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A new *Dendrocephalus* (Crustacea, Anostraca, Thamnocephalidae) from Rio Grande do Sul State, Brazil

D. Christopher Rogers[1] and Matheus Vieira Volcan[2]

1 Kansas Biological Survey, Kansas University, Higuchi Hall, 2101 Constant Avenue, Lawrence, KS 66047-3759 USA.
DCR E-mail: Branchiopod@gmail.com

2 Instituto Pró-Pampa (IPPampa), Laboratório de Ictiologia, Rua Uruguai, 1242. 96010-630 Pelotas, Rio Grande do Sul, Brazil.
MVV E-mail: matheusvolcan@hotmail.com

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ABSTRACT

Dendrocephalus riograndensis n. sp., a new species of fairy shrimp, is described from a single temporary pool in Santa Vitória do Palmar, Rio Grande do Sul, Brazil. Males are readily separated from all other *Dendrocephalus* Daday, 1908 species by the form of the frontal appendage and the form of the first thoracopods. This new species is most similar to *Dendrocephalus goiasensis* Rabet & Thiéry, 1996 and could be confused with this species. This new species appears to be endemic to Rio Grande do Sul.

KEY WORDS

Fairy Shrimp, endangered species, identification key, Laguna dos Patos Ecoregion.

INTRODUCTION

Dendrocephalus Daday, 1908 comprises 17 species in two subgenera (Rogers, 2006; 2013). The subgenus *Dendrocephalinus* Rogers, 2006 contains three North American species, whereas *Dendrocephalus* (*sensu stricto*) is comprised of 14 described species from Central and South America, as well as the Galapagos Islands and Aruba (Rogers, 2006; 2013) and one undescribed species from Brazil (Chaves *et al.*, 2011). Rabet (2006, updated in part in Rogers *et al.*, 2012) provided a key to the males of *Dendrocephalus* (*sensu stricto*), listing 13 species, and Chaves *et al.* (2011) presented a key to the known Brazilian species, reporting yet another undescribed *Dendrocephalus* from Minas Gerais State. Hirose *et al.* (2015) demonstrated that many characters used in previous keys were variable between individuals within a species, and presented a key developed on less variable characters. We present a new species from Rio Grande do Sul, Brazil. This new species is the seventh Brazilian *Dendrocephalus* reported. Chaves *et al.* (2011) predicted that more

CORRESPONDING AUTHOR
D. Christopher Rogers
Branchiopod@gmail.com

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Dendrocephalus species would be discovered from Brazil and other portions of the Neotropical region, and while we are pleased to prove them correct, we are sure that there are still more *Dendrocephalus* species to discover.

Material and Methods

The second author discovered this species during fish survey in Rio Grande do Sul State, Brazil. Live specimens were accidentally collected using a dip net (60 cm x 30 cm, 2 mm mesh size) during fish collection activities in temporary pools, which were focused on annual fishes (Rivulidae), in the Campos Sulinos region in southern Brazil (*Projeto Peixes Anuais dos Campos Sulinos*). Samples were preserved in 70% ethanol. In the laboratory, the samples were analyzed and transferred to fresh 70% ethanol. Sampling site coordinates, area (m^2) and elevation were recorded using GPS (Garmin III), and the pool depth was measured with a ruler.

Specimens were deposited in Crustacean collection of Museu de Ciências e Tecnologia (MCP) of Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS). The specimens were then sent to the senior author for identification. Descriptive terminology of the frontal appendage follows Pereira (1983).

Comparative material. ***Dendrocephalus affinis*** Pereira, 1984. Venezuela. Zulia, two males, two females (paratypes), temporary pool near the cemetery for Carrasquero, 10°37'N 71°40'W, October 1978, D. Taphorn and J. Bang coll., gift from G. Pereira to D. Belk (DB-542); one male, one female, gift to D.C. Rogers, DCR-431. ***Dendrocephalus argentinus*** Pereira & Belk, 1987. Argentina. La Rioja, two males, two females, brick materials pit at the edge of Mazán, 1 December 1993, A.C. Hulse coll., DCR-323. ***Dendrocephalus brasiliensis*** Pesta, 1921. Brazil. Minas Gerais: 8 males, 8 females, Gorutuba, from the CODEVASF fishponds, 1998, A.O. Ferreira coll., det. D.C. Rogers, DCR-282. ***Dendrocephalus carajaensis*** Rogers, Gomes & Vieira, 2012. Brazil. Pará: 49 females, 29 males, Canaã dos Carajás, Serra Sul, Carajás region, temporary pool, 06°24'12.58"S 50°18'36.40"W, 10 November 2008, F. Vieira & J.P.C. Gomes coll., Coleções Taxonômicas da Universidade Federal de Minas Gerais UFMG-0001, 0002. ***Dendrocephalus cervicornis*** (Weltner, 1890). Argentina, Rio Negro: six males, five females, roadside ditch on south side of Highway 22, 11 February 1987, K.A.L. Reading coll., gift of D. Belk (DB-775), DCR-62. ***Dendrocephalus geayi*** Daday, 1908. Venezuela. Anzoategui: two males, two females, May 1979, G. Pereira and Martínez coll., gift to D. Belk (DB-544); gift to D.C. Rogers, DCR-432. ***Dendrocephalus goiasensis*** Rabet & Thiéry, 1996. Brazil. Goiás (paratypes): one male, one female, Jaciara, 16 January 1989, W. Costa and J.C. Oliveira coll., gift of N. Rabet, DCR-442. ***Dendrocephalus orientalis*** Rabet & Thiéry, 1996. Brazil. Paraíba (paratypes): 2 males, 2 females, Cabo Branco, Mare #3, 20 July 1993, gift of N. Rabet, DCR-437. ***Dendrocephalus spartaenovae*** Margalef, 1961. Aruba. 81 males, 96 females, gravel pit ponds 4 and 5 south of Boton, 4 March 1989, K.A.L. Reading coll., DCR-318. ***Dendrocephalus venezolanus*** Pereira, 1984. Colombia. 4 males, 2 females, near the village of San Juan de Arama, close to the northeast and the northern point of the Macarena Mountain Range, 3°26'N 73°45'W, 400 m elevation, 1995, E. Roessler coll., DCR-322.

Systematics

***Dendrocephalus riograndensis* n. sp.**

(Figs. 1–2)

Type material. Holotype, male: Brazil. Rio Grande do Sul: Santa Vitória do Palmar, temporary pool, close to Mirim Lagoon, 32°46'41.5"S 52°40'26.6"W, 10 m elevation, 3 November 2015, M.V. Volcan & A.C. Gonçalves, MCP 3144. Allotype: female, same data as holotype, MCP 3145. Paratypes: 6 females, 6 males, same data as holotype, MCP 3146.

Type locality. (Fig. 2G) The site is located in the Coastal Plain of Rio Grande do Sul, the southernmost state of Brazil, and in the Pampa Biome (IBGE, 2004). This region is dominated by grasslands in flat terrain (IBGE, 2004). The hydrography is represented by the Patos-Mirim Lagoon system, Laguna dos Patos Ecoregion, lying across southern Brazil and eastern Uruguay (Abell *et al.*, 2008).

This area is subtropical, with an average temperature of 13°C in the coldest months (June and July) and above 22°C in the warmest months (January and February). The average annual rainfall (1200–1500 mm) is uniform in all seasons, but varies greatly in different years (Nobre *et al.*, 1986).

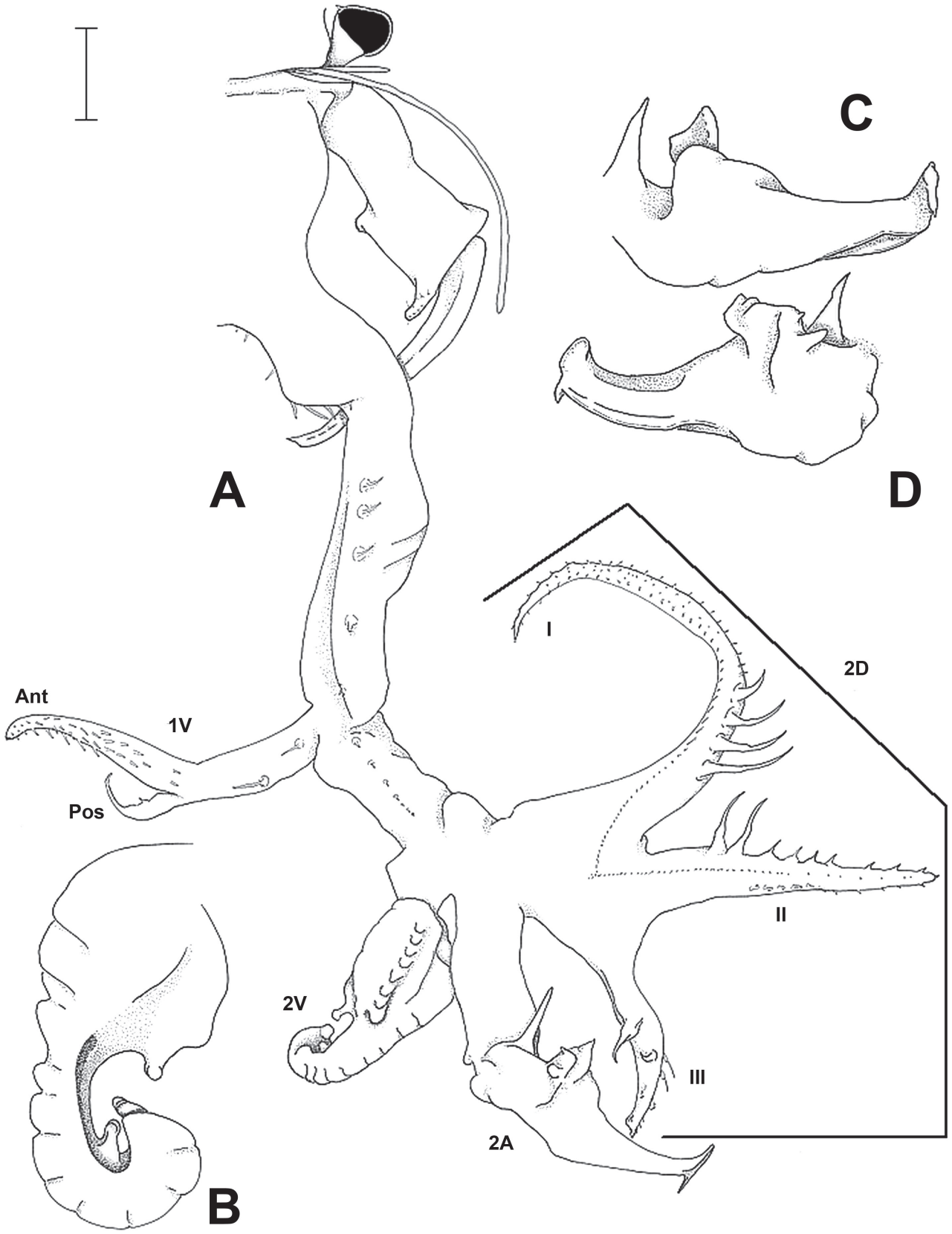

Figure 1. *Dendrocephalus riograndensis* n. sp., male holotype (MCP 3144): A) left side of head anterior view, with left half of cephalic appendage, medial view. Terminology follows Pereira (1983): 1V = first ventral branch (with anterior (Ant) and posterior (Pos) sub-branches); 2V = second ventral branch; 2D = dorsal branch (with sub –branches I, II and III); 2A = apical branch. B) 2V detail, lateral view. C) 2A detail, medioposterior view. D) 2A detail, lateral view. Scale bar: A, 2 mm; B–D, 1 mm.

Dendrocephalus riograndensis n. sp. was found in a small (~120 m^2), shallow (< 60 cm depth) temporary pool, exposed to direct sunlight, near the margin of Mirim lagoon. The water tends to be humic. The pool is in a small depression, in grassland areas of private farms. The aquatic vegetation was abundant (especially submerged macrophytes), but *D. riograndensis* n. sp. was only observed in the deepest portions of the pool, where there was no vegetation.

Dendrocephalus riograndensis n. sp. co-occurs with the annual fish *Austrolebias charrua* Costa & Cheffe, 2001; an endangered endemic species in Brazil and Uruguay (Loureiro *et al.*, 2013; MMA, 2014). *Dendrocephalus riograndensis* n. sp. suffers from the same problems that led *A. charrua* to be considered endangered: habitat loss and fragmentation due to their natural habitat converted to rice agriculture.

Etymology. The name "*riograndensis*" refers to the state of Rio Grande do Sul where this species was discovered.

Diagnosis. (Figs. 1, 2A–E) Typical *Dendrocephalus*. Male bearing eye spine; second antenna, proximal antennomere with medial projection, bearing small denticles; frontal appendage bearing several spines along the anterior margin, between primary branches; branch 1V anterior sub-branch acute, posterior sub-branch in subdistal position; branch 2V posterior surface deeply concave, bearing two nearly apical cell pads and one cell pad on medial surface; branch 2D sub-branch I greater than twice the length of sub-branch II; sub-branch I and II with medial longitudinal row of close set, fine spines, joining at branch 2D base; branch 2A apex podiform; thoracopod I with single medial spiniform process; thoracopod I mediodistal corner triangular; thoracopod I proximolateral margin greatly elongated, arcuate, spiniform projection.

Description. Average length of preserved material: 18.6 mm from apex of head to apex of telson (males averaging 18.8, n = 7; females averaging 18.4, n = 7).

Male. (Fig. 1A) Anterolateral corner of head projecting over eyestalk base. Compound eye with posteroventral spine (Figs. 1A, 2A). First antenna filiform, approximately 60% length of second antenna. Antenna like appendage anterobasal to eyestalk, filiform, slightly longer than eyestalk peduncle.

Frontal (cephalic) appendage prominent, typical of genus (Fig. 1A), when expanded reaching thoracomere X or XI. Frontal appendage basal trunk and primary branches anterior margin bearing six spines at bifurcation point, spines increasing in size from proximal to distal. Primary branch from bifurcation to branch 1V base twice as long as trunk, bearing four to six dorsal spines. Primary branch from branch 1V base to branch 2V base approximately one third length of primary branch from bifurcation to branch 1V base, bearing medial, longitudinal row of small spines, decreasing in size distally.

Branch 1V well developed, anterior sub-branch tapering to rounded apex, never tumid (Fig. 1A). Peduncle length 40% anterior sub-branch, bearing two large, dorsal spines proximal to posterior sub-branch. Anterior sub-branch bearing numerous scattered proximally directed spines, distal of posterior sub-branch base. Posterior sub-branch originating midlength, length approximately 20% anterior sub-branch, bearing one subproximal spine.

Branch 2V thick, flattened, with numerous semiannulations (Figs. 1A, B). Apex subcoiled posteriorly, bearing one apical and one subapical "knob structure" (Pereira, 1983) or "cell pad" (Margalef, 1961), with similar structure projecting distally from posterior surface, nearly in contact with apex. Medial margin bearing longitudinal row of projecting smooth lobes.

Branch 2D base broadly triangular (Fig. 1A). Sub-branch I length subequal to primary branch from bifurcation to branch 1V, subcylindrical basally, tapering to acute apex. Sub-branch I anterior surface with longitudinal row of four large, long, recurved spines. Sub-branch I medial surface with longitudinal row of small, close set spines, extending from branch 2D base, to sub-branch I apex. Sub-branch I distal 50% covered in small scattered spines; apex tipped with single small spine. Sub-branch II length approximately 50% of sub-branch I, tapering to rounded apex. Sub-branch II posterior surface with longitudinal spine row, with proximal first two spines three to four times size and length of remaining spines. Sub-branch II medial surface with longitudinal row of small, close set spines, extending from branch 2D base, joining small spine row from sub-branch I, extending to sub-

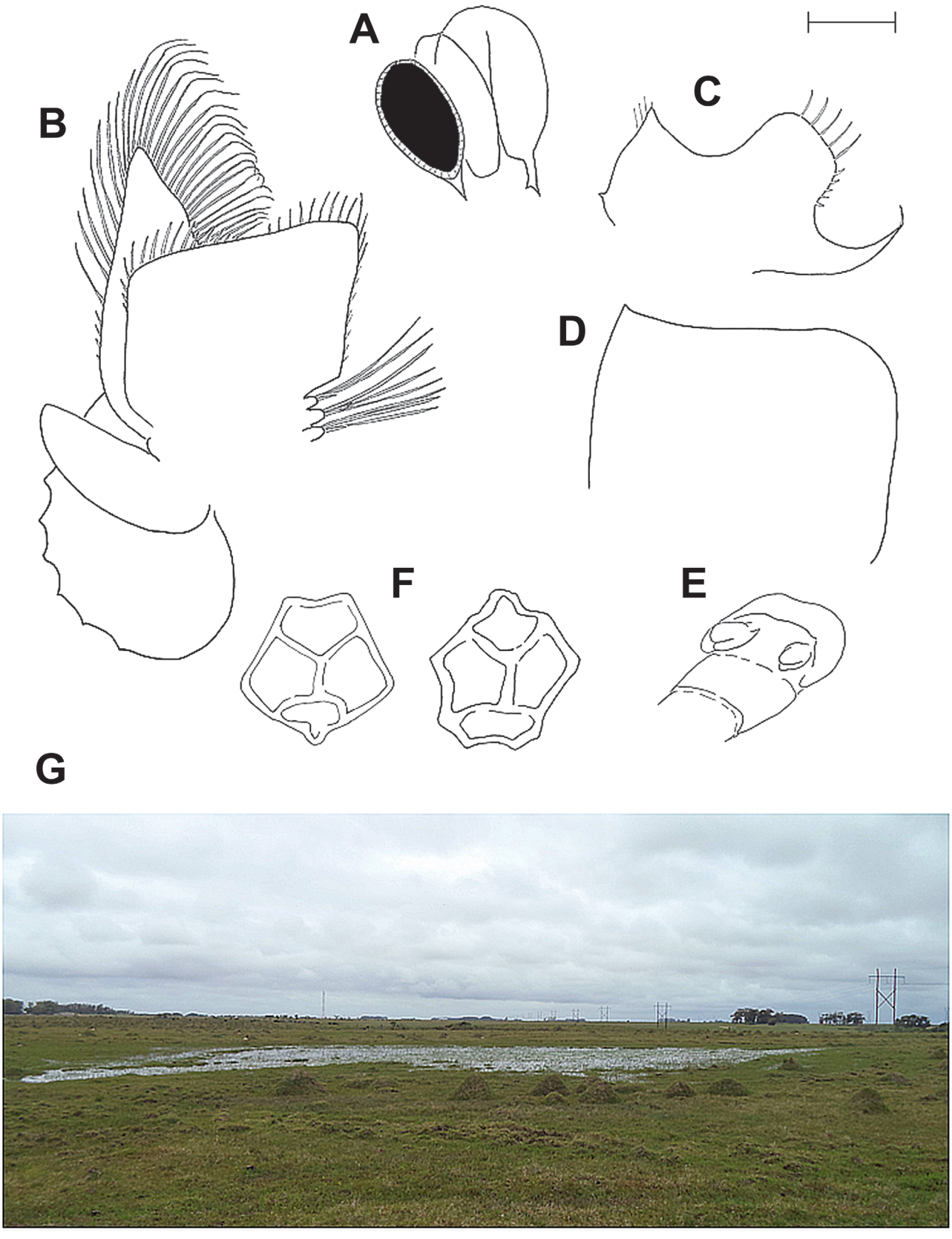

Figure 2. *Dendrocephalus riograndensis* n. sp., male holotype (MCP 3144): A) Left eye, mandible, and maxillary gland, lateral view. B) Right thoracopod V, anterior view. C) Right thoracopod I endopodite, anterior view. D) Right thoracopod II endopodite, anterior view (spines and setae not shown). E) Genital segments, posterolateral view. F) Eggs. G) View of the type locality, temporary pool close to Mirim Lagoon, Santa Vitória do Palmar, Rio Grande do Sul, Brazil. Scale bar: A–D, 2 mm; E, 3 mm; F, 200 μm.

branch II apex. Sub-branch II anteriomedial surface with longitudinal row of spines. Sub-branch III with two large basomedial spines, proximal spine twice as large as distal spine. Sub-branch III posterior surface with longitudinal spine row on distal 50%. Sub-branch III apex asymmetrical, subtruncate to subangular.

Branch 2A basal 50% cylindrical, inerm (Figs. 1A–D). Apical portion with large, proximodorsal, triangular spine, apically acute. Distal to proximodorsal spine lies transverse ridge, becoming lamellar laterally. Basal cell pad lacking. Distal portion arcuate, directed medially, apex flattened, podiform, with ventral spine. Apical margin truncate.

Second antenna (Fig. 1A) extending to thoracomere I or II. Proximal antennomere subcylindrical, posteromedial surface with rounded projection midlength. Posteromedial projection bearing small denticles, distal side sloping towards antennomere medial apex. Distomedial margin lobiform, projecting over distal antennomere base, bearing numerous denticles and scattered small setae. Distolateral margin angular, projecting slightly. Distal antennomere subequal in length to proximal antennomere; anterioposteriorly flattened, arcing gently medially approximately 20˚. Apex asymmetrical, with dorsal corner acute, ventral corner rounded.

Labrum smooth. Maxillae lobiform and transverse, no setae visible. Maxillary gland with long ventral spine, occasionally with single subdistal spinule (Fig. 2A).

Thoracopod I endopod (Fig. 2C) bearing single small, medial, spiniform projection. Distomedial corner triangular, bearing few filiform setae on medial margin. Distal margin deeply and broadly emarginate. Distolateral corner broadly subquadrate, lobiform, bearing distal, marginal row of four or five long spines, each separated by approximately one fourth their length, lateral margin with row of four or five short, stout spines. Proximolateral corner produced as elongated, spiniform projection, curving ventrally, apex with stout spine.

Thoracopod II endopod (Fig. 2D) broadly quadrate, lacking spines or setae. Distomedial corner acute, slightly produced distally. Distolateral corner broadly rounded.

Thoracopods III through XI serially homologous. Thoracopod V (Fig. 2B) endites lobiform, tipped with elongate, plumose setae. Endopod subquadrate, distomedial corner produced, medial margin bearing row of short spiniform setae, distal margins with short plumose setae. Exopod ovate, margined with plumose setae, distomedial setae geniculate, with distal portions filiform and plumose. Epipodite elliptic and without marginal setae. Praepipodite broadly oval, lamellar, crenulate, without setae.

Genital segments smooth (Fig. 2E). Retracted gonopod as for genus. Gonopod posteromedial surface with pyriform projection. Everted gonopods typical for genus.

Female. As typical for the genus. Head rounded, anterolateral corners not projecting over eyestalk base. First antenna 1.3 times length of second antenna. Second antenna broadly elliptic, lamellar. Thorax smooth. Thoracopods as in male, except first three thoracopods with endopodites not modified. Thoracopod XI with exopodite narrowly elliptic, curving dorsally, and margined with plumose setae. Brood pouch fusiform, extending to distal margin of postgenital abdominal segment IV.

Egg. (Fig. 2F) Subspherical, diameter approximately 250 μm, with broad pentagonal or quadragonal facies, each face diameter approximately 60 μm.

Distribution and habitat. To date, *D. riograndensis* n. sp. is known only from the type locality (Fig. 2G). The vicinity is primarily rice farming, which has resulted in the loss and degradation of most temporary wetlands in southern Brazil (Volcan *et al.*, 2015). The type locality of *D. riograndensis* n. sp. is an 'island' in the middle of rice agriculture. The site is located on a private farm that cultivates rice and cattle. The type locality is not protected, but due to the high concentration of temporary pools in the region, this species may occur at Taim ecological station (about 15 km to the north), a federal conservation unit. Presently, this species meets the criteria under the IUCN Red List (IUCN, 2001) as Critically Endangered (CR), with the area of occupancy less than 10 km^2, known only to exist at a single site (B2), and projected decline in extent of occurrence, occupancy and quality of habitat (ab).

Discussion

Male *D. riograndensis* n. sp. is separated from all other reported *Dendrocephalus* species by the form

of the second antennae, the frontal appendage and the thoracopod I endopods. In the key provided by Chaves *et al.* (2011) *D. riograndensis* n. sp. would key to *D. goiasensis*. The two species are remarkably similar, sharing a basically similar frontal appendage. However, they differ in the form of branch 2V, which bears four apical cell pads and three medial cell pads in *D. goiasensis*, but only two apical and one medial cell pad in *D. riograndensis* n. sp. Branch 2D in *D. goiasensis* has a single row of large spines on the medial surface of sub-branch I and sub-branch III has two basal spines opposite each other, with two apical and one subapical spine, whereas *D. riograndensis* n. sp. has the distal portion of sub-branch I covered in small spines, the medial surface spine row is composed of numerous small spinules, and sub-branch III has the two proximal spines next to each other and the posterior surface has a row of spines. Branch 2A has two cell pads and the proximal spine is arcuate and curved 90° in *D. goiasensis*, but there are no cell pads and the spine is straight and triangular in *D. riograndensis* n. sp.

The second antenna proximal antennomere of *D. goiasensis* lacks the posteriomedial projection that is so prominent in *D. riograndensis* n. sp. Finally, in *D. goiasensis* endopod I and II both are rectangular with a prominent lateral, multiramal projection, the distolateral corner bears a row of short, conical spines, and the distal margin is straight. In *D. riograndensis* n. sp. endopod I has the lateral projection is shaped like a long hook, the distolateral corner is produced, subquadrate, margined with long spines, the distal margin is sinuate, and the distomedial corner is triangular and acute, whereas endopod II is subquadrate and lacks setae or spines. No diagnostic characteristics were present in the female.

Six *Dendrocephalus* species have been previously reported from Brazil: *D. brasiliensis*, *D. orientalis*, *D. goiasensis*, *Dendrocephalus thieryi* Rabet, 2006, *D. carajaensis*, and an undescribed species (Rabet and Thiéry, 1996; Rabet, 2006; Chaves *et al.*, 2011; Rogers *et al.*, 2012). Our new species increases that number to seven, and is the southernmost record of the genus in Brazil. Rabet and Thiéry (1996), Rabet (2006), Chaves *et al.* (2011) each provided a key to the *Dendrocephalus* species for Brazil. Substitution couplets were provided by Rogers *et al.* (2012) to accommodate *D. carajaensis*. However, in order to facilitate identification of *Dendrocephalus sensu stricto* species, we present a key to all currently known species in the subgenus.

Key to the *Dendrocephalus* (*Dendrocephalus*) species

This key is based on males. This key does not include the undescribed species in Chaves *et al.* (2011). This key is only useful for mature males, which can be identified as being slightly larger than those females with mature eggs in the brood pouch.

1 Everted gonopods extending to abdominal segment two or three; gonopods bearing a medial subterminal tubercle and a comb plate; endopodites of first or first and second thoracopods modified, usually with cornified projection that may be spiniform or bearing one or more stout spines; temperate and tropical species ..... *Dendrocephalus sensu stricto* 2

1' Everted gonopods extending to abdominal segment three or four; gonopods with comb plate lacking; first thoracopods not modified; temperate North America ..... subgenus *Dendrocephalinus* Rogers, 2006

2(1) Thoracopod I with endopod subequal in length to thoracopod II endopod 3

2' Thoracopod I with endopod elongate, broadly ovate, two to four times longer than thoracopod II endopod ..... *Dendrocephalus cervicornis* (Weltner, 1890) (*sensu* Pereira, 1983) [Argentina]

3(2) Frontal appendage with branch 2A apex sharply hamulate or podiform 4

3' Frontal appendage with branch 2A apex directed distally, slightly arcuate ..... *Dendrocephalus carajaensis* Rogers, Corrêa & Vieira, 2012 [Brazil]

4(3) Frontal appendage branch 2A sharply hamulate, apex bent 45° or greater 5

4' Frontal appendage branch 2A podiform 8

5(4) Thoracopod I without a basolateral lobe or spiniform projection 6

5' Thoracopod I without a basolateral lobe ..... *Dendrocephalus orientalis* Rabet & Thiéry, 1996 [Brazil]
6(5) Frontal appendage branch 2A with apex curving 7
6' Frontal appendage branch 2A with apex bent at sharp 45° angle; thoracopod I and II endopod each with an inerm basolateral spiniform projection ..... *Dendrocephalus venezolanus* Pereira, 1984 [Venezuela]
7(6) Frontal appendage branch 2D with all three sub-branches subequal in length; sub-branches I and II each with a proximal row of elongated spines, each four to six times longer than remaining spines ..... *Dendrocephalus argentinus* Pereira & Belk, 1987 [Argentina, Paraguay]
7' Frontal appendage branch 2D with all sub-branch II less than one third the length of sub-branch II and III; sub-branches I and II with all spines subequal in length ..... *Dendrocephalus geayi* Daday, 1908 (*sensu* Pereira, 1983) [Venezuela]
8(4) Thoracopod I endopod lacking a basolateral spiniform process 9
8' Thoracopod I endopod with a basolateral spiniform process 10
9(8) Thoracopod I endopod similar to thoracopod II - V endopods, unmodified; frontal appendage branch 1V with anterior sub-branch distally tumid ..... *Dendrocephalus brasiliensis* Pesta, 1921 (*sensu* Rabet & Thiérry, 1996) [Brazil]
9' Thoracopod I – III with endopod modified, dissimilar to thoracopod V endopod; frontal appendage branch 1V with anterior sub-branch distally tapering ..... *Dendrocephalus sarmentosus* Periera & Belk, 1987 [Galapagos Islands]
10(8) Frontal appendage branch 1V with anterior sub-branch distal portion tumid 11
10' Frontal appendage branch 1V with anterior sub-branch distal portion tapering 13
11(10) Thoracopod II endopod distolateral corner projecting beyond endopod distal margin 12
11' Thoracopod II endopod distolateral corner rounded, bearing a few spines, but never projecting beyond endopod distal margin ..... *Dendrocephalus cornutus* Pereira & Belk, 1987 [Costa Rica]
12(11) Thoracopod I, II and III with endopod distolateral corner lobiform, projecting distolaterally well beyond the endopod distal margin; thoracopod I, II and III with endopod bearing a basolateral projection, bearing spines ..... *Dendrocephalus affinis* Pereira, 1984 [Venezuela]
12' Thoracopod II and III only with endopod distolateral corner lobiform, projecting distolaterally beyond the endopod distal margin; thoracopod I with endopod bearing a basolateral projection bearing spines, thoracopod II with endopod bearing a basolateral spiniform inerm projection, thoracopod III endopod lacking a basolateral projection ..... *Dendrocephalus thieryi* Rabet, 2006 [Brazil]
13(10) Thoracopod I (or I through III) endopod with basolateral spiniform projection inerm 14
13' Thoracopod I and II endopod with basolateral spiniform projection with two to four spines ..... *Dendrocephalus goiasensis* Rabet & Thiéry, 1996 [Brazil]
14(13) Thoracopod I endopod with basolateral spiniform projection, thoracopods II and III with endopod lacking a basolateral projection 15
14' Thoracopods I through III with endopod bearing a basolateral spiniform projection ..... *Dendrocephalus spartaenovae* Margalef, 1961 (*sensu* Pereira, 1983) [Venezuela]
15(14) Frontal appendage branch 2V with apex directed distally ..... *Dendrocephalus conosuris* Pereira & Ruiz, 1995 [Argentina]
15' Frontal appendage branch 2V with apex coiled ..... *Dendrocephalus riograndensis* n. sp. [Brazil]

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