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Description of the Female of *Navicordulia aemulatrix* Pinto & Lamas and Additional Notes on the Male (Odonata: Corduliidae)

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Abstract

The female of *Navicordulia aemulatrix* Pinto & Lamas is described and illustrated for the first time based on a single specimen from the same locality of the type series (state of Santa Catarina, [municipality of São Bento do Sul, 26°14'58"S, 49°22'59"W, railroad station] Rio Vermelho, 29.I.1952, in MZSP). In addition, further morphological notes for the male are provided based on three specimens collected at the type locality and at a new locality in the state of Santa Catarina (Timbó municipality). The pronotal process present in *N. aemulatrix* is re-evaluated and considered non-homologous to that found in *Neocordulia setifera* (Hagen *in* Selys) as previously suggested.

Introduction

South American representatives of Corduliidae, commonly known as emerald dragonflies, due to their secretive habits are rare in collections, and general aspects on their biology, ecology and behavior are virtually unknown (Geijskes 1970, Machado & Costa 1995, Garrison *et al* 2006, Pinto & Carvalho 2010). Previous phylogenetic analyses suggested that the group comprises at least three distinct lineages, i.e. Corduliinae *sensu stricto*, GSI-group (Gomphomacromiinae, Synthemistinae and Idionychinae), and Macromiidae, thus Corduliidae, in its most traditional sense, is considered paraphyletic in relation to Libellulidae (Ware *et al* 2007, 2009, Bybee *et al* 2008). In South America, there are nine genera and 44 species of corduliids recognized, with 11 species in *Navicordulia* Machado & Costa, making it the second largest genus of the continent (Pinto & Lamas 2010).

Species of *Navicordulia* can be distinguished from all other corduliids occurring in the New World by the presence of an accentuated excavation distal to Hw anal triangle, by a pilose complex on male sternite S7, and by female subgenital plate boat-shaped, projected posteriorly beyond S10, with a supralaminar process projected posteriorly beyond apex of cerci (Machado & Costa 1995, Garrison *et al* 2006). Furthermore, the presence of a cylindrical tergal process in the prothorax of two species, *Navicordulia aemulatrix* Pinto & Lamas and *Navicordulia errans* (Calvert), character apparently shared only with *Neocordulia setifera* (Hagen *in* Selys), was also reported by Pinto & Lamas (2010).

Navicordulia aemulatrix was recently described based on three males. The specimens were collected in the locality of a deactivated railway station named Rio Vermelho in the municipality of São Bento do Sul, state of Santa Catarina, southern Brazil (Pinto & Lamas 2010). All of them are from the collection of Richard von Diringshofen, an amateur German-Brazilian entomologist, whose collection was inherited by the Museu de Zoologia da Universidade de São Paulo in the year of 1987 after his death (*cf.* Costa *et al* 2000). This large material, which lacks any sort of systematic organization, is still being

incorporated into the main collection, so progress on its curatorial work has been very slow. As a result, some months after the manuscript describing *N. aemulatrix* was accepted for publication, we located four additional specimens, including a female, previously unknown. These specimens are described here, complementing the original description.

Material and Methods

Specimens examined are deposited in the Museu de Zoologia da Universidade de São Paulo – MZSP.

The terminology used here, is the same adopted by Pinto & Lamas (2010). Measurements (in mm) were made with the aid of a stereomicroscope equipped with a camera lucida. Specimens were photographed with a Leica MZ16 stereomicroscope equipped with a Leica DFC420 camera, and source images combined using Auto-montage© software by The Synoptic Group. The following abbreviations were used along the text: Ax = antenodal crossveins; Fw = forewing; Hw = hindwing; LC = lateral abdominal carina; Px = postnodal crossveins; pt = pterostigma; S1-10 = abdominal segments; TC = transverse abdominal carina.

Geographic coordinates not provided in the collection labels were acquired from a digital database (IBGE 2007).

***Navicordulia aemulatrix* Pinto & Lamas** (Figs 1a-f, 2)

Material examined

Total 5 ♂ and 1 ♀. Holotype ♂ and 1 ♂ paratype. BRAZIL.

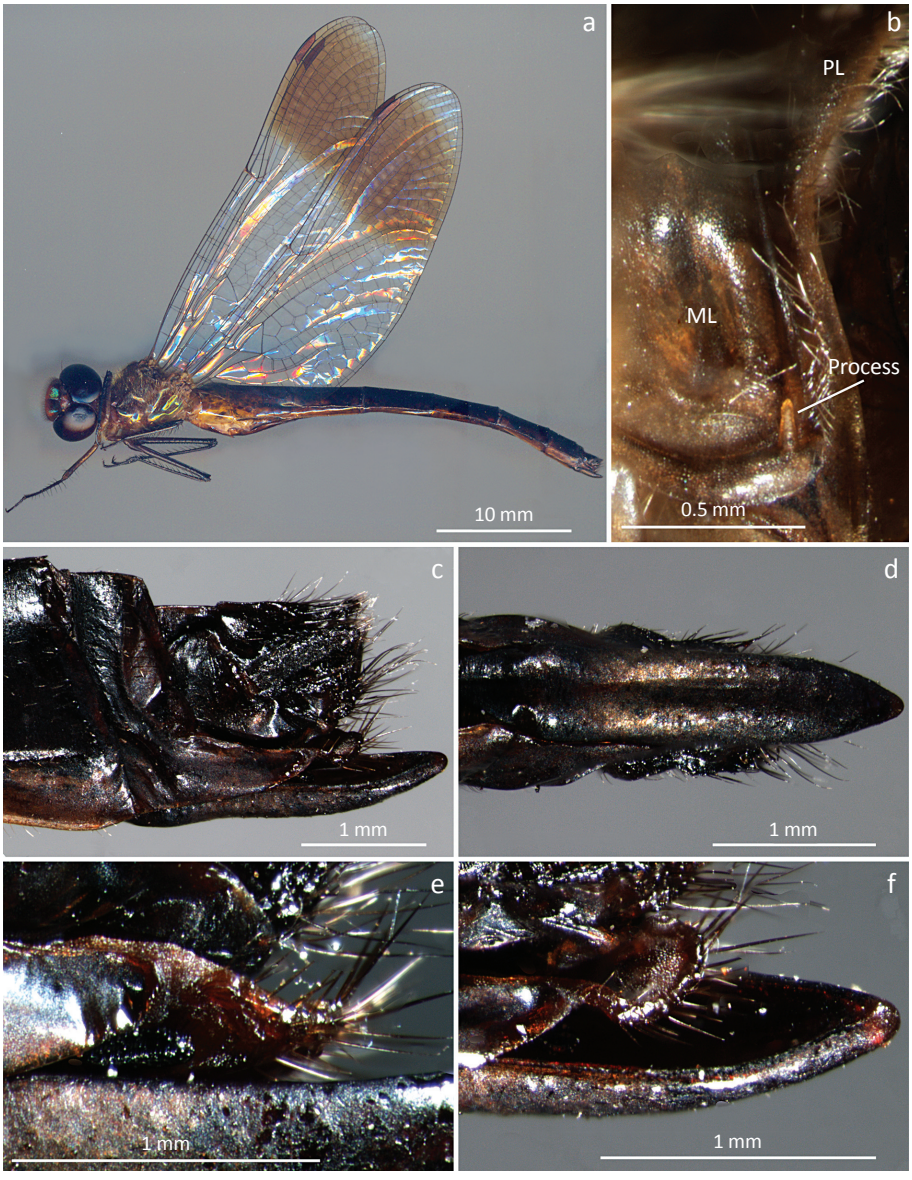

Fig 1a-f Female specimen of *Navicordulia aemulatrix* (MZSP, Brazil. SC: São Bento do Sul). a) scanned image of entire specimen; b) detail of prothorax in lateral view; c) caudal appendages in lateral view; d) subgenital plate in ventral view; e) detail of caudal appendages in lateral view showing the left gonapophysis of S9 (black structure with micropunctures); f) detail of caudal appendages in oblique dorsal view showing the dish-shaped supralaminar process and part of the boat-shaped subgenital plate. ML, middle and PL, posterior lobes of prothorax, respectively.

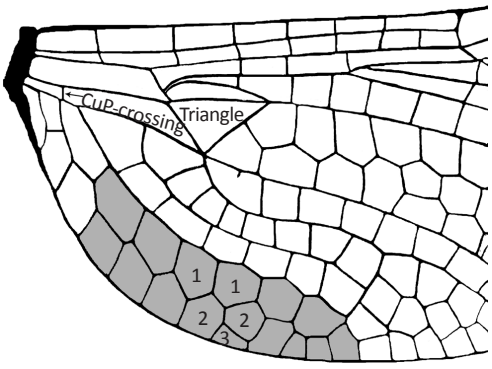

Fig 2 Diagrammatic representation of proximal half of left hind wing of female specimen of *Navicordulia aemulatrix* (MZSP, Brazil. SC: São Bento do Sul); shaded area depicts number of rows of cells in the anal field.

State of Santa Catarina, [São Bento do Sul municipality, 26°14'58"S, 49°22'59"W, 858 m a.s.l.], [railway station] Rio Vermelho, II.1952, [Richard von] Dirings[hofen] leg.; additional material with same data as the types, but 1 ♂ and 1 ♀, 29.I.1952; same data, but 1 ♂, 10.II.1952; 1 ♂ [apparently under pre-reproductive period], Timbó municipality [26°49'22.80"S, 49°16'19.20"W, 69 m a.s.l.], 1954. All in MZSP.

Description of female

Head (Fig 1a). Face in anterior view four banded, with alternating dark and pale transverse stripes; covered with dark brown setae, except for yellow setae on labium and free margins of postclypeus. Labium light orange. Labrum orange, with a pair of small dark spots on each side and an irregular brown line on the clypeolabral suture. Clypeus brownish-orange; central portion of postclypeus irregularly spotted with orange. Frons with deep furrow; antefrons orange without metallic reflections, darkening to brownish-orange laterally; postfrons brownish-orange with faint metallic bluish-green reflections above, lateral parts brownish-orange. Vertex brown, with indistinct metallic reflections, dorsal area with a suboval orange spot. Antenna with scapus and pedicel dark brown to black, flagellum brown lighter distally. Occipital triangle brown; rear of head orange with irregular dark brown areas.

Thorax (Fig 1a-b). Pronotum with anterior margin of anterior lobe pale yellow; rest of prothorax color varying from brownish-orange to greenish-brown; suture between middle and posterior lobes with a small cylindrical yellowish-orange process directed dorsally (Fig 1b), similar to that of holotype. Synthorax brown with metallic green reflections; ventral surface, antealar sinus, interalar sclerite and metapostepimeron brown without metallic reflections; entire surface covered with yellow hair-like setae, except antealar sinus with short brown setae. Legs dark brown to black; coxa, postero-ventral surface of prothoracic trochanter, and femur lighter; tarsal claws brown.

Wings (Figs 1a, 2). Membrane with ca. proximal 0.66 (up to third Px) hyaline, distal 0.33 tinged with an oblique large brown spot covering total width of the wing, center of some cells paler; spot faints distally and becomes hyaline at apex (Fig 1a); veins dark-brown to black, costal triangle pale-brown; pt brown, paler than adjacent veins, slightly trapezoidal, distal side most oblique; membranula brown with a small white spot on extreme antero-distal base. Venation as follows: 8-9 Ax in Fw, 6 Ax in Hw; 5 Px in Fw, 7 Px in Hw; 4 postsubnodals in Fw, 4-5 in Hw; bridge crossvein arising on RP1-2, before subnodus in Fw and under subnodus in Hw, left Hw with an additional bridge crossvein anterior to oblique vein; arc between Ax1-2, but closer to Ax2; not stalked, origin located ca. of basal 0.30 in all wings; RP3-4 not undulate; Rspl distinct, with one cell row of six cells in Fw, 6-7 in Hw; discoidal triangles and supratriangles not crossed in all wings; subtriangles with one crossvein in both Fw; Hw triangle base arising distinctly proximal to arc; space between CuP-crossing and proximal side of discoidal triangle not crossed in all wings (Fig 2); Fw discoidal field convergent, with two rows of cells over its entire length; Hw discoidal field divergent, with four rows of two cells, three of three cells, two of four cells and eight cells in the wing margin; Mspl indistinct in Fw (weakly defined with 3-4 cells), undefined in Hw; anal loop (Fig 2) elongated with distinct midrib, reaching distally near the RP-midfork level; total of cells in anal loop 15 (proximal row seven cells, distal eight); apex of anal loop slightly dilated with two cells, quadrangular; three paranals in Hw; space between anal loop and posterior border of wing with two cell rows and one row with three cells to triangle level (Fig 2); Fw PsA ends near the proximal angle of triangle.

Abdomen (Fig 1a, c-f). Cylindrical, S1 to anterior 0.33 of S3 slightly swollen dorsally; regularly cylindrical posteriorly; S1-2 and S10 without LC. Ground color brown to black; latero-ventral surface of S1-2 and part of S3 orange-brown; dorsal of S2-3 and S4-10 with dull metallic green reflections; ventral carina of S3-8 yellowish-brown; ventro-tergal areas in all segments paler than dorsal, without distinct metallic reflections; sternites dark brown to black. Shape of S8-10 typical of females of the genus; supralaminar process dish-shaped, posterior margin covered by stiff brown setae (Fig 1c, f), width similar to that of subgenital plate in dorsal view; gonapophyses of S9 black, cylindrical, with their surfaces covered by micropunctures (Fig 1e); subgenital plate dark brown to black, projected posteriorly 0.6 mm beyond supralaminar process (Fig 1c-d, f). Epiproct (Fig 1c) dark brown to black; triangular, apex rounded; cerci black, cylindrical, obliquely directed slightly upwards in lateral view (Fig 1c).

Measurements (mm). Total length (incl. subgenital plate) 47.5; abdomen length (excluding subgenital plate)

35.5; maximum width of head 6.6; eyes seam length 0.9; length of Fw 31, Hw 30; width of wing (proximal to costal nodus) 8.5 in Fw, 11 in Hw; length of distance of base-nodus 18 in Fw, 14 in Hw; ratio between base-nodus distance / total length of wing 0.58 in Fw, 0.47 in Hw; pt length 2.7 in Fw, 2.6 in Hw; length of postnodal space (*sensu* May 1992) 0.49 in Fw, 0.43 in Hw; length of metathoracic femur 7.1; of metathoracic tibia 6.9; length of cercus in lateral view 0.95; of epiproct in lateral view 0.8; length of subgenital plate (vulvar lamina *sensu* Machado & Costa 1995) in lateral view 2.5; ratio between total length (from S8 posterior margin) of supralaminar process and total length of subgenital plate 0.8.

Remarks

The abdomen is crushed on S2-S4 (Fig 1a), and was broken in three pieces, which we joined using a water soluble glue. Afterwards it was transferred to a cellophane envelope.

Additional notes on the male

The three specimens are very similar to the type-series and only the differences are reported here.

Head. Two specimens with orange color of face fading, obscuring the transverse four-banded pattern observed in the type-series. Metallic reflections on postfrons greenish-blue. Vertex with metallic reflections ill-defined; two specimens with antero-dorsal area between barely developed tubercles regularly brown, without a suboval orange spot.

Thorax. Small cylindrical yellowish process on the suture between middle and posterior lobes of pronotum present in all specimens, but reduced as observed in the paratypes.

Wings. Pt pale brown and membranula grayish-brown (specimen from Timbó). Venation as follows: 4-5 postsubnodals in Fw and Hw, Rspl composed by 5-7 cells in Hw; one specimens from type locality with subtriangle in left Fw not crossed, with a vestige of crossvein, while right Fw has three cells; discoidal triangle in left Hw crossed with two cells (specimen from Timbó).

Abdomen. Ratio of carinated portion / total length of cercus 0.29-0.33, smaller than type-series; one specimen from type locality with ratio between cerci and epiproct total length in lateral view of 0.55, outside the range observed in the type series of 0.58-0.62.

Measurements. Length of Fw 32, Hw 31 (specimen from Timbó); pt length 2.2 in Fw in two specimens, 2.1 in Hw in one specimen from type locality; length of postnodal space (*sensu* May 1992) 0.47-0.49 in Fw, 0.41-0.45 in Hw; length of metathoracic femur 7.2-7.3; metathoracic tibia 7.0-7.1; maximum width of abdomen (between S7-8) in one specimen from type locality 3.2.

Remarks

The specimen from Timbó represents a new locality record from Santa Catarina and was found fragmented in a big paper envelope with several specimens of *Orthemis discolor* (Burmeister) and some unidentified *Macrothemis*. The two specimens from the type locality were located in a drawer holding well-curated papered specimens belonging to many families and different localities. The specimens of *N. aemulatrix* were identified, likely by Richard von Diringshofen, with "124 Libell[en]"; similar handwriting label was found in the paratype formerly pinned (see Pinto & Lamas 2010). Studying Diringshofen's collection we realize that he maintained the finest preserved specimens of dragonflies in a distinct drawer with some kind of determination and chose one of them to be pinned. Curiously, Diringshofen was able to correctly associate these males to the same species, as we observed for several others specimens of distinct species designated with numbers or another sort of determination by him.

Discussion

Females of *Navicordulia* are poorly known. From the total of 11 species, just seven have the female described (including the probable *Navicordulia nitens* De Marmels; see below). Machado & Costa (1995) presented 41 female specimens in their synopsis, of which 82% belong to *N. errans* and *N. leptostyla* Machado & Costa, with 19 and 15 specimens each, respectively. Furthermore, Machado & Costa (1995: 197) included *N. nitens* in their females' key, based in the Venezuelan specimen illustrated by Rácenis (1970: 37, fig 7) as *Paracordulia sericea* (Selys), which was carefully studied by De Marmels (1983) under the provisional name "*Paracordulia* sp.1". However, as correctly highlighted by the same authors (Machado & Costa 1995: 188, 195), this specimen must be considered probably as *N. nitens* in agreement with De Marmels (1991:109) opinion: "…[Rácenis specimen] ist zweifellos eine weibliche *Dorocordulia* [*Navicordulia*]….könnte es sich um das Weibchen von *D. nitens* [*N. nitens*] oder einer ihr nahestehenden Art handeln". For this reason the actual identity of *N. nitens* female remains still uncertain and caution should be taken when identifying females when not associated with the corresponding males.

The female of *N. aemulatrix* keys out between *Navicordulia longistyla* Machado & Costa and *Navicordulia mielkei* Machado & Costa using the key provided by Machado & Costa (1995). A modification in couplet 6 will allow separating it from that of the two mentioned species.

6. Supralaminar process spoon-shaped with apex upturned and bearing a tuft of hair-like setae ..... *N. longistyla*

6'. Supralaminar process cup or dish-shaped with apex almost parallel to abdominal axis, if bearing a tuft of hair-like setae then not spoon-shaped 7
7. Supralaminar process shaped like a small cup and not provided with a tuft of hair-like setae; ratio between total length (from S8 posterior margin) of supralaminar process and total length of subgenital plate ca 0.66 .... *N. mielkei*
7'. Supralaminar process dish-shaped and apex bearing a tuft of hair-like setae; ratio between total length (from S8 posterior margin) of supralaminar process and total length of subgenital plate 0.8 ..... *N. aemulatrix*

The dish-like shape of the supralaminar process is undoubtedly similar to that of *N. miersi* Machado & Costa and *N. mielkei* (Machado & Costa 1995, figs 29-30). *Navicordulia aemulatrix* and *N. mielkei* can be distinguished by the characters in the key. *Navicordulia miersi* is known only from the female holotype from Joinville municipality, also in the state of Santa Catarina. This specimen is the only one of the genus with an additional crossvein to the CuP-crossing in Hw, and seems to be the unique distinction between these two species. The presence of an additional crossvein in the cubito-anal space may be a reliable parameter for specific distinction in *Navicordulia*, but the number of crossveins in this sector is particularly variable in other dragonfly species, such as in the Libellulidae genus *Uracis* Rambur (Costa & Santos 1997). Furthermore, it is relatively common to find additional crossveins in unexpected sectors of the wings, for example a pinned male specimen of *Dasythemis mincki mincki* Karsch in the Museu de Ciências e Tecnologia da PUCRS – MCTP has both Hw with one additional crossvein between CuP-crossing and proximal side of discoidal triangle, an uncommon feature among species of this genus. Probably, the number of cell rows in the anal field represents a more consistent character, since *N. aemulatrix* has two rows of cells and just one row with three cells (Fig 2), while *N. miersi* has three rows of cells for a distance of 3-4 cells. In addition, *N. miersi* has supralaminar process wider than subgenital plate in dorsal view (supralaminar process with same width of subgenital plate in *N. aemulatrix*) and ratio between total length of supralaminar process and total length of subgenital plate 0.66 (0.8 in *N. aemulatrix*). However, due the fact that both females are known from only one specimen, it is not possible to securely separate these two species without direct comparison.

The knowledge of females of Atlantic Forest species of *Navicordulia* is still far to be satisfactory. Considering the five species (*N. aemulatrix*, *N. atlantica* Machado & Costa, *N. kiautai* Machado & Costa, *N. mielkei* and *N. miersi*), three of them have the females described (*N. miersi, N. mielkei*, and now *N. aemulatrix*). The fact that *N. miersi* is known only by its female holotype turns the situation worse, since *N. atlantica*, described from only one male collected in the same locality (municipality of Joinville, state of Santa Catarina, Brazil), are badly preserved, with some parts lost, including the anal area of Hw (Machado & Costa 1995: 205), precluding the observation of the presence of an additional crossvein to CuP-crossing. Odonatologists have avoided describing new species based in female specimens, as females, in general, are less informative for species recognition. Indeed, in some cases, females are virtually undistinguishable, such as some species of the New World Calopterygidae (Garrison 2006).

Based in venational features and vesica spermalis morphology, *Navicordulia* most probably belongs to Corduliidae *sensu stricto* (*cf*. Ware *et al* 2007). Pfau (2005) considered p-ps sclerite, which is present in the vesica spermalis of *Navicordulia*, as characteristic of the primitive corduloid glans mechanism. This sclerite is reduced or completely absent in the GSI-group and Libellulidae species. The long subgenital plate found in all species of *Navicordulia* is uncommon in 'Corduliidae', as stated by Machado & Costa (1995). These authors discussed the probable relationship with other 'Corduliidae' taxa such as *Gomphomacromia* Brauer (Andean), *Somatochlora* Selys (Holarctic) and Synthemistinae genera (Australasian). However, only *Somatochlora* (Corduliidae *s.s.*) is likely to be closely related to *Navicordulia*. Furthermore, the subgenital plate of the Australasian genus *Metaphya* Laidlaw possess a great similarity to that of *Navicordulia* (*cf*. Campion 1921: 66, Laidlaw 1913: 66, plate IV, Theischinger & Hawking 2006: 242) and investigations are required to establish what is the phylogenetic relationship between these two genera.

In general *Navicordulia* can be considered highland forest-dependent dragonflies. The administrative center of Timbó is located in a valley at low altitude (69 m a.s.l.); however, based in the locality of the other specimens, we believe that it was probably collected in the adjacent mountains, with elevations little higher than 650 m a.s.l. The same interpretation could be applied to the known localities of *N. mielkei* and *N. miersi*, known from Joinville, whose administrative center is located at maximum 100 m a.s.l., but there are adjacent forested mountains with more than 900 m a.s.l.

The presence of a developed pronotal process in the female of *N. aemulatrix* (Fig 1b), similar to the one presented by its males (*cf*. Pinto & Lamas 2010), allowed us to reevaluate this structure. In the complete series of seven specimens only the holotype and the female have a fully developed process, and it is less conspicuous in the remaining specimens. Although Pinto & Lamas (2010) stated the possibility of *N. setifera* also presenting this structure, direct comparison revealed that it probably should not be considered homologous to the one of *Navicordulia*, which seems to be exclusive. In order to test this hypothesis, examination of a large sample

of species and even of other 'corduliid' genera will be necessary.

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