, A.N. 2020. A checklist of 'Psocoptera' (Psocodea) from Brazil: an update to the list of 2009 of GarcíaAldrete and Mockford, with an identification key to the families. *Papéis Avulsos de Zoologia*, 60(29):1-14, e20206029. https://doi.org/10.11606/1807-0205/2020.60.29.
- Silva-Neto, A.M.; García-Aldrete, A.N. & Rafael, J.A. 2016. A Storage Method for "Psocoptera" (Insecta: Psocodea) in "CD Box". *Entomobrasilis*, 9(3): 220-223. <u>https://doi.org/10.12741/ebrasilis.v9i3.656</u>.