

A new genus for seven Brazilian land planarian species, split off from *Notogynaphallia* (Platyhelminthes, Tricladida)

Fernando Carbayo

Escola de Artes, Ciências e Humanidades Universidade de São Paulo Av. Arlindo Bettio, 1000, São Paulo/SP. 03828-000 Brazil

Corresponding author: Fernando Carbayo; e-mail: baz@usp.br

ABSTRACT. Special attention is given to cephalic structures of a species complex within the *Notogynaphallia* (Platyhelminthes, Tricladida). *Notogynaphallia muelleri* is redescribed. The species possesses a cephalic musculo-glandular organ. Its glandular and muscular organization are similar to that previously observed in *N. caissara* and *N. fita* and to that herein described for *N. abundans*, *N. ceciliae*, *N. ernesti*, and *N. graffi*. Based on these unique cephalic specializations, a new genus is proposed for these seven species. Functionally, the musculo-glandular organ may be an adaptation for capturing and holding prey.

KEY WORDS: *Luteostriata* gen. nov., *Luteostriata muelleri*, cephalic retractor muscle, mesenchymal musculature, Geoplaninae, Terricola.

INTRODUCTION

In recent years, the taxonomic status of some species of *Notogynaphallia* Ogren & Kawakatsu, 1990 (Geoplaninae, Tricladida) has been discussed. The genus does not present unique characteristics, but a combination of features that are also shared with other genera of the subfamily. Indeed, LEAL-ZANCHET & FROEHLICH (2001, 2006) and FROEHLICH & LEAL-ZANCHET (2003) suggested a heterogeneous status for the genus based on certain characteristics of the reproductive organs. They also subdivided the genus into two non-formal groups according to similarities in external and internal features. One of these groups, the so-called group 2, includes *N. abundans* (Graff, 1899), *N. caissara* (Froehlich, 1955), *N. ceciliae* Froehlich & Leal-Zanchet, 2003, *N. ernesti* Leal-Zanchet & Froehlich, 2006, *N. fita* (Froehlich, 1959), *N. graffi* Leal-Zanchet & Froehlich, 2006, and *N. muelleri* (Diesing, 1861), in addition to *N. guaiana* Leal-Zanchet & Carbayo, 2001, which stands apart from the others because of the dorsal color pattern and the epithelium lining the female atrium (LEAL-ZANCHET & FROEHLICH, 2006). More recently, *N. arturi* Lemos & Leal-Zanchet, 2008 and *N. pseudoceciliae* Lemos & Leal-Zanchet, 2008 were added to this species complex.

The necessity of giving attention to the cephalic region of geoplaninid land planarians has been stressed (CARBAYO & LEAL-ZANCHET, 2003). The finding of a cephalic musculo-glandular organ in *N. caissara* and *N. fita* once again pointed to the heterogeneity of the genus *Notogynaphallia* (CARBAYO, 2006).

In the present study, we examine the cephalic region of *N. muelleri*, *N. abundans*, *N. ceciliae*, *N. ernesti*, and *N. graffi*. *Notogynaphallia guaiana* was not studied because this species does not possess cephalic musculo-glandular organs and presents a highly-developed longitudinal mesenchymal muscle system (pers. obs.). *Notogynaphallia arturi* Lemos

& Leal-Zanchet, 2008 and *N. pseudoceciliae* Lemos & Leal-Zanchet, 2008 do fit into group 2, but are not included because the material was not available for the present study.

MATERIALS AND METHODS

Specimens studied are deposited in the MZU (Museu de Zoologia da Unisinos, São Leopoldo, Rio Grande do Sul, Brazil), IPP (Instituto de Pesquisas de Planárias, Unisinos), FCB (F. Carbayo's collection, Universidade de São Paulo), and EMF (E. M. Froehlich's collection, Universidade de São Paulo). Specimens of EMF's collection histologically-processed elsewhere were assigned additional identification numbers. When possible, the external morphology was observed before and after fixation. Tissue blocks of specimens were processed following CARBAYO (2006), and sectioned at 6-8 μ m. The relationship between the height of sub-epidermal musculature and the height of the body (CMI = mc:h) was calculated after FROEHLICH (1955a). Drawings were prepared using a camera lucida.

RESULTS

TAXONOMIC SECTION

Family Geoplanidae Stimpson, 1857

Subfamily Geoplaninae Stimpson, 1857

Luteostriata gen. nov.

Diagnosis. Body slender, with parallel margins, anteriorly slightly rounded. Sensory pits in the shape of a simple invagination, encircling the cephalic end. Eyes encircling anterior end of the body. Cephalic musculo-glandular organ

present; the cephalic glands of the organ open onto a U-shaped surface at the ventral region of the cephalic region; retractor muscles of the organ mainly formed by the ventral longitudinal sub-epidermal musculature. Bundle of retractor muscles lens-shaped in cross-section; muscle fibers sunken into the mesenchyma near the anterior end of the body; part of these muscles laterally traverses to the opposite side before attaching to the basement membrane. Transverse mesenchymal sub-neural muscle layer present throughout the body. Testes under the supra-intestinal mesenchymal muscle layer. Penial papilla absent. Common glandular ovovitelline duct run backwards, dorsal to the female atrium.

Type species. *Geoplana elegans* Diesing, 1861, here designated, following recommendation 69A of the CINZ (2000), since the species is herein redescribed and illustrated in detail, in addition to being common in urban areas in Blumenau, Brazil, the place of origin of the first specimens studied by Fritz Müller.

Etymology. The generic epithet refers to the yellowish, often yellow-orange (*luteus*) color of the dorsum with dark longitudinal stripes (*striatus*). The gender is female.

***Luteostriata muelleri* (Diesing, 1861) comb. nov.**

Figs 1-9

Geoplana pallida n. sp. Schultze & Müller, 1857: 24

Geoplana mulleri nom. nov. Diesing, 1861: 511

Planaria elegans: Diesing, 1861: 511

See complete synonymies in Ogren & Kawakatsu, 1990

Diagnosis. Dorsal surface with a median, longitudinal black stripe; often an additional lateral ferruginous stripe on each side. Prostatic vesicle elongated, non-bifurcated.

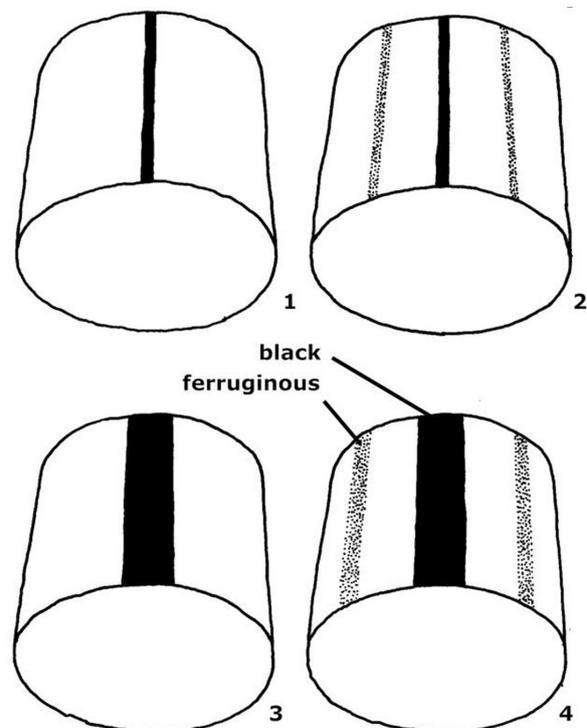
Distribution. Penha, Navegantes, Cabeçudas, Itajaí, Pomerode, Blumenau, Brusque (state of Santa Catarina, SC).

Material examined. EMF=IPP Nr. 1267: Blumenau (SC), 10/VII/1966. Anterior region 1: transverse sections on 10 slides; anterior region 2: sagittal sections on 21 slides; prepharyngeal region: transverse sections on 6 slides; pharynx and copulatory apparatus: sagittal sections on 19 slides. EMF=IPP Nr. 1521: Parque Morumbi, São Paulo (SP), 3/VII/1985, O. Françoso, leg. Anterior region 1: transverse sections on 9 slides; copulatory apparatus: sagittal sections on 16 slides. FCB F0072: Cabeçudas (SC), 20/II/2002, F. Carbayo, col. Anterior region 1: sagittal sections on 3 slides. FCB F0079: Navegantes (SC), 21/II/2002, F. Carbayo, col. Preserved in ethanol 70%. FCB F0086: Blumenau (SC), 22/II/2002, F. Carbayo, col. Copulatory apparatus: sagittal sections on 13 slides. EMF=IPP Nr. 1420: Cabeçudas (SC), 20/II/2002, Rejane dos A. de Castro, leg. Anterior region 1: transverse sections on 16 slides; copulatory apparatus: sagittal sections on 17 slides. EMF Nr. 192=IPP Nr. 1311: Blumenau (SC), 02/VII/1953. Anterior region 1: sagittal sections on 6 slides; anterior region 2: sagittal sections on 8 slides; anterior region 3: sagittal sections on 7 slides; pre-

pharyngeal region: transverse sections on 4 slides; pharynx: sagittal sections on 5 slides; copulatory apparatus: horizontal sections on 10 slides. EMF (=FCB F1006): Blumenau (SC), 17.VII.1966. Anterior region 1: horizontal sections on 3 slides.

External morphology of fixed specimens. *Luteostriata* species of 90 mm in maximum length (Table 1). Body slender (relationship of width: length is 3.6-6.7%); parallel margins; anterior extremity rounded, posterior pointed. Body elliptical in cross-section. Background color of the dorsal surface yellowish with one or three longitudinal stripes arranged in one of the following four color patterns: (a) a median black stripe 1/20th of body width (specimens from Itajaí, Fig. 1); (b) a median black stripe 1/20th of body width, and two lateral ferruginous stripes (specimens from Blumenau, Cabeçudas, Navegantes and Pomerode, Fig. 2); (c) one median black stripe 1/5th of body width (specimens from Brusque, Fig. 3); (d) one median black stripe 1/5th of body width and two lateral ferruginous stripes (specimens from Blumenau, Fig. 4).

Ventral side whitish with the surface of the cephalic glandular area (see below) being slightly darker. The eyes are monolobated, 30-40 µm in diameter, not set in pigment-free areas (halos), encircling the cephalic region. At 8 mm from anterior end of the body, the eye cups extend dorsally as a lateral band being 22% of the body width. Posteriorly this band narrows progressively and is located only at the margin of the body. Sensory pits are simple 28-30 µm deep invaginations; they encircle ventrally the entire cephalic region



Figs 1-4. – *Luteostriata muelleri*. Diagrammatic color pattern of animals from (1) Itajaí, (2) Blumenau and Pomerode, (3) Brusque, and (4) Blumenau.

and extend posteriorly to a distance equivalent to 16% of body length. The width of the creeping sole is 71%-89% of that of the body in the pre-pharyngeal region. Towards the anterior tip, the creeping sole narrows considerably more than the body and disappears close to the tip. Distance of mouth from anterior tip equivalent to 54-72% of the body length; the gonopore, 70-83%.

TABLE 1

Measurements (in mm) of specimens of *Luteostriata muelleri* (Diesing, 1861) comb. nov., living and fixed.

Specimen	IPP Nr. 1267	IPP Nr. 1311	IPP Nr. 1420
Maximum length crawling	?	?	100
Maximum width crawling	?	?	3
Length at rest	?	?	78
Width at rest	?	?	4
L (length after fixation)	49	35	90
W (width after fixation)	2.22	1.71	3.21
height	0.87	0.80	1.46
ratio W : L	4.5%	4.9%	3.6%
M (mouth – anterior body tip)	33.2	20	54
ratio M : L	67.7%	57.1%	54.0%
G (gonopore – anterior body tip)	40.8	26	69.9
ratio G : L	83.3%	74.3%	69.9%

Epidermis and sub-epidermal secretions. The epidermis is ciliated only on the creeping sole. Three types of secretory cells open onto the entire cephalic region: first, cells with fine erythrophilic granular secretions, second, cells with amorphous cyanophilic secretions, and a third type with amorphous xanthophilic secretions (when stained with Cason; also coarse weak cyanophilic granules and erythrophilic cytoplasm when treated with Masson/Goldner stain). Xanthophilic secretions are abundant in the ventral region, constituting the cephalic glands of the musculo-glandular organ. The surface of the epithelium penetrated by the cephalic glands is U-shaped and ca. 3 mm in length (specimen EMF=IPP Nr. 1267). The epithelium traversed by the cephalic glands is 80 μ m in height, and that of the adjacent creeping sole is 50 μ m high. The ducts of the xanthophilic cells run parallel together in bundles. Their cell bodies are located at least 5 mm behind the anterior end of the body.

Three types of secretory cells open onto the epidermis of the pre-pharyngeal region: cells with erythrophilic granules,

cells with cyanophilic granules, and rhabditogen cells. All of these cells increase in number in the dorso-lateral epidermis. Secretory cells with xanthophilic granules also open onto the lateral epidermis. Glandular margin absent.

Cephalic musculature. At approximately 2.5 mm from the anterior end of the body, the longitudinal muscle fibers of the ventral sub-epidermal musculature concentrate progressively in the median region, thus forming a bundle of cephalic retractor muscles, lens-shaped in cross-section. At ca. 2 mm from anterior end of the body, bundles of 2-7 fibers detach from the retractor and continue forwards obliquely to the dorsal surface and the body margins. Subsequently, these bundles separate into single fibers before each fiber attaches to the basement membrane. Some of these fibers traverse to the opposite side of the body before attaching to the basement membrane (Fig. 5).

The large number of secretory cells hampers clear visualization of this mesenchymal muscle system. The most likely muscular organization of the cephalic end is as follows: The most abundant mesenchymal muscle fibers are dorso-ventral, oblique, running from marginal epidermis to that part of the epidermis traversed by the openings of cephalic glands. Other mesenchymal fibers are arranged in four weak layers: a diagonal, a supra-intestinal, a sub-intestinal, and a sub-neural layer (= under the ventral nerve plate), the latter being the most conspicuous one. At the anterior tip of the body, fibers of this layer anchor onto the basement membrane of the lateral epidermis and onto that of the ventral side.

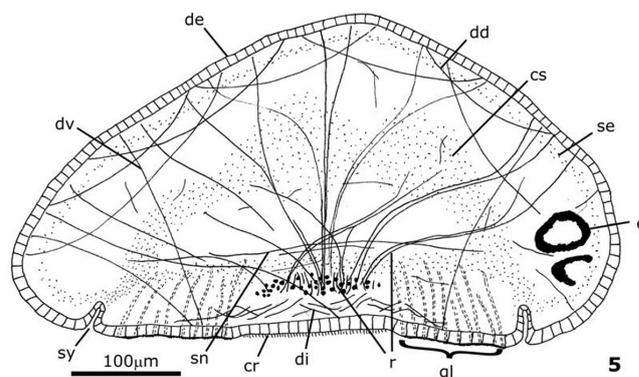


Fig. 5. – *Luteostriata muelleri* (Diesing, 1861) comb. nov. Diagrammatic transverse reconstruction of cephalic region of specimen EMF=IPP Nr. 1267 at 0.2 mm from anterior tip of the body.

Sub-epidermal and mesenchymal musculature at the pre-pharyngeal region. The three typical sub-epidermal layers of the Geoplaninae are present: one of circular fibers –thinner towards body sides–, then a double one with diagonal decussate bundles, and then a layer with longitudinal fibers arranged in bundles (Table 2). The latter is 1.1-1.5 times thicker dorsally than ventrally. SMI, 16.3%-18.9%.

The mesenchymal muscle fibers are extended in various directions. Of these, the dorso-ventral ones, which are partially

TABLE 2

Thickness (in μm) of sub-epidermal musculature in the pre-pharyngeal region of *Luteostriata muelleri* (Diesing, 1861) comb. nov. The lowest and highest numbers of muscle fibers per bundle are given in parentheses. SMI refers to sub-epidermal musculature thickness relative to body height.

Specimen	IPP Nr. 1267	IPP Nr. 1311
dorsal circular	3 (1-2)	2.2 (1-2)
dorsal diagonal	6 (2-4)	4.3 (2-4)
dorsal longitudinal	102.9 (50-63)	45.6 (48-53)
dorsal total	111.9	52.2
ventral circular	3 (1-2)	2.2 (1-2)
ventral diagonal	8.8 (2-4)	6.5 (2-4)
ventral longitudinal	67.6 (20-25)	34.8 (21-25)
ventral total	79.4	43.5
SMI	17.1%	18.9%
creeping sole : body width	70.6%	88.9%

joined in bundles, are the most abundant. Other mesenchymal fibers are arranged in four layers (Fig. 6): (1) well-developed dorsal layer with decussate diagonal fibers ($30\ \mu\text{m}$), (2) supra-intestinal ($30\ \mu\text{m}$), (3) sub-intestinal ($12\ \mu\text{m}$, with part of its fibers joined in bundles), and (4) sub-neural (= under the ventral nerve plate, $38\ \mu\text{m}$), with transverse muscle fibers. Towards the anterior end, the layers become thinner and eventually are absent. Mesenchymal longitudinal musculature absent.

Digestive system. Mouth at the end of the first-third of the pharyngeal pocket. Pharynx bell-shaped (Fig. 7), with the dorsal insertion at the level with the mouth, occupying most of the pharyngeal pocket. Esophagus absent. Pharyngeal pocket: musculature composed of a one-fiber-thick sub-epithelial layer with circular fibers. Outer pharyngeal musculature composed of a longitudinal layer ($2\ \mu\text{m}$), followed by a circular one ($20\text{--}25\ \mu\text{m}$) with some intermingled longitudinal fibers at its innermost region. Inner pharyngeal musculature composed of a sub-epithelial circular layer ($12\ \mu\text{m}$) followed by a longitudinal one ($5\ \mu\text{m}$).

Male reproductive system. Testes rounded, approximately $250\ \mu\text{m}$ in diameter, dorsal in position, located under the supra-intestinal muscle layer and between the intestinal branches (Fig. 6). Testis follicles are arranged in one irregular row on each side of the body, extending from the ovaries to the pharynx. The most anterior and posterior testes are located at a distance equal to 25% and 66% of body length in relation to anterior end, respectively (specimen EMF=IPP Nr. 1267).

The efferent ducts run between the fibers of the sub-intestinal muscle layer or just above this layer. These ducts recurve before opening laterally into the anterior region of the prostatic vesicle (Figs 8-9). The prostatic vesicle is an elongated sinuous ($\sim 10\ \text{x}$ as long as wide) and non-bifurcated cavity with folded walls. The distal portion of the prostatic vesicle penetrates the common muscle coat and the penis bulb and continues as an ejaculatory duct. The latter opens into the anterior region of the male atrium, which is an irregularly folded cavity. In specimen EMF=IPP Nr. 1267, there is a penis-shaped fold in the anterior region of the atrium (asterisk in Fig. 9).

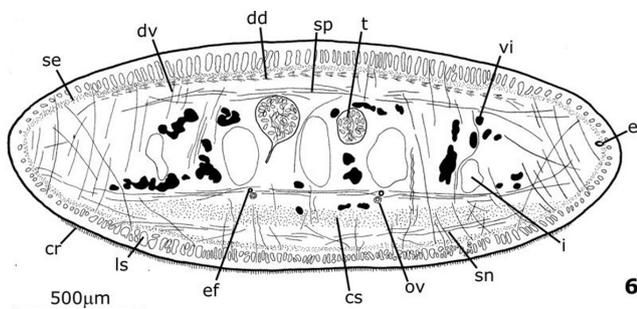


Fig. 6. – *Luteostriata muelleri*. Diagrammatic transverse section of pre-pharyngeal region of specimen EMF=IPP Nr. 1267.

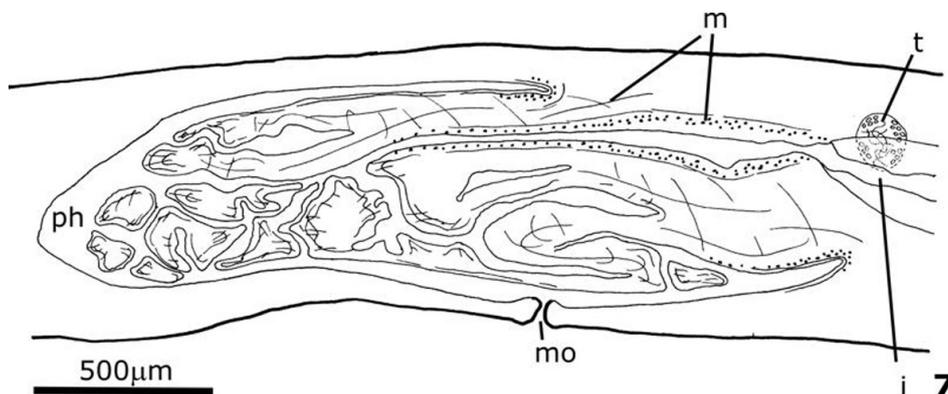


Fig. 7. – *Luteostriata muelleri*. Drawing of a sagittal section of the pharynx of specimen EMF Nr. 192=IPP Nr. 1311.

The efferent ducts are lined with a ciliated, cuboidal epithelium. The distal portion of these ducts receives erythrophilic granular secretions. The ducts are surrounded by circular muscle fibers (10 μm). The prostatic vesicle is composed of a columnar ciliated epithelium that becomes cuboidal at its distal portion. Two types of secretory cells traverse the epithelium of the prostatic vesicle: a type with erythrophilic granules, and another type with xanthophilic granules that is most abundant proximally and scarce distally. The prostatic vesicle is surrounded by circular muscle fibers (37 μm). The ejaculatory duct has a cuboidal, ciliated epithelium, and is surrounded by a layer of circular muscle fibers (6 μm). The male atrium has a columnar, non-ciliated epithelium, the proximal half of which is apically lobed. Epithelium of the ventral side of the atrium erythrophilic. Cyanophilic granular secretory cells and erythrophilic granular secretory cells open through the entire epithelium of the atrium. The musculature of the atrium consists of a sub-epithelial layer with circular fibers (5-15 μm ; thinner proximally) followed by a thin layer with longitudinal fibers (5 μm). In the posterior region of the atrium, the fibers of these layers are partially intermingled.

Female reproductive system. Ovaries elongated (600 μm x 100 μm), ventral in position, between the sub-intestinal muscle layer and the ventral nerve plate, lying at a distance of 25% of body length from the anterior body end. The ovo-

vitelline ducts arise from the medium dorsal side of ovaries and run posteriorly between the sub-intestinal muscle layer and the ventral nerve plate. The ducts join dorsally to the female atrium to form a common oviduct (Figs 8-9). The common glandular ovovitelline duct, 5x longer than wide, curves downwards to open into an obliquely-oriented diverticulum (vagina) of the funnel-shaped female atrium. Percentage, length of female atrium: length of male atrium, 15-36%.

The ovovitelline ducts are lined with a ciliated, cuboidal epithelium; shell glands open into the distal portions of the ducts, which are covered with a layer of circular muscle fibers (5 μm). The common glandular ovovitelline duct has a columnar, ciliated epithelium, and is also covered with a layer of circular muscle fibers (4 μm). Diverticulum of the female atrium or vagina lined with columnar epithelium and surrounded by a layer of circular muscle fibers (7 μm). This vagina is penetrated by the openings of granular, erythrophilic glands. Female atrium lined with a non-ciliated columnar epithelium and receiving the openings of erythrophilic granular glands as well as granular cyanophilic ones. Female atrium surrounded by scarce longitudinal muscle fibers that are continuous with the common muscle coat around the entire copulatory complex. This common muscle coat consists of a layer of longitudinal and diagonal fibers, thicker in the region of the male atrium (18 μm) than in the region of the female atrium (8 μm) (Figs 8-9).

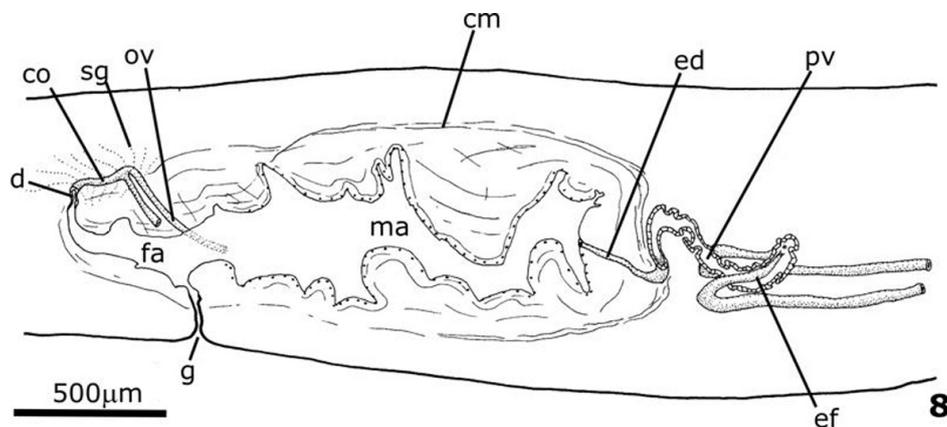


Fig. 8. – *Luteostriata muelleri*. Diagrammatic sagittal reconstruction of the copulatory apparatus of specimen FCB F0086.

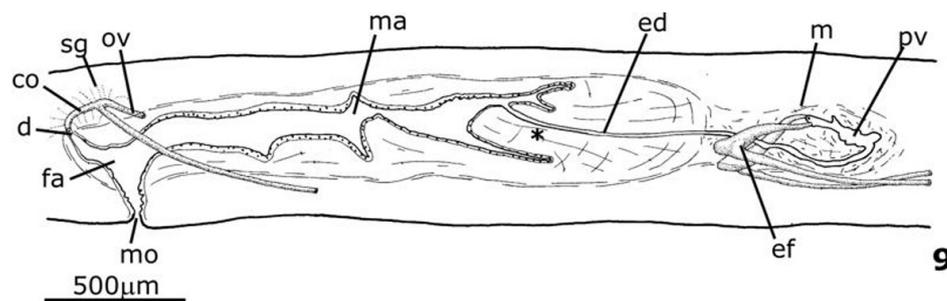


Fig. 9. – *Luteostriata muelleri*. Diagrammatic sagittal reconstruction of the copulatory apparatus of specimen EMF=IPP Nr. 1267. Asterisk indicates a penis-shaped fold in male atrium.

***Luteostriata abundans* (Graff, 1899) comb. nov.**

Figs 10-11

Diagnosis. Dorsal surface with seven black stripes. Prostatic vesicle elongated, non-bifurcated.

Distribution. Nova Petrópolis (new record), Taquara, Parobé (new record), Tupandi, Glorinha, Poço das Antas, São Sebastião do Caí, Campo Bom, Novo Hamburgo, São Leopoldo, Salvador do Sul, Porto Alegre, Barra do Ribeiro (new record) (state of Rio Grande do Sul, RS).

Ecology. Species common in urban environments. In natural forests only seen once by the author (municipality of Barra do Ribeiro, RS). One specimen found in an urban garden in Porto Alegre (RS), 19-V-1999 in a nest of Termitidae, under a fallen log, probably feeding on the termites. Another specimen was found feeding on a woodlouse *Atlantoscia floridana* (van Name, 1940) under wooden boards in a rural environment at Novo Hamburgo (RS), 7-XI-2004.

Material examined. MZU PL. 00061: São Leopoldo (RS), 19/VIII/1997, W. Hilier and L. Dornelles, *leg.* Anterior region 1: transverse sections on 16 slides; anterior region 2: sagittal sections on 16 slides; pre-pharyngeal region: transverse sections on 8 slides; pharynx: sagittal sections on 13 slides; copulatory apparatus: horizontal sections on 37 slides. MZU PL. 00064: Novo Hamburgo (RS), 21/X/1997, M. Cardoso, *leg.* Anterior region 1: sagittal sections on 9 slides; anterior region 2: sagittal sections on 12 slides; anterior region 3: sagittal sections on 17 slides; pre-pharyngeal region: transverse sections on 4 slides; pharynx: sagittal sections on 14 slides; copulatory apparatus: sagittal sections on 14 slides. MZU PL.00068: São Leopoldo (RS), 25/VIII/1998, F. Carbayo and M. Urien Herrero, *leg.* Anterior region 1: sagittal sections on 8 slides; anterior region 2: sagittal sections on 17 slides; anterior region 3: sagittal sections on 8 slides; pre-pharyngeal region: transverse sections on 10 slides; pharynx: sagittal sections on 26 slides; copulatory apparatus: sagittal sections on 49 slides. FCB F0225: Parobé (RS), 27/III/2004, F. Carbayo, *col.* Anterior region 1: horizontal sections on 3 slides. FCB F0372: Taquara (RS), 10/VII/2004, F. Carbayo, *col.* Anterior region 1: sagittal sections on 6 slides. FCB F0391: Nova Petrópolis (RS), 05/VI/2004, F. Megiolaro, *leg.* Anterior region 1: horizontal sections on 3 slides.

Morphological notes. Anterior region of the body ventrally slightly concave, more accentuated when creeping. Sensory pits simple invaginations 15 µm deep, ventrally encircling the entire anterior tip and extending posteriorly until a distance equivalent to 15-20% of body length. Epidermis only ciliated on the creeping sole; the first 4-6 millimeters of the ventral anterior region are laterally gray-yellowish, and slightly protuberant, delimiting the glandular surface of the cephalic glands of the musculo-glandular organ. This epidermis is 20 µm high, while that of the rest of the ventral cephalic region is 13 µm high. The cell glands are of three types: 1) abundant cells with coarse xanthophilic granules, 2), cells with fine erythrophilic

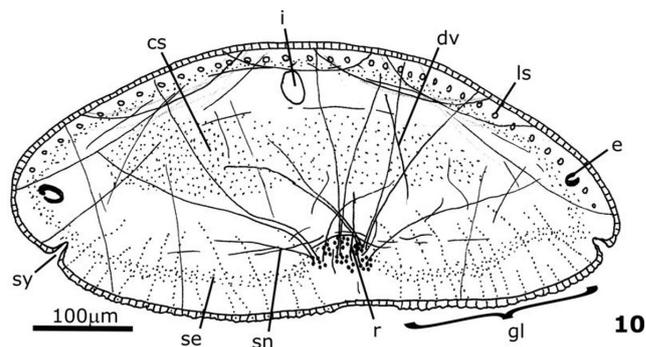


Fig. 10. – *Luteostriata abundans*. Diagrammatic transverse reconstruction of the cephalic region at 0.2 mm from anterior end of specimen MZU PL.00061.

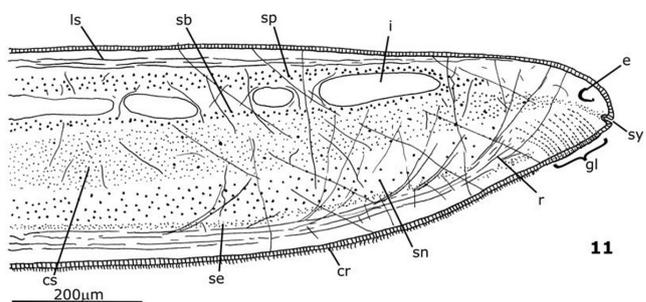


Fig. 11. – *Luteostriata abundans*. Diagrammatic sagittal section of cephalic region of specimen MZU PL.00064.

granules, and 3), scarce, with fine cyanophilic granules. Ducts of erythrophilic cells traverse the epidermis as bundles. At 7-10 mm from the anterior tip, the layer with longitudinal sub-epidermal muscle fibers is ventrally 1.5 to 2.9 times thicker than dorsally. More anteriorly, this muscle layer, already modified as the retractor (Figs 10-11), is 1.7 times thicker. The retractor is similar to that of *L. muelleri*; however, fibers traversing to the opposite side were not found.

***Luteostriata caissara* (Froehlich, 1955) comb. nov**

Diagnosis. Dorsal surface with five evenly-distributed dark longitudinal stripes. Prostatic vesicle elongated, bifurcated, and intricately folded, with bifurcations embracing the pharynx.

Distribution. Teresópolis, Barreira, Gávea Pequena (state of Rio de Janeiro, RJ), Ubatuba, Ribeirão Pires, Itanhaém (state of São Paulo, SP).

Material examined. See CARBAYO (2006). Specimens studied are deposited in the MZU (Museu de Zoologia da

Morphological notes. CARBAYO (2006) incorrectly described the organization of the muscle layers underlying the inner pharyngeal epithelium. The arrangement is as follows: immediately beneath the epithelium lies a layer comprised of circular muscle fibers (30 µm), followed by a layer of longitudinal fibers (10-15 µm).

Luteostriata ceciliae
(Froehlich & Leal-Zanchet, 2003) comb. nov.

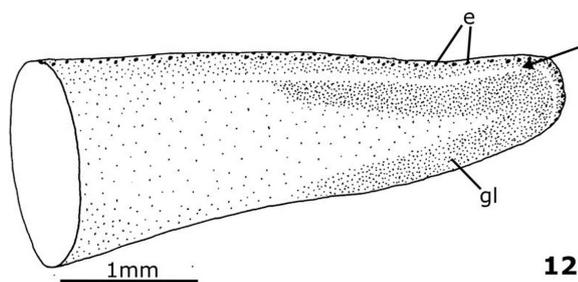
Figs 12-14

Diagnosis. Dorsal surface with five longitudinal black stripes; wide marginal zone without stripes. Efferent ducts branched, each branch opening into the proximal half of the prostatic vesicle, the latter being bifurcated.

Distribution. São Francisco de Paula (state of Rio Grande do Sul, RS).

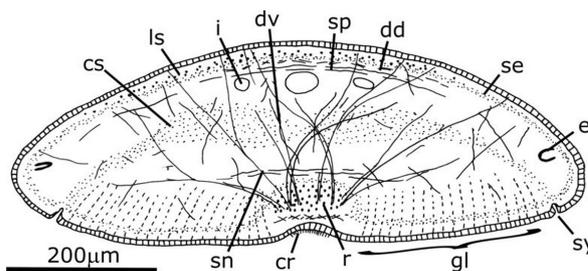
Material examined. São Francisco de Paula. Paratype: MZUSP PL. 151: 25/XI/1998, S.A. Souza, *leg.* Anterior region 1: horizontal sections on 5 slides; anterior region 2: sagittal sections on 18 slides; anterior region 3: sagittal sections on 18 slides; pre-pharyngeal region: transverse sections on 16 slides; pharynx: sagittal sections on 17 slides; copulatory apparatus: sagittal sections on 18 slides. Paratype MZU PL. 00029: 16/XII/1998, M. Cardoso, *leg.* Anterior region 1: transverse sections on 15 slides; anterior region 2: horizontal sections on 4 slides; anterior region 3: sagittal sections 16 slides; pre-pharyngeal region: transverse sections on 7 slides; pharynx: horizontal sections on 6 slides; copulatory apparatus: horizontal sections on 33 slides. Paratype MZU PL. 00027: 8/VI/1998, L. dos Santos Teixeira, *leg.* Anterior region 1: sagittal sections on 7 slides. Paratype MZU PL. 00028: 31/VII/1998, M. Cardoso, *leg.* Anterior region 1: sagittal sections on 9 slides.

Morphological notes. Sensory pits are simple invaginations 20 µm deep; ventrally encircling the entire cephalic region in a single row and extending posteriorly at a distance equivalent to 17% of the body length. Epidermis ciliated only on the creeping sole. Dorsal epidermis 10 µm high, 15 µm on the medio-ventral body region. Epidermis 10, 15 and 22 µm in height on the dorsal, the medio-ventral, and the ventral glandular region of the musculo-glandular organ, respectively. The latter is 2.5-3 mm in length (Fig. 12), and its epidermal glandular surface is orange-brownish and penetrated by the openings of two types of secretory cells: (1) cells with fine erythrophilic granules, and (2) cells with coarse weak cyanophilic granules. The necks of the erythrophilic glands run joined. At 2 mm from the anterior tip of the body, the ventral longitudinal sub-epidermal musculature is modified as a retractor, 1.6 times thicker than at 6 mm



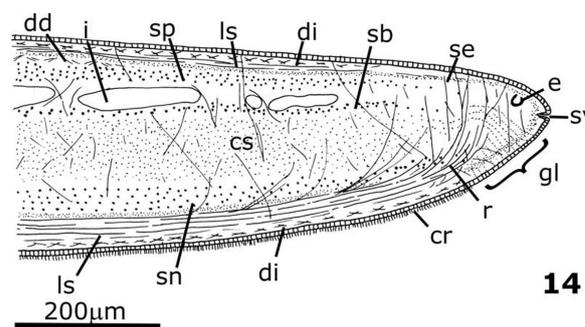
12

Fig. 12. – *Luteostriata ceciliae*. Perspective drawing of the cephalic region of specimen IPP Nr. 346d mainly showing the ventral surface. Arrow indicates sensory border.



13

Fig. 13. – *Luteostriata ceciliae*. Diagrammatic transverse reconstruction of the cephalic region at 0.7 mm from anterior end of specimen MZU PL. 00029.



14

Fig. 14. – *Luteostriata ceciliae*. Diagrammatic sagittal section of cephalic region of specimen MZU PL. 00027.

from the tip (specimen MZU PL. 00029), where it is 30 µm thick. Retractor (Figs 13-14) similar to that of *L. muelleri*.

Luteostriata ernesti
(Leal-Zanchet & Froehlich, 2006) comb. nov.

Figs 15-16

Diagnosis. Dorsal surface with five evenly-distributed longitudinal black stripes, the median one being the thinnest. Prostatic vesicle elongated and non-bifurcated.

Distribution. Pirassununga, Valinhos, Jundiaí, São Paulo, Mogi das Cruzes, Ibiúna, Ribeirão Pires (state of São Paulo, SP), Curitiba (state of Paraná, PR), São Francisco de Paula (state of Rio Grande do Sul, RS).

Material examined. MZUSP PL. 174: São Francisco de Paula (RS), 5/XII/2002, R. A. de Castro, *leg.* Anterior region 1: transverse sections on 4 slides. EMF=IPP Nr. 1289: Ibiúna (SP), 26/VII/1965. Anterior region 1: sagittal sections on 2 slides; copulatory apparatus: sagittal sections on 9 slides. MZU PL.00047: São Francisco de Paula (RS), 25/IX/1998, F. Carbayo, *leg.* Anterior region 1: sagittal sections on 3 slides; pre-pharyngeal region: transverse sections on 9 slides; pharynx: sagittal sections on 13 slides; copulatory apparatus: sagittal sections on 17 slides. EMF Nr. 927: Serra do Japi, Jundiaí (SP), 22/VI/1996, C. F. Rocha, *leg.* Anterior region 1: transverse sections on 5 slides.

Morphological notes. Ventral side concave, more accentuated when creeping. Sensory pits are simple invaginations 20 μm deep, ventrally-encircling the entire cephalic region and extending posteriorly to a distance equivalent to 8% of body length. Epidermis only ciliated on the creeping sole. First 4-6 millimeters of the ventral cephalic tip slightly darker, denoting the glandular region. Epidermis in this region 22 μm high, 7 μm higher than on the remainder of ventral cephalic region. Dorsal epidermis 12 μm high. Cephalic glands of two types: cells with xanthophilic granules, and cells with coarse granules with weak affinity to the cyanophilic stain. Distal portion of xanthophilic cellular ducts run joined in bundles. At 2.5 mm from the anterior tip, ventral layer with sub-epidermal longitudinal muscle fibers is 25 μm thick. At this point, the dorsal sub-epidermal longitudinal layer is 20 μm . More anteriorly, the dorsal layer is modified as the retractor muscle, 25 μm thick (Figs 15-16). Arrangement of its fibers is similar to that in *L. muelleri*.

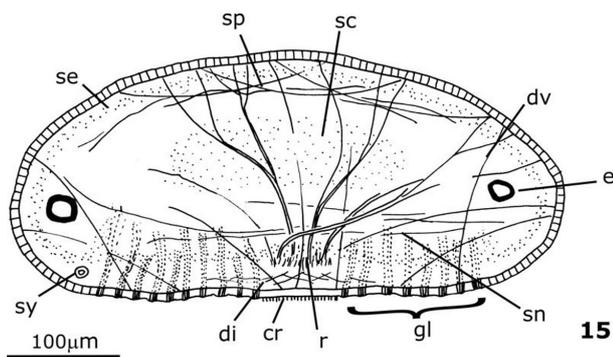


Fig. 15. – *Luteostriata ernesti*. Diagrammatic transverse reconstruction of cephalic region of specimen EMF=IPP Nr. 1521 at 0.15 mm from anterior tip of the body.

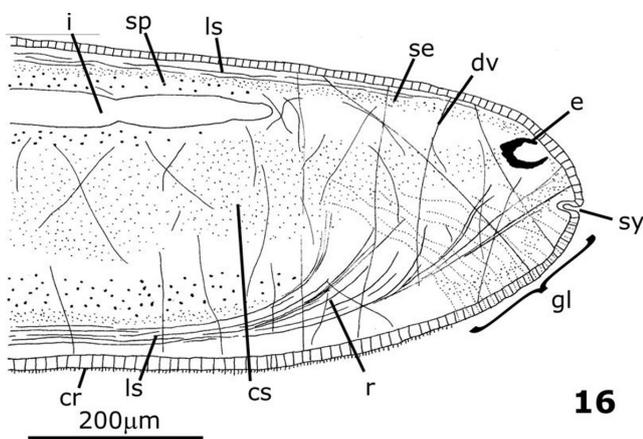


Fig. 16. – *Luteostriata ernesti*. Diagrammatic sagittal section of cephalic region of specimen EMF=IPP Nr. 1289.

***Luteostriata fita* (Froehlich, 1959) comb. nov.**

Diagnosis. Very slender body. Dorsal surface with four longitudinal dark stripes plus a fifth one in the cephalic region. Dorsal cephalic epidermis ciliated. Pharyngeal pocket twice the length of the pharynx. Efferent ducts open into the posterior region of the prostatic vesicle, the latter being very elongated and non-bifurcated.

Distribution. Blumenau (state of Santa Catarina, SC).

Material examined. See CARBAYO (2006).

***Luteostriata graffi*
(Leal-Zanchet & Froehlich, 2006) comb. nov.**

Figs 17-18

Diagnosis. Dorsal surface with five black stripes: a median one, two lateral and two sub-marginal stripes; the lateral stripes the widest, being about 1/5 of the body width. Female atrium as long as the male atrium.

Distribution. Praia Grande (state of Santa Catarina, SC), São Francisco de Paula, Três Coroas, Taquara, Parobé (new record), Morro Reuter (new record), Salvador do Sul, São Leopoldo (state of Rio Grande do Sul, RS).

Material examined. MZUSP PL. 176: São Francisco de Paula (RS), 25/XI/1998, F. Carbayo, *leg.* Anterior region 1: sagittal sections on 4 slides; anterior region 2: sagittal sections on 12 slides; pre-pharyngeal region: transverse sections on 5 slides. Paratype MZU PL.00052: São Francisco de Paula (RS), 11/XII/1997, M. Cardoso, *leg.* Anterior region 1: sagittal sections on 4 slides; anterior region 2: sagittal sections on 10 slides; pre-pharyngeal region: transverse sections on 16 slides. Paratype MZU PL.00058: Salvador do Sul (RS), 26/VII/2000, A. M. Leal-Zanchet, *leg.* Anterior region 1: transverse sections on 19 slides. FCB F0204: Parobé (RS), F. Carbayo, *col.* Anterior region 1: horizontal sections on 5 slides;

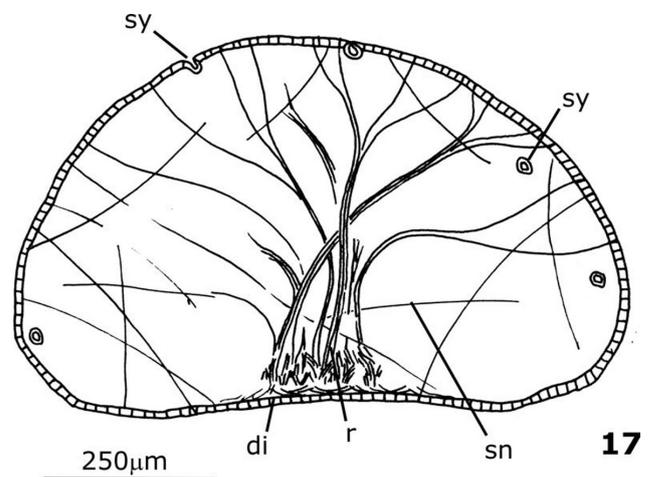


Fig. 17. – *Luteostriata graffi*. Diagrammatic horizontal reconstruction of cephalic region at 0.5 mm from anterior end of the body of specimen FCB F0204.

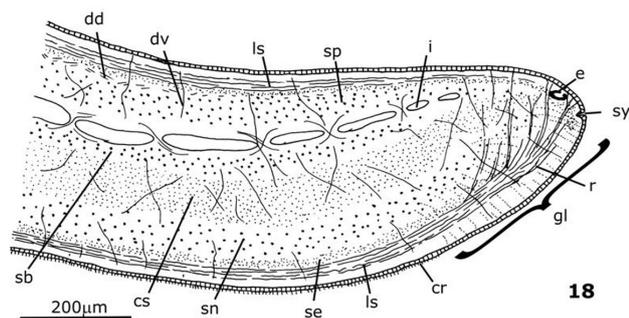


Fig. 18. – *Luteostriata graffi*. Diagrammatic sagittal section of cephalic region of specimen MZUSP PL. 176.

anterior region 2: horizontal sections on 3 slides; pre-pharyngeal region: transverse sections on 4 slides; pharynx: sagittal sections on 4 slides; copulatory apparatus: sagittal sections on 4 slides. FCB F0467: Morro Reuter (RS), F. Carbayo, col. Copulatory apparatus: sagittal sections on 5 slides.

Morphological notes. Sensory pits are simple invaginations, 20 μm deep, ventrally-encircling the entire cephalic region and extending posteriorly to a distance equivalent to 21-25% of body length. Epidermis only ciliated on the creeping sole. The epidermis is 12 μm high dorsally, 15 μm ventrally. Glandular region in the ventral cephalic end 2-3 mm in length. In fixed animals, the surface of the cephalic glands is slightly protuberant. The organ is formed by two types of secretory cells: (1) abundant cells with erythrophilic granules and necks running joined, and (2) cells with fine pink granules (stained with Cason and Masson-Goldner). At the point where the epidermis is traversed by the openings of these secretory cells, it is 20 μm in height. In the first 4 millimeters of the body, the organization of the ventral longitudinal sub-epidermal musculature is different from that in the rest of the body. At 2 mm from the anterior tip, this layer is modified to form a retractor muscle similar to that of *L. muelleri*, 1.7 times thicker than at the pharyngeal region, and traversed by some dorso-ventrally-running mesenchymal fibers (Figs 17-18).

DISCUSSION

Luteostriata nov. gen. differs from all other geoplanid genera in the following combination of features: it has a slender body with a slightly rounded, not rolled cephalic region; cephalic musculo-glandular organ present, consisting of glands crossing a U-shaped glandular ventral surface; lens-shaped retractor muscle in cross-section; close to the anterior end of the body, the fibers of the retractor detach from it and are sunken into the mesenchyma, continuing forwards obliquely to the dorsal surface and the body margins before attaching to the basement membrane; transversal sub-neural muscle fibers and those of the retractor do not intermingle.

Below we discuss the differences between the new genus and the geoplanid genera that also have a cephalic musculo-glandular organ, viz., *Cephaloflexa* Carbayo & Leal-Zanchet, 2003, *Choeradoplana* Graff, 1896, *Issoca* Froehlich, 1955 and *Supramontana* Carbayo & Leal-Zanchet, 2003

(Tab. 3). The retractor muscle of the organs of these genera is also derived from the ventral longitudinal sub-epidermal musculature.

Luteostriata nov. gen. is distinguished from *Cephaloflexa* and *Choeradoplana* in that, in the latter two genera (a) the cephalic region is backwardly-rolled; (b) eyes and sensory pits are absent at the anterior tip of the body; (c) the fibers of the retractor muscle run parallel to the sagittal plane; and (d) the sub-neural mesenchymal muscle layer is present only in the cephalic region. Furthermore, in *Cephaloflexa* (e) the cephalic region is very narrow; and (f) glands associated with the retractor muscle are absent, while in *Choeradoplana* (g) the cephalic region is laterally expanded; (h) and the glandular surface of the cephalic musculo-glandular organ has two cushion-like organs; (i) the retractor is deltoid in cross-section; (j) in the cephalic region a dense muscle net ("Muskelgeflecht"), is present and formed by fibers of the supra-intestinal mesenchymal transverse muscle layer and by those of the dorso-ventral mesenchymal muscle system; (k) in the cephalic region cellular bodies of rhabditogen cells lie between the retractor muscle and the epidermis; and (l) part of the sub-epidermal longitudinal muscle layer is sunken along the entire body (Tab. 3).

Luteostriata gen. nov. is also different from in *Issoca* in that, in the latter (a) the cephalic region is spoon-shaped; (b) the glandular surface of the cephalic musculo-glandular organ is lunate; (c) the retractor muscle is rounded in cross section; (d) the sub-neural mesenchymal muscle layer is intermingled with retractor.

From *Supramontana*, *Luteostriata* gen. nov. differs in that the former genus (a) possesses a relatively wide body with a rounded anterior end; (b) cephalic glands associated with the retractor muscle are absent; (c) the retractor is irregularly lenticular; (d) cellular bodies of rhabditogen cells lie between the retractor muscle and the epidermis in the cephalic region; and (e) part of the sub-epidermal longitudinal muscle layer is sunken along entire body.

The cephalic regions of *Notogynaphallia arturi* and *N. pseudoceciliae*, both assigned to group 2 (FROEHLICH & LEAL-ZANCHET 2003), should be investigated in order to check whether they match the diagnostic features of the new genus.

Some observations on feeding behavior may help to further understand the function of the cephalic musculo-glandular organ. FROEHLICH (1955a) suggested a role for the organ of *Issoca rezendei* hunting prey. The action of the retractor of this organ could provide a sucker-like function to the cephalic ventral surface of the flatworm by increasing the concavity of this surface. This sucker action, combined with the putative adhesive nature of the abundant erythrophilic granular secretions of the cephalic glands (FROEHLICH, 1955), could facilitate the capture of prey. E. M. Froehlich (unpublished) observed in laboratory conditions that *Issoca rezendei* is able to attack woodlice (Crustacea: Isopoda), a behavior rarely observed in land planarian species. During this attack the animal swiftly throws its anterior body region onto the prey, with its ventral cephalic surface directed forwards and the cephalic region curved dorsally (pers. obs.).

TABLE 3
Diagnostic features of the five genera of Geoplaninae provided with cephalic retractor muscle.

Feature	<i>Cephaloflexa</i>	<i>Choeradoplana</i>	<i>Supramontana</i>	<i>Issoca</i>	<i>Luteostriata</i> nov. gen.
body	slender	slender	wide	slender	slender
cephalic shape	very narrow, rolled backwards	expanded, rolled upwards	rounded	spoon- shaped	slightly rounded
eyes at anterior tip of the body	no	no	yes	yes	yes
sensory pits at the anterior tip of the body	no	no	yes	yes	yes
cephalic glands associated with retractor muscle	no	yes	no	yes	yes
shape of epidermal surface crossed by cephalic glands	-	two elongate cushions	-	lunate	U-shaped
cross sectioned retractor	lenticulate	deltoid	irregularly lenticulate	rounded	lenticulate
retractor muscle fiber orientation	parallel to sagittal plane	parallel to sagittal plane	towards body margins	towards body margins	towards dorsal surface and body margins, some fibers cross the sagittal plane
sub-neural mesenchymal muscle layer	only in cephalic region	only in cephalic region	along entire body	along entire body	along entire body
sub-neural mesenchymal muscle layer intermingled with retractor	no	no	no	yes	no
Muskelgeflecht	no	yes	no	no	no
cellular bodies of rhabditogen cells between retractor and epidermis	no	yes	yes	no	no
part of sub-epidermal longitudinal muscle layer sunken along entire body	no	yes	yes	no	no

If the attack succeeds, the isopod is first held on the glandular surface of the organ, hindering the woodlouse's escape, which is then manipulated by the flatworm for feeding.

Likewise, *L. abundans* (see Prasniski & Leal-Zanchet, 2009), *L. caissara* (Bresslau, in RIESTER, 1938; FROELICH, 1955b), *L. ernesti* (see above) also feed on woodlice. Under laboratory conditions, *L. ernesti* attacks such prey in a manner similar to *I. rezendei* (pers. obs.).

ACKNOWLEDGEMENTS

We are grateful to EM Froehlich (USP, São Paulo) for the loan of specimens in her care. We wish to thank Paula Beatriz de Araujo (UFRGS) for isopod identification. We are also grateful to M Kawakatsu (Sapporo, Japan) for his help on etymology, EM Froehlich for a critical reading of the manuscript, J. Hesson for English revision of an early draft of the manuscript, and two anonymous referees for the valuable suggestions and advice on the text. This study was supported by FAPESP (proc. 2007/03890-6) and Fundación BBVA.

REFERENCES

- CARBAYO F (2006). Redescription of two land planarian species of *Notogynaphallia* Ogren & Kawakatsu, 1990 (Platyhelminthes, Tricladida, Geoplaninae) and confirmation of heterogeneity of the genus. *Revista Brasileira de Zoologia*, 23 (3): 746-757.
- CARBAYO F & LEAL-ZANCHET AM (2003). Two new genera and species of Geoplaninae (Tericola: Tricladida: Platyhelminthes) of Brazil in the light of cephalic specialisations. *Invertebrate Systematics*, 17 (3): 449-468.
- CINZ (2000). Código internacional de nomenclatura zoológica. CSIC, Madrid.
- DIESING KM (1861). Revision der Turbellarien. Abtheilung: Dendrocoelen. Sitzungsberichte der Mathematisch-Naturwissenschaftlichen Classe der Kaiserlichen Akademie der Wissenschaften 44 I (6-10): 485-578.
- FROELICH CG (1955a). Sobre morfologia e taxonomia das Geoplanidae. *Boletim da Faculdade de Filosofia, Ciências e Letras da Universidade de São Paulo, São Paulo, série Zoologia*, 19: 195-279.
- FROELICH CG (1955b). On the biology of land planarians. *Boletim da Faculdade de Filosofia, Ciências e Letras da Universidade de São Paulo, São Paulo, série Zoologia*, 20: 263-271.
- FROELICH CG (1959). On geoplanids from Brazil. *Boletim da Faculdade de Filosofia, Ciências e Letras da Universidade de São Paulo, São Paulo, série Zoologia*, 22: 201-265.
- FROELICH EM (1955). Sobre espécies brasileiras do gênero *Geoplana*. *Boletim da Faculdade de Filosofia, Ciências e Letras da Universidade de São Paulo, São Paulo, série Zoologia*, 19: 289-369.
- FROELICH EM & LEAL-ZANCHET AM (2003). A new species of terrestrial planarian of the genus *Notogynaphallia* Ogren & Kawakatsu, 1990 (Platyhelminthes, Tricladida, Terricola) from South Brazil and some comments on the genus. *Revista Brasileira de Zoologia*, 20 (4): 745-753.
- GRAFF L VON (1899). Monographie der Turbellarien. II. Tricladida Terricola. Two vols, text and atlas. Engelmann, Leipzig.
- LEAL-ZANCHET AM & CARBAYO F (2001). Two new species of Geoplanidae (Platyhelminthes, Tricladida, Terricola) from Brazil. *Journal of Zoology*, 253: 433-446.
- LEAL-ZANCHET AM & FROELICH EM (2001). A species complex in the genus *Notogynaphallia* (Tricladida: Terricola). *Belgian Journal of Zoology*, 131 (Suppl.): 225-226.
- LEAL-ZANCHET AM & FROELICH EM (2006). A species complex in the genus *Notogynaphallia* Ogren and Kawakatsu (Platyhelminthes: Tricladida: Terricola) with a taxonomic revision of homonyms of *Geoplana marginata* Schultze & Müller and a reinterpretation of *Notogynaphallia caissara* (Froehlich) anatomy. *Belgian Journal of Zoology*, 136 (1): 81-100.
- LEMOVS VS & LEAL-ZANCHET AM (2008). Two new species of *Notogynaphallia* Ogren & Kawakatsu (Platyhelminthes: Tricladida: Terricola) from Southern Brazil. *Zootaxa*, 1907: 28-46.
- OGREN RE & KAWAKATSU M (1990). Index to the species of the family Geoplanidae (Turbellaria, Tricladida, Terricola). Part I: Geoplaninae. *Bulletin of the Fuji Women's College, Sapporo*, 28 Serie II: 79-166.
- PRASNISKI, MET & LEAL-ZANCHET, AM (2009). Predatory behaviour of the land flatworm *Notogynaphallia abundans* (Platyhelminthes: Tricladida). *Zoologia*, 26 (4): 606-612.
- RIESTER E (1938). Beiträge zur Geoplaniden-Fauna Brasiliens. *Abhandlungen der Senkenbergischen Naturforschenden Gesellschaft*, 441: 1-88.
- SCHULTZE M & MÜLLER F (1857). Beiträge zur Kenntnis der Landplanarien, nach Mittheilungen des Dr. Fritz Müller in Brasilien und nach eigenen Untersuchungen von Dr. Max Schultze. *Abhandlungen der Naturforschenden Gesellschaft zu Halle*, 4: 61-74.

