

## Record of *Argyrodiaptomus bergi* (Crustacea: Copepoda: Calanoida) after 36 years and first record in Brazil

Gilmar Perbiche-Neves<sup>1</sup>; Daniel Previattelli<sup>2</sup> & Marcos Gomes Nogueira<sup>1</sup>

<sup>1</sup> Departamento de Zoologia, Instituto de Biociências, Universidade Estadual Paulista. Distrito de Rubião Júnior, 18618-970 Botucatu, SP, Brazil.

<sup>2</sup> Instituto de Pesquisas da Amazônia. Avenida André Araújo 2936, Manaus, AM, Brazil.

<sup>3</sup> Corresponding author. E-mail: gilmarpneves@yahoo.com.br

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**ABSTRACT.** The first record of *Argyrodiaptomus bergi* (Richard, 1897) from a small roadside pool at high altitude in the southern region of Brazil is presented. This is the ninth record of this species in South America (previously known from Argentina and Uruguay) since its original description, and a new occurrence after 36 years, extending its known distribution to the northeast. The environments where this species was found differ sharply, and possible explanations include the loss of habitat, high species selectivity or deficient sampling efforts. An additional description is provided, with scanning electron microscopy (SEM) photomicrographs and line drawings. Similarly to other species of *Argyrodiaptomus*, such as *Argyrodiaptomus falcifer* (Daday, 1905), *Argyrodiaptomus denticulatus* (Pesta, 1927) and *Argyrodiaptomus granulatus* (Brehm, 1933), this species shows a restricted distribution in the lower stretches of the Paraná and Uruguay rivers, particularly in small pools. The importance of better understanding the dynamics and diversity of small water bodies is discussed.

**KEY WORDS.** New record; rare species; Santa Catarina.

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RICHARD (1897) described zooplanktonic organisms from a pool of water near the city of Buenos Aires, Argentina, among them *Argyrodiaptomus bergi* (Richard, 1897). Since then, very few records of this species have appeared. All of these records emphasize the rarity of the taxon, with low numbers and a sparse distribution in the lower La Plata River basin. The checklists of DUSSART & DEFAYE (1983, 2002) reported its occurrence in Argentina and Uruguay.

*Argyrodiaptomus bergi* is the first described species of the *bergi* group. Although WRIGHT (1938) did not recognize the genus as such, he proposed the *bergi* group, composed of *Diaptomus granulatus* Brehm, 1933, *Diaptomus denticulatus* Pesta, 1927, *Diaptomus azevedoi* (Wright, 1935), *D. bergi*, *Diaptomus furcatus* (Sars, 1901), *Diaptomus aculeatus* (Douwe, 1911), and two new species, *Diaptomus neglectus* Wright, 1938 and *Diaptomus argentinus* Wright, 1938. All of them were recognized as *Argyrodiaptomus* Brehm, 1933, after the work of BREHM (1933). Recently, PAGGI (2006) validated *Argyrodiaptomus argentinus* (Wright, 1938) as a junior synonym of *Argyrodiaptomus falcifer* (Wright, 1939), now considered a valid species. BREHM (1933) defined *A. granulatus* as the type of the genus. However, this species has not been recorded for many years. According to the principle of priority established by the International Code of Zoological Nomenclature, and in our opinion, *A. bergi* should be considered the type of the genus.

SANTOS-SILVA (2008) traced the history of the genus, clearly defining the current state of knowledge. The latest addition to the genus is *Argyrodiaptomus paggii*, described by PREVIAATELLI &

SANTOS-SILVA (2007) from the southwestern Amazon region. This extended the genus distribution to a more western limit, corroborating the prediction of BRANDORFF (1976). REID (1997) raised *Argyrodiaptomus macrochaetus* Brehm, 1937 to species rank. Other species of the same genus are *Argyrodiaptomus nhumirim* Reid, 1998 and *Argyrodiaptomus robertsonae* Dussart, 1986.

Records of *A. bergi* prior to the present study are shown in table I and figure 1. Most of the reports also indicated its occurrence in small pools, usually temporary environments. The conditions in small water bodies vary widely along the seasons, because of the low water volume. Furthermore, the records are from temperate regions, with low water temperature. Probably global warming and high temperatures in summer may be affecting this species, which is poorly studied.

Here we present the first record of this species in Brazil, and the first in 36 years; the geographical distribution and the main morphological structures; and emphasize the importance of studying small pools.

### MATERIAL AND METHODS

Zooplankton samples were taken from a small road-side pool (Fig. 2) situated at 28°16'3.93"S, 49°54'38.25"W (WGS38 Datum), in the municipality of São Joaquim, state of Santa Catarina, Brazil, on August 23, 2009. The climate is temperate (Cfb) and the mean annual air temperature is 13°C (www.saojoaquim.sc.gov.br accessed June 6, 2010).

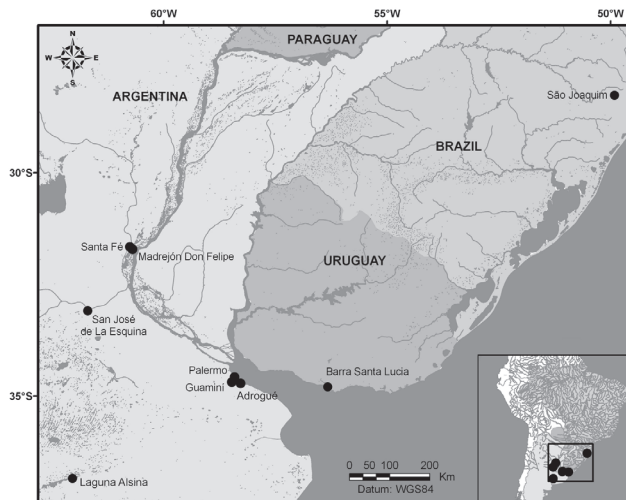


Figure 1. Geographical distribution of *Argyrodiaptomus bergi*. Individual localities are listed in table I.

Table I. Previous records of *Argyrodiaptomus bergi*.

| Author                       | Locality   |
|------------------------------|--|
| RICHARD (1897)               | Adrogué, Gran Buenos Aires, Argentina                        |
| BRIAN (1926)                 | Palermo, Buenos Aires, Argentina                             |
| WRIGHT (1933)                | Roadside pool near Guaminí, Buenos Aires Province, Argentina |
| BREHM (1937)                 | Barra Santa Lucia, near Montevideo, Uruguay                  |
| BREHM (1958)                 | San José de La Esquina, Santa Fé Province, Argentina         |
| RINGUELET (1962)             | Laguna Alsina, Buenos Aires Province, Argentina              |
| MARTÍNEZ DE FERRATO (1967)   | Madrejoñ Don Felipe, Santa Fé Province, Argentina            |
| PAGGI & JOSÉ DE PAGGI (1974) | Santa Fé, Santa Fé Province, Argentina                       |

At the time of sampling, the pool was approximately 70 m<sup>2</sup> in area and 1.5 m in maximum depth (Fig. 2). It was situated at an altitude of 1,400 m a.s.l. Water temperature was 10°C. Samples were obtained through horizontal hauls using a plankton net of 50-µm mesh size, with an aperture diameter of 25 cm, through open water. The filtered volume was estimated using the cylinder formula and the distance of haul. The material was concentrated and preserved in 90% ethanol.

Quantitative and qualitative analyses were performed in the laboratory. One sample was quantified from three subsamples of 10 ml each, and a minimum of 100 individuals was counted, in gridded acrylic chambers. The abundance was expressed as individuals.m<sup>-3</sup>.

Subsequently, male and female copepods were sorted and washed with distilled water. Ten males and ten females were

dissected and mounted on slides in lacto-phenol and glycerin. Measurements of the following structures (n = 30 for each sex) were made: 1) total body length excluding furcal setae; 2) total body length including furcal setae; 3) length of thoracic segments; 4) antennule length; 5) maximum thoracic segment width. All measurements were made with the aid of a Zeiss Discovery V-20 stereoscopic microscope, and the software Axio-Vision 6.0. Line drawings were made using a Zeiss AxioScope 25 light microscope equipped with a drawing tube.

Twenty specimens of both sexes were prepared for scanning electron microscopy (SEM) following protocols used by FELGENHAUER (1987) and HUYS & BOXSHALL (1991). Observations and photographs were taken with a Quanta 200 FEI electron microscope. Occurrences of *A. bergi* were plotted using ARCGIS 9.0 software.

Vials containing male and female specimens (10 of each) were deposited in the microcrustacean collections of the Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP), Brazil; in the Museu de Zoologia da Universidade de São Paulo, Brazil (MZUSP No. 23473), and in the Instituto Nacional de Pesquisas do Amazonas, Brazil (INPA no. 1876).

The original description of RICHARD (1897) was adapted according to the terminology used by HUYS & BOXSHALL (1991), and PREVIATTELLI & SANTOS-SILVA (2007). Abbreviations: thoracic segments (Th), urosome segments (Ur), genital segment (GS), antennule (A1), antenna (A2), mandible (Md), maxillule (Mxl), maxilla (Mx), maxilliped (Mxp), first to fourth swimming legs (P1-P4), fifth leg (P5), endopod (Enp), exopod (Exp). Exp-1 (-2, -3) refers to the first, second and third segments of the exopod. The abbreviation Enp-1 (-2, -3) refers to segments 1-3 of the endopod.

## RESULTS

The present record is the farthest north and east (approximately 950 km from the nearest previously recorded locality). All records are shown in table I and figure 1.

At the time of sampling, the copepods showed an intense red color, with a large body size. About 2,400 specimens including copepodids and adults (males and females) were collected.

Few other zooplankton species were observed. Cladocerans were represented by a large species, *Simocephalus* cf. *semiserratus* (3.0-4.0 mm) and some members of Chydoridae. A dense population of the green alga *Volvox* sp. was observed.

Mean and standard deviations of the measurements are presented in table II. The standard deviations of the structures were low; only antennule length varied more than the other structures. General views of the specimens are presented in figures 3-30. The morphological features, according to the original description of RICHARD (1897), are presented below.

Female. Last thoracic segments fused in dorsal region. Left lateral wing more developed than right. Modified sensil-



Figure 2. General view of the roadside pool at São Joaquim, Santa Catarina, Brazil. The surrounding winter-killed vegetation evidences the frequent frosts in this region. The pool is possibly formed by accumulation of rainwater in a depression.

Table II. Measurements ( $\mu\text{m}$ ) of males and females of *Argyrodiaptomus bergi* from the Brazilian population.

| Measurements                                    | Male     |        |          |          | Female   |        |          |          |
|---|----------|--------|----------|----------|----------|--------|----------|----------|
|   | Mean     | SD     | Max      | Min      | Mean     | SD     | Max      | Min      |
| Total body length                               | 2,477.05 | 187.83 | 2,689.00 | 2,170.00 | 2,858.58 | 105.75 | 3,100.00 | 2,641.00 |
| Total body length from tip of furca             | 2,196.58 | 193.02 | 2,613.00 | 1,866.00 | 2,546.23 | 86.95  | 2,758.00 | 2,403.00 |
| Total body length from posterior end of abdomen | 1,577.16 | 177.36 | 2,004.00 | 1,303.00 | 1,935.85 | 92.37  | 2,135.00 | 1,711.00 |
| Total Antennule length                          | 1,937.53 | 269.53 | 2,540.00 | 1,522.00 | 2,366.85 | 294.19 | 2,950.00 | 2,005.00 |
| Maximum thorax width                            | 591.05   | 83.27  | 775.00   | 419.00   | 671.38   | 62.50  | 813.00   | 550.00   |

lum of left lateral wing smaller than right. Genital segment longer than the remaining Ur. Left/anterior margin of GS longer than right. Presence of a small expansion at posterior third of Th5 in dorsal region. Ur2 and Ur3 similar in length. Fu very large and with inner (medial) margin plumose. Fu setae approximately equal to length of Fu and Ur together. Leg 5: enp clearly segmented, with the two segments of similar size. Leg 5: enp length exceeds half the exp length; the extremity bears two sub-apical spines, approximately one-third the enp length; the apical region shows a clear spinule crown. Leg 5: exp-2 cylindrical, distinct, and bears a small apical spine and one robust serrated spine medially, the latter twice the length of the former. Leg 5: exp-1 present on the lateral margin, near the insertion of the last segment, a very small spine, and the medial margin prolonged as a slightly curved claw, with the apex subacute and armed on the margins after the middle, with strong teeth (spinules), sharp and numerous.

Male. Left lateral wing larger than right. Right lateral wing with small spinules. Th5 right edge slightly shorter than right edge, so that right furca appears slightly warped laterally. Ur1: shorter than wide; with extremity on left posterior margin with two small lobes; and right extremity with a small spine, missing on left extremity. Ur3: elongated, all the same width; seta is part of the lateral distal end of the outer edge of the segment. Left antennule reaches middle of abdomen. Right antennule with

segments 14 to 18 swollen. Right antennule, segment 13 bears a strong hook, segment 15 with spinous process; the penultimate segment has a curved clawlike extension, long, slender, and acute, and if straightened would reach almost to end of the antenna. Left P5: enp consisting of 1 sub-cylindrical segment, its apex reaching almost the beginning of the last segment of the endopod; enp apex with two spines and a series of spinules; exp1 with a small delicate seta on the last third of the external margin; exp1 inner border forms a terminal projection with coarse tubercles; end of left P5 reaches slightly beyond the middle of the last segment of the right leg; basis internal margin with small rounded chitinous projections; exp1 of left P5 inner surface with bilobed projection ornamented with setules; exp2 distal portion with subspherical projection ornamented with many setules; exp2 end with digitiform, denticulate process; Exp2 with spine slightly curved at its acute tip. Right P5 terminal claw strongly sigmoidal (clearly seen when it is in a perpendicular plane to the two legs).

## DISCUSSION

The addition of the present record to the few previous records of *A. bergi* considerably extends its known distribution to the northeast. The paucity of records may indicate a very selective species; however, sampling efforts are not usually di-



Figure 3-13. (3) *Argyrodiaptomus bergi* adult male, scanning electron microscope (SEM) photomicrographs (1,000  $\mu\text{m}$ ); (4) right A1, segments 11-18 (400  $\mu\text{m}$ ); (5) right A1, segments 20-22 (100  $\mu\text{m}$ ); (6) rostrum (50  $\mu\text{m}$ ); (7) right maxilliped (200  $\mu\text{m}$ ); (8-12) frontal view: (8) leg 5 (400  $\mu\text{m}$ ); (9) basis, part of exopod 1 and 2, and endopod of right leg 5, and left leg 5 (200  $\mu\text{m}$ ); (10) leg 5 (400  $\mu\text{m}$ ); (11) basis and endopod of right leg 5, and left leg 5; (12) left leg 5 in frontal view (200  $\mu\text{m}$ ); (13) left leg 5 in caudal oblique view (100  $\mu\text{m}$ ). Scale bars: 3 = 1000  $\mu\text{m}$ ; 4, 8, 10 = 400  $\mu\text{m}$ ; 5, 13 = 100  $\mu\text{m}$ ; 6 = 50  $\mu\text{m}$ ; 7, 9, 12 = 200  $\mu\text{m}$ ,

rected to find this sort of organism in time and space. At present, small roadside pools are relatively poorly studied, due to the ease of transportation to large rivers, lakes and reservoirs. Pioneer studies in the beginning of the 20<sup>th</sup> century, such as those of S. Wright and F. Kiefer, analyzed many small roadside pools, because of the ease of capturing typical lentic organisms.

*Argyrodiaptomus bergi* shows an endemic distribution in the lower La Plata River basin. The present record is nearly 1,000 km from the other known sites, and is probably near the northern limit of the species' distribution. However, compared to other species of the genus that are distributed over larger areas, such as *A. azevedoi* which occurs in northeastern, cen-

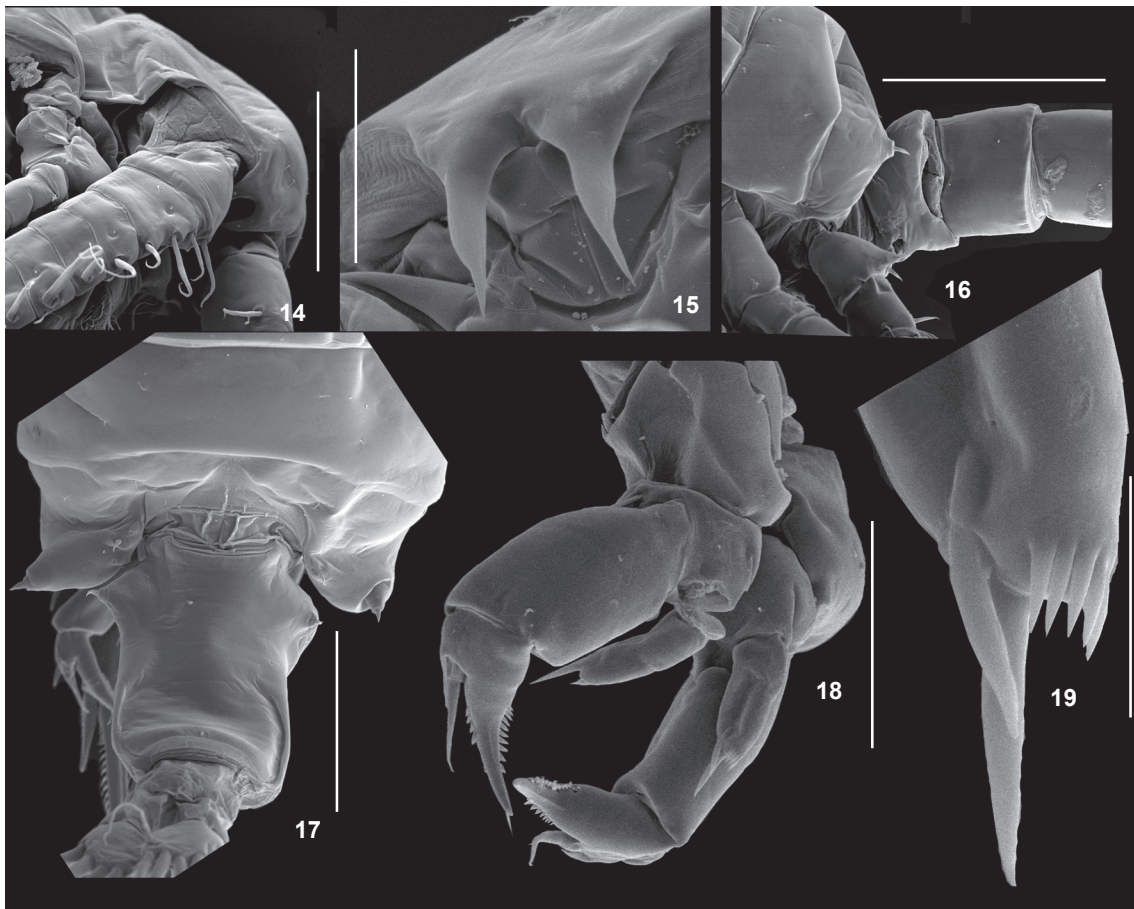


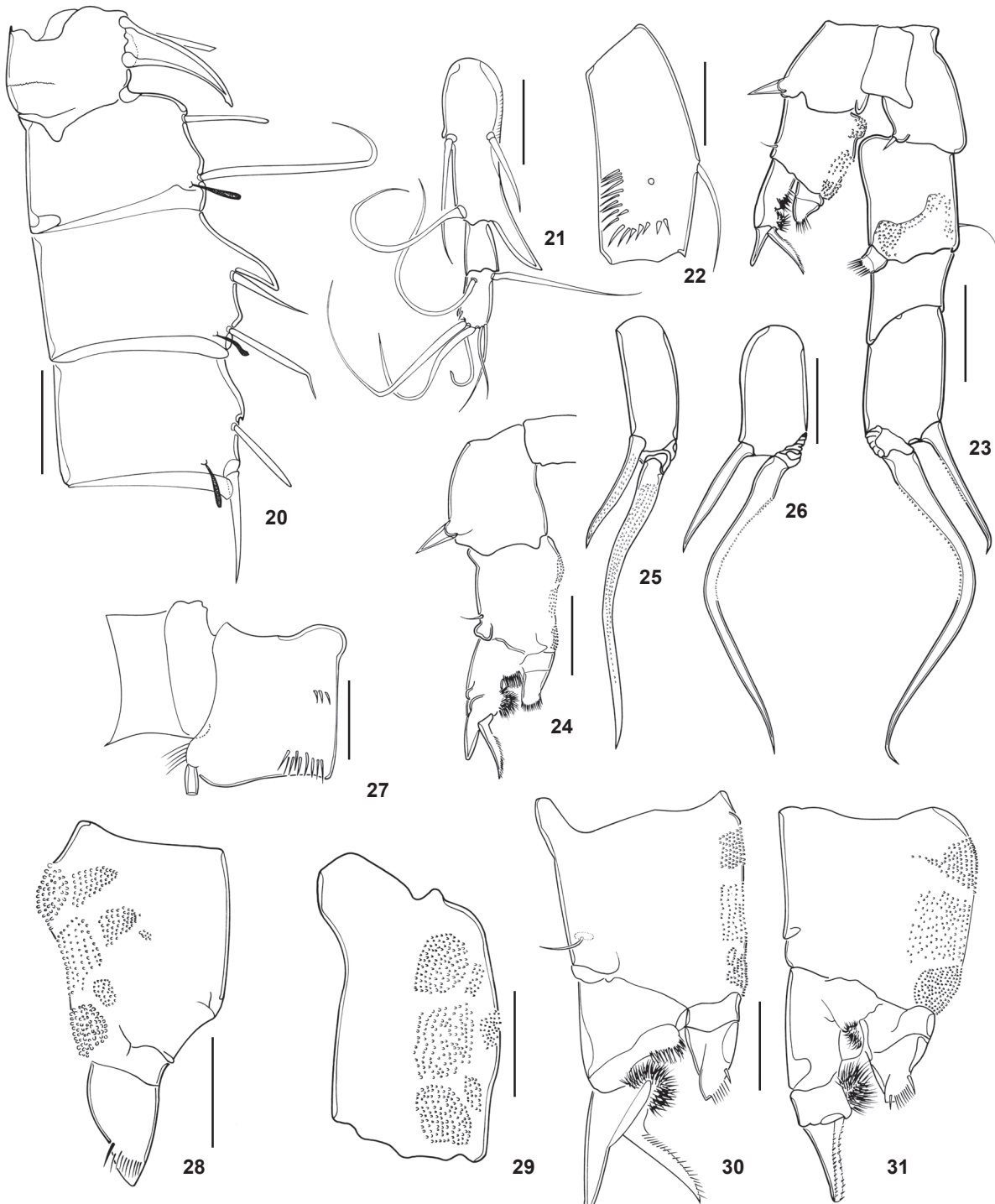
Figure 14-19. *Argyrodiaptomus bergi* adults, scanning electron microscope (SEM) photomicrographs: (14) rostrum, proximal segments of right (geniculate) antennule of male; (15) rostrum; (16) genital somite of male, lateral view; (17) posterior prosomites and urosome of female, dorsal view; (18) leg 5 of female, frontal oblique view; (19) detail of leg 5 endopod of female. Scale bars: 14 = 200  $\mu\text{m}$ , 15 = 50  $\mu\text{m}$ , 16 = 300  $\mu\text{m}$ , 17 = 500  $\mu\text{m}$ , 18 = 100  $\mu\text{m}$ , 19 = 20  $\mu\text{m}$ .

tral-western and southeastern Brazil, and others distributed through the Amazon region, such as *A. robertsonae*, we can state that the distance observed in the present record is not so far, being within the limits of species distributions for this genus.

Three other species of *Argyrodiaptomus* also occur only in the lower Paraná and Uruguay rivers, but they are more abundant in rivers and marginal lakes: *A. granulatus*, *A. denticulatus*, and *A. falcifer*. In Brazil, only *A. denticulatus* is recorded in state of Rio Grande do Sul, in Patos Lagoon, which is the northernmost record of the species. The Patos Lagoon is situated approximately 300 km from the site where *A. bergi* was found, which indicates that the Brazilian states of Rio Grande do Sul and Santa Catarina may be the limits of distribution for these two species of *Argyrodiaptomus*, typical of the lower La Plata basin. It is possible that *A. granulatus* and *A. falcifer* also occur in Brazil. However, further studies are necessary to elucidate this question. According to previous records, *A. bergi* occurs in different environments

(rivers, lagoons and freshwater pools), with a high altitudinal variability (10-1,400 m a.s.l.), and also occurs during different seasons, between August (present study) and February. RICHARD (1897) found it in November, BRIAN (1926) in September and October; and PAGGI & JOSÉ DE PAGGI (1974) in January. Complete seasonal variations need to be studied, noting that in winter, the region has frosts and occasional snow, and pools may freeze. We suggest that this species is rather plastic in its environmental requirements.

Fish were not observed in the small pool during the sampling, and were probably absent. The large size of the copepods and their red color would certainly be a limiting factor for development, if fish were present in the pool. Another species that occurs in the same region, *A. granulatus*, has a larger body size. Predation by fish and invertebrates (such as *Mesostoma*) may have contributed to the low abundance and paucity of records for this species, as pointed out by AKOPIAN *et al.* (1999) and TROCHINE *et al.* (2006).



Figures 20-31. Morphological structures of *Argyrodiaptomus bergi* adult male: (20) segments 13-17 of right antennule; (21) terminal three segments of right antennule; (22) second segment of endopod of antenna; (23) leg 5 in caudal view; (24) endopod of leg 5 in frontal view; (25) last segment of leg 5 in lateral oblique view; (26) last segment of leg 5 in frontal view; (27) intercoxal sclerite and basis of leg 4; (28) left leg 5 in caudal view; (29) left leg 5 in caudal oblique view; (30) left leg 5 in frontal view; (31) left leg 5 in frontal oblique view. Scale bars: 20-22, 24, 25, 27-31 = 50  $\mu\text{m}$ ; 23, 26 = 100  $\mu\text{m}$ .

Studies on ecology, reproduction and development of *A. bergi* are necessary. Other rare species reported from the lower La Plata River Basin, such as *A. granulatus*, *Odontodiptomus michaelsoni* (Mrázek, 1901) and *Odontodiptomus thomseni* (Brehm, 1933), should also be rediscovered and studied. Small roadside pools require intensive studies, and if fish are absent, the possibility of collecting large copepods increases.

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