

TAXONOMY, ECOLOGY, AND GEOGRAPHICAL
DISTRIBUTION OF THE SPECIES OF THE GENUS
Thermocyclops KIEFER, 1927 (COPEPODA, CYCLOPOIDA)
IN SÃO PAULO STATE, BRAZIL, WITH DESCRIPTION
OF A NEW SPECIES

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(With 6 figures)

ABSTRACT

The taxonomy and ecology of the cyclopoid copepod genus *Thermocyclops* were studied. Samples were collected in 207 water bodies located in the 22 hydrographic basins of São Paulo State, Brazil, including large reservoirs, small and shallow lakes, and ponds and rivers. The genus *Thermocyclops* inhabits mainly water bodies within a limnetic region. Four species were found, of which one is new: *Thermocyclops iguapensis*, which occurred in the reservoirs of the Ribeira do Iguape and Parafba do Sul basins. The description of the new species and the geographical distribution of all four species in São Paulo State are presented. *Thermocyclops decipiens* was the most frequent species, occurring in 71% of the water bodies within a limnetic region. This species is characteristic of eutrophic environments where it can occur in great abundance, whereas *Thermocyclops minutus* is characteristic in oligotrophic systems. *Thermocyclops inversus* and *Thermocyclops iguapensis* n. sp. were not common but can occur together with *Thermocyclops decipiens*.

Key words: taxonomy, ecology, geographical distribution, *Thermocyclops iguapensis* n. sp. co-occurrence.

RESUMO

Taxonomia, ecologia e distribuição geográfica das espécies do gênero *Thermocyclops* Kiefer, 1927 no estado de São Paulo, com a descrição de uma espécie nova

Foram realizadas coletas em 207 corpos de água, distribuídos em 22 unidades de gerenciamento de recursos hídricos (UHGRH) do estado de São Paulo no período de 1999 a 2002, abrangendo grandes e pequenos reservatórios, lagoas marginais e grandes rios. Nestas coletas foram analisadas as espécies do gênero *Thermocyclops* quanto à taxonomia, distribuição geográfica e frequência de ocorrência. O gênero *Thermocyclops* ocorreu em corpos de água com zona limnética bem desenvolvida e com raras exceções em ambientes estritamente litorâneos. Foram registradas quatro espécies, sendo *Thermocyclops iguapensis* espécie nova, que ocorreu nos reservatórios das UHGRHs Ribeira do Iguape e Parafba do Sul. A descrição da espécie nova e a distribuição das quatro espécies são apresentadas, mostrando que *Thermocyclops decipiens* foi a espécie mais frequente, ocorrendo em 71% dos corpos de água com região limnética desenvolvida. Esta espécie é característica de ambientes eutróficos, onde ocorre em grande número, e a espécie *Thermocyclops minutus* é característica de ambientes oligotróficos. *Thermocyclops inversus* e *Thermocyclops iguapensis* n. sp. não são espécies frequentes, mas podem co-ocorrer com a espécie *Thermocyclops decipiens*.

Palavras-chave: Copepoda Cyclopoida, distribuição geográfica, *Thermocyclops*, *Thermocyclops iguapensis* n. sp.

INTRODUCTION

The genus *Thermocyclops* Kiefer, 1927 (Copepoda, Cyclopoida) originated in the tropical region, in which it presents a high diversity of species (Dumont & Decraemer, 1977). In many tropical water bodies, this genus represents the most important component of the zooplankton biomass (Margalef, 1983). Despite the presence of the genus in South America, high diversity has not been recorded in this continent, as compared to the African and Asian continents (Rocha *et al.*, 1995). In the Western Hemisphere, nine species and subspecies have been recorded (Reid, 1989), four of them occurring in Brazil (Rocha & Botelho, 1998).

Until 1998, three species of *Thermocyclops* had been recorded in the freshwater systems of São Paulo State (Rocha & Botelho, 1998; Matsumura-Tundisi & Silva, 1999). *Thermocyclops decipiens* (Kiefer, 1929) was the most frequent species, found in several reservoirs and ponds, followed by *T. minutus*. *Thermocyclops inversus* Kiefer, 1936, a rare species, was registered in one reservoir located in São Paulo, SP (Rocha & Botelho, *op. cit.*).

The aim of this work was to evaluate the occurrence of the species of the genus *Thermocyclops* in the water bodies of São Paulo State, located in 22 basins that are under hydrographic management and which are referred to as hydrographic management units (HMU).

MATERIAL AND METHODS

Fig. 1 includes two maps of São Paulo State showing its 22 hydrographic basins as well as the hydrographic network with the main rivers where several reservoirs have been constructed in cascade to generate hydroelectricity.

Samplings were carried out during the period of 1999-2002. For each UHGRH, a minimum of 3 and maximum of 29 water bodies were sampled, including the limnetic and littoral regions of large and small reservoirs, as well as ponds and rivers. Geographical coordinates were determined at each site using a Garmin III GPS.

Zooplankton was collected by making vertical and horizontal hauls using a standard plankton net of mesh size 68µm. The samples were preserved in 4% formaldehyde and deposited in the Plankton Museum of the International Institute of Ecology. Species

identifications were performed using only adult females. Drawings and measurements were made using an optical microscope with image acquiring system and drawing software (TurboCAD Version 6.5).

Samples obtained from Barra Bonita Reservoir during the period of September 1983 to October 1984 at fortnightly intervals, were analyzed to study the seasonal fluctuations of two species of *Thermocyclops*.

RESULTS

Taxonomical studies

Thermocyclops iguapensis n. sp.

Types collected in Brazil, São Paulo State, Ibiuna County, Fumaça Reservoir (24°00' 16''S and 47°15' 40''W), collected by William M. Silva on 9/19/2001. All types were deposited in the USP museum.

Holotype ♂: Body size: 720 µm, specimen dissected and mounted on 1 slide (MZUSP: 16196).

Allotype ♀: Body size: 589 µm, specimen dissected and mounted on 1 slide (MZUSP: 16197).

Paratypes: 20 ♂ (average size: 735 µm ± 21) and 10 ♀ (average size: 585 µm ± 9), not dissected preserved in alcohol 70%, MZUSP 16198 and 16199 respectively.

Description of the female

Figs. 2 shows the general aspect of the female (Fig. 2a) and her appendages. Antennule (Fig. 2b): 17 segments, extending past 3rd thoracic segment, 17th segment without hyaline membrane. Antenna (Fig. 2c): 1st segment with few rows of spinules and one seta on caudal side; 4th segment with hyaline serrate ornamentation. Mouth appendages: mandibule (Fig. 2d), maxillule (Fig. 2e), maxilla (Fig. 2f), and maxilliped (Fig. 2g) with no special ornamentation. Legs 1-4 (Figs. 2h-2k): all of them with 3 articles, spine formula: 2,3,3,3 and intercoxal sclerite of the swimming legs without spine ornamentation on the distal margin. Endopodite 3 of leg 4 with terminal inner spine about 3.5 times longer than terminal external spine. Leg 5 (Fig. 2l): with spine in the inner article short, 1.4 time longer than distal article. Receptaculum seminis (Fig. 2m) with anterior margin of lateral arms not curved in the proximal part and the lateral canal jointed in the copulatory pore. Caudal rami (Fig. 2n) is 3.15 times longer than wide. Length of caudal setae: internal: 61 µm; medial internal: 243 µm; medial external: 131 µm; and external: 24 µm.

Description of the male

Fig. 3a shows the general aspect of the male. Antenna (Fig. 3b): 17 segments with geniculation in the 9th and 15th segments. Leg 5 (Fig. 3c): internal apical spine passing leg 6 insertion.

Etymology: A reference to the Ribeira do Iguape Hydrographic Basin where this species was found in high abundance.

Differential diagnosis: *Thermocyclops iguapensis* n. sp. differs from other American *Thermocyclops* species by a combination of characteristics such as intercoxal sclerite of legs 1-4 without spinular ornamentations on distal margins;

ratio between the terminal spines of endopodite 3 of leg 4; and principally, the difference in the morphology of the receptaculum seminis.

Remarks: *T. iguapensis* n. sp. was recorded in the reservoirs of the Ribeira do Iguape Basin and in reservoirs of the Paraíba do Sul hydrographic basins by Sendacz & Kubo (1982) but was identified as *T. minutus*.

The figures (51 to 56) presented by the authors show characteristics similar to those presented by *T. iguapensis* n. sp. and differing from the characteristics of *T. minutus*, especially in the morphology of the receptaculum seminis.

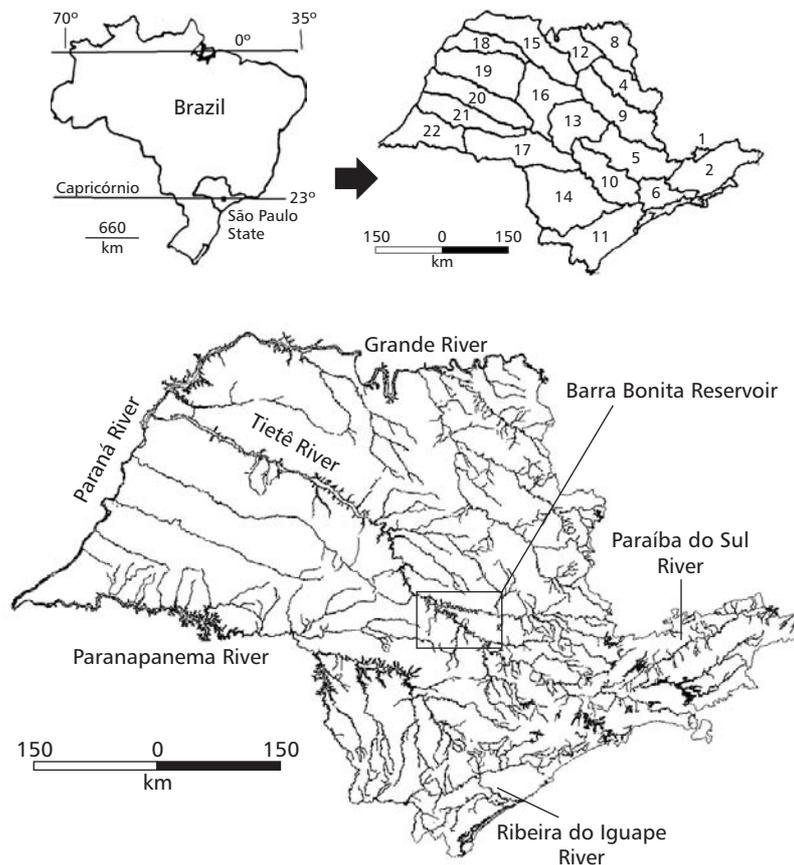


Fig. 1 — São Paulo State geographical position; a: São Paulo State and its 22 hydrographic management units (1-Mantiqueira, 2-Paraíba do Sul, 3-Litoral Norte, 4-Pardo, 5-Piracicaba/Capivari/Jundiá, 6-Alto-Tietê, 7-Baixada Santista, 8-Sapucaí-Mirim/Grande, 9-Mogi-Guaçu, 10-Sorocaba-Médio-Tietê, 11-Ribeira do Iguape e Litoral Sul, 12-Baixo Pardo/Grande, 13-Tietê/Jacaré, 14-Alto Paranapanema, 15-Turvo/Grande, 16-Tietê/Batalha, 17-Médio Paranapanema, 18-São José dos Dourados, 19-Baixo Tietê, 20-Aguapeí, 21-Peixe, 22-Pontal do Paranapanema); b: hydrographic network, with main rivers identified and the position of Barra Bonita Reservoir indicated.

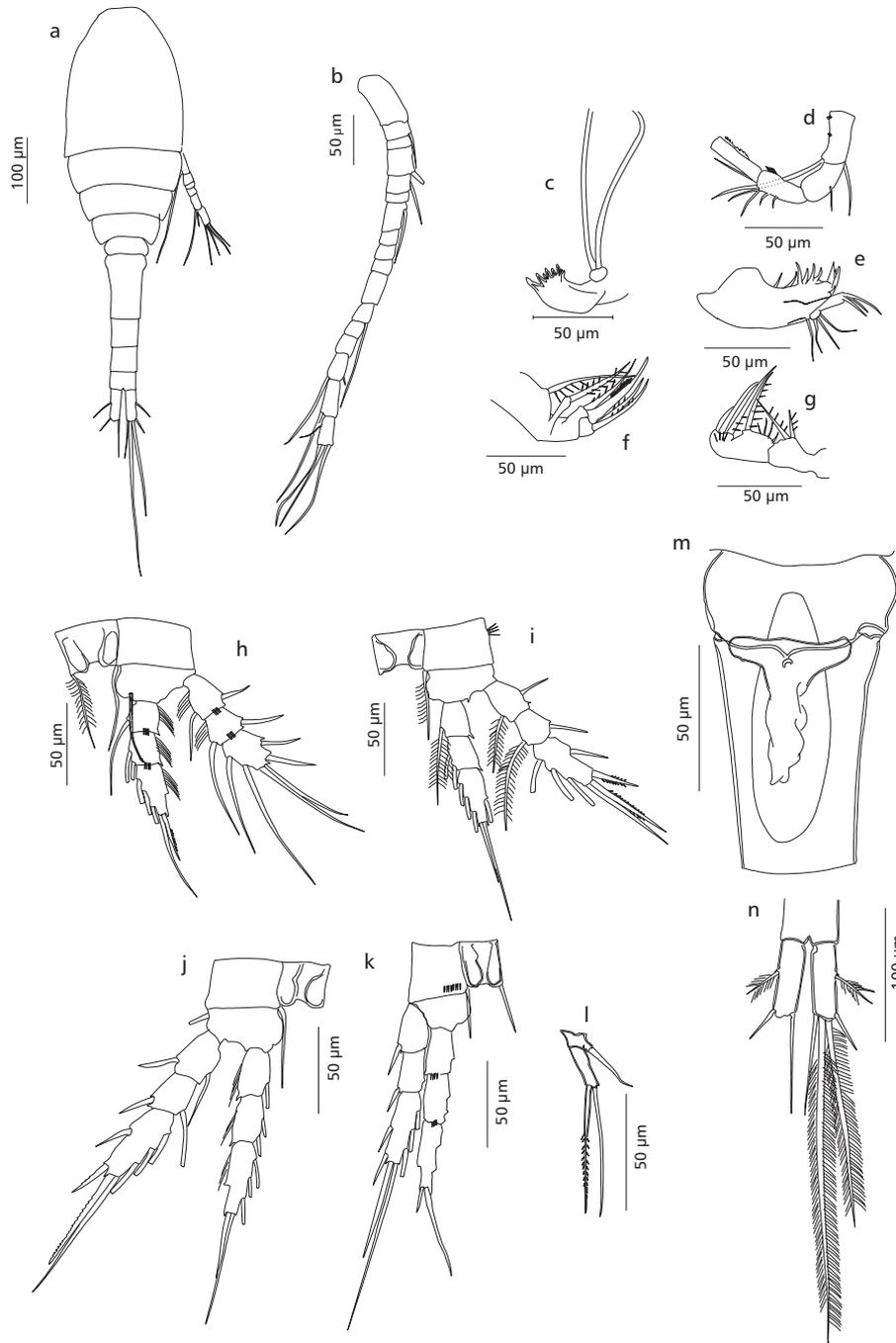


Fig. 2 — Female of *Thermocyclops iguapensis* n. sp. a) General aspect; b) antennule; c) antenna; d) mandible; e) maxillule; f) maxilla; g) maxilliped; h) leg 1; i) leg 2; j) leg 3; k) leg 4; l) leg 5; m) genital segment; n) anal segment and furca.

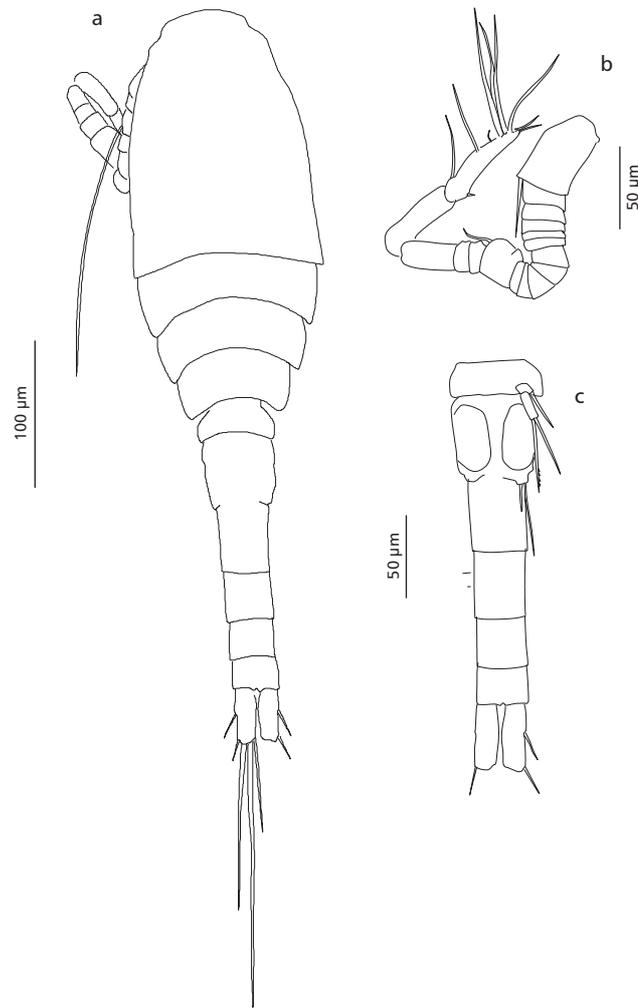


Fig. 3 — Male of *Thermocyclops iguapensis* n.sp.: a) general aspect; b) antennule; c) last thoracic segment and abdominal segments.

Differential diagnosis and key for São Paulo *Thermocyclops* species

Fig. 4 shows the main differences presented by the four species of *Thermocyclops* found in São Paulo State: *T. decipiens*, *T. inversus*, *T. minutus* and *T. iguapensis* n. sp.

Thermocyclops decipiens: average size of 10 adult females: $823 \mu\text{m} \pm 21$. Leg 4: intercoxal sclerite with ornamental spines in prominences on distal margins (Fig. 4-a1) and 3rd endopodite with outer apical spine 2.4 times as long as the inner (Fig. 4-b1). Receptaculum seminis (Fig. 4-c1): lateral arms slightly curved in the proximal and distal parts. Caudal rami (Fig. 4-d1): 2.28 times longer than wide,

lateral setae nearly on the distal margin, and internal setae 3 times longer than the external.

Thermocyclops inversus: average size of 10 adult females: $637 \mu\text{m} \pm 17$. Leg. 4: intercoxal sclerite without ornamental spines in prominences on distal margins (Fig. 4-a2), and 3rd endopodite with outer apical spine 0.8 time as long as the inner (Fig. 4-b2). Receptaculum seminis: lateral arms narrow (Fig. 4-c2). Caudal rami: 3.2 times as long as wide, lateral setae on the middle of the caudal rami, internal setae 2.16 times long than the external (Fig. 4-d2).

Thermocyclops minutus: average size of 10 adult females: $602 \mu\text{m} \pm 18$. Leg 4 (Fig. 4-a3):

intercoxal sclerite without ornamental spines in prominences on distal margins, and 3rd endopodite with outer apical spine 5 times longer than the inner (Fig. 4-b3). Receptaculum seminis (Fig. 4-c3): lateral arms slightly curved in the proximal part of anterior margin, pore canal curved and posterior margin located above the lateral arms. Caudal rami (Fig. 4-d3): 2.4 times longer than wide, lateral spine on the middle of the caudal rami, internal setae 1.8 times longer than the external.

Thermocyclops iguapensis n. sp.: 4th leg (Fig. 4-a4): intercoxal sclerite without ornamental spines in prominences on distal margins, 3rd endopodite with outer apical spine 3.5 times longer than the inner (Fig. 4-b4). Receptaculum seminis (Fig. 4-c4): lateral arms slightly curved on the distal margin, pore canal short, and posterior margin located in the middle of the lateral arms. Caudal rami (Fig. 4-d4): 3.1 times as long as wide, lateral spine on the middle of the caudal rami, internal setae 2.6 times longer than the external.

Identification key for *Thermocyclops* species found in the hydrographic basins of São Paulo State

1. Sclerite intercoxal of leg 4 with spine ornamentation on the distal margin (Fig. 4-a1).....2
Sclerite intercoxal of leg 4 without spine ornamentation on the distal margin (Fig. 4-a2 and a4).....3
2. 3rd endopodite of leg 4 with outer apical spine 2.4 times as long as inner (4-b1).....*T. decipiens*
3. 3rd endopodite of leg 4 with apical outer spine longer than inner (Fig. 4-b2).....*T. inversus*
3rd endopodite of leg 4 with apical outer spine shorter than inner spine.....4
4. 3rd endopodite of leg 4 with outer apical spine 5 times longer than the inner (Fig. 4-b3) and receptaculum seminis with anterior margin showing a depression in the proximal part (Fig. 4-c3).....*T. minutus*
3rd endopodite of leg 4 with outer apical spine 3.5 times longer than the inner (Fig. 4-b4).....5
5. Receptaculum seminis with anterior margin having no depression in the proximal part (Fig. 4-c4).....*T. iguapensis* n. sp.

Geographical distribution and frequency of occurrence of *Thermocyclops* species of São Paulo State

Among the Cyclopoida, the genus *Thermocyclops* is characteristic of the limnetic region of lakes.

Table 1 shows the number of water bodies studied in the 22 hydrographic basins of São Paulo State, the number of water bodies that present a limnetic zone, and the frequency of occurrence of the four species in each hydrographic basin.

Thermocyclops decipiens was the most frequent species, having been found in 71% of the water bodies with a limnetic region, and occurring in all the hydrographic basins with the exception of the Mantiqueira. *Thermocyclops minutus* was found in 25% of the water bodies with a limnetic region. This species occurred in a large number of the water bodies considered oligotrophic. It was distributed in the three largest river basins: Tietê, Parapanema, and Rio Grande, but was not found in the Mantiqueira, Litoral Norte, Baixada Santista, and Ribeira do Iguape basins.

Thermocyclops inversus and the new species, *Thermocyclops iguapensis*, were rare, the former occurring in 8% and the latter in 6% of the limnetic samplings. Both species occurred in several reservoirs of the Ribeira do Iguape Basin. *Thermocyclops inversus* was recorded also in water bodies from the Pardo, Alto Tietê, Mogi, Tietê/Jacaré, Turvo Grande, and São José dos Dourados basins. *Thermocyclops iguapensis* was recorded only in the Ribeira do Iguape and Paraíba do Sul basins, so that its distribution was restricted to the hydrographic basins, which are coastal basins, located n. sp. in the east of São Paulo State where the rivers flow to the Atlantic Ocean.

Fig. 5 shows the distribution maps of *Thermocyclops decipiens*, *Thermocyclops inversus*, *Thermocyclops minutus*, and *Thermocyclops iguapensis* n. sp. in São Paulo State obtained from the SINBIOTA Atlas (www.biota.org.br).

TABLE 1
 Number of samples studied in each of 22 the hydrographic basins, number of reservoirs with limnetic zone, and the frequency of occurrence of *Thermocyclops* species recorded for each hydrographic basin.

Hydrographic basins	Number of water bodies sampled	Number of water bodies with limnetic zone	<i>Thermocyclops decipiens</i>	<i>Thermocyclops minutus</i>	<i>Thermocyclops inversus</i>	<i>Thermocyclops iguapensis</i> n. sp.
Mantiqueira (1)	19	3	–	–	–	–
Paraíba do Sul (2)	8	5	5	0	0	2
Litoral Norte (3)	11	3	1	0	0	0
Pardo (4)	5	4	3	0	2	0
Piracicaba/Capivari/Jundiá (5)	6	6	3	0	0	0
Alto-Tietê (6)	16	12	9	3	1	0
Baixada Santista (7)	7	4	2	0	0	0
Sapucaí-Mirim/Grande (8)	4	3	2	3	0	0
Mogi-Guaçu (9)	29	19	16	2	1	0
Sorocaba-Médio-Tietê (10)	3	3	1	1	0	0
Ribeira do Iguape e Lit. Sul (11)	11	11	11	0	5	6
Baixo Pardo/Grande (12)	7	5	3	2	0	0
Tietê/Jacaré (13)	21	15	7	4	1	0
Parapanema (14, 17 and 22)	7	7	7	6	0	0
Turvo/Grande (15)	13	12	8	0	1	0
Tietê/Batalha (16)	8	3	2	2	0	0
São José dos Dourados (18)	5	3	1	2	1	0
Baixo Tietê (19)	8	3	4	3	0	0
Aguapeí (20)	12	5	5	4	0	0
Peixe (21)	7	5	4	1	0	0
Total	207	131	94	33	12	8
Frequency of occurrence	–	131	71%	25%	9%	6%

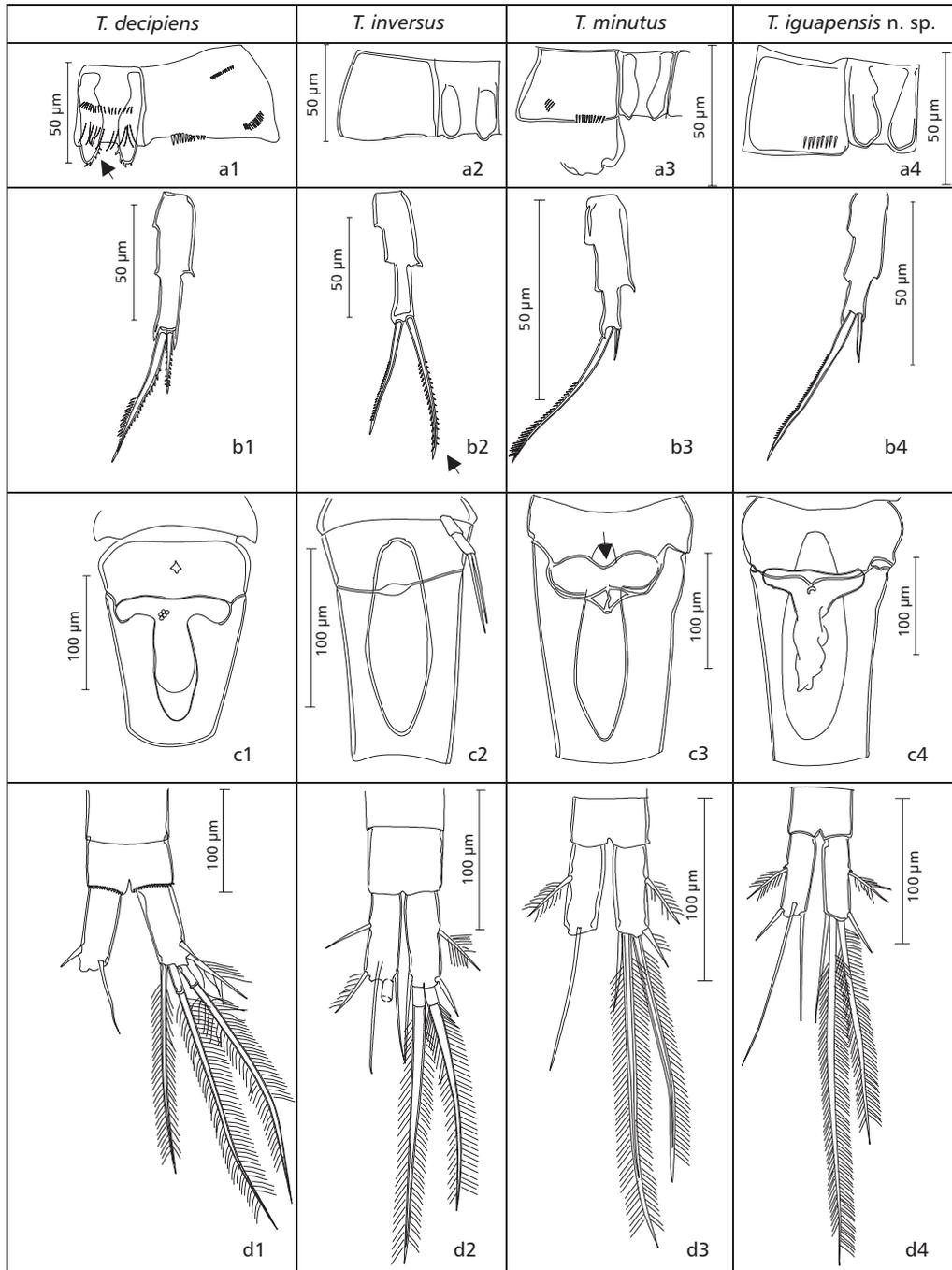


Fig. 4 — Differential characteristics of the species of *Thermocyclops*: a) coxopodite and intercoxal sclerite; B) 3rd endopodite of leg 4; C) genital segment; D) anal somite and furcal rami.

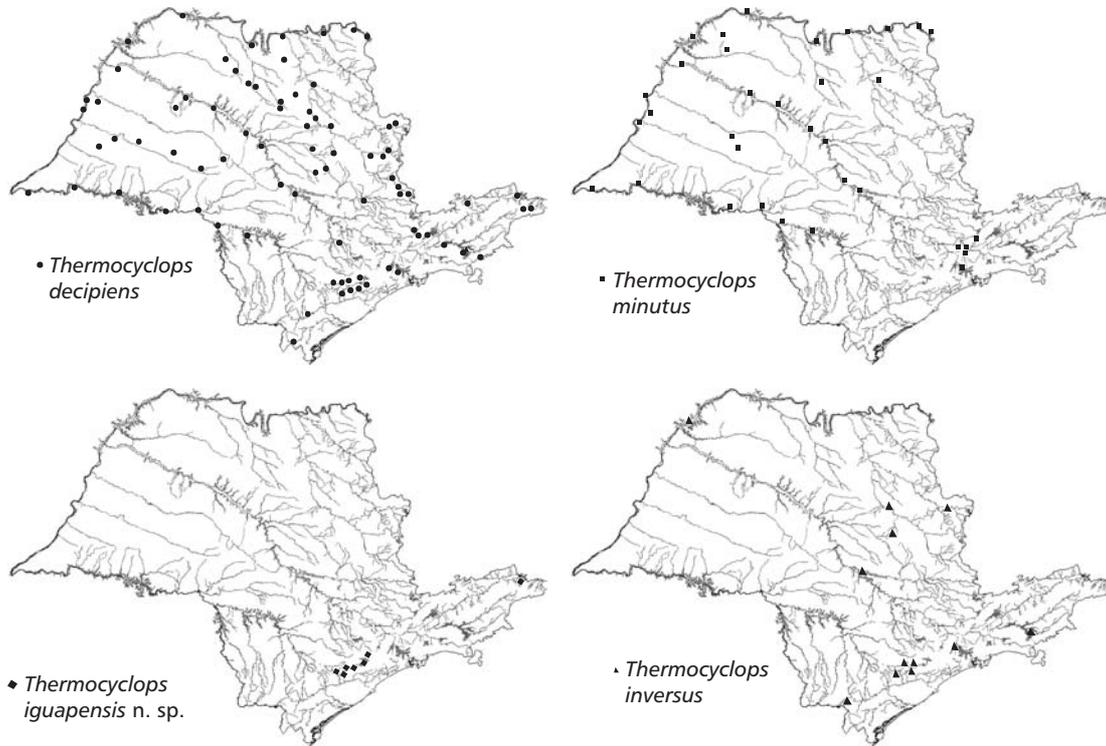


Fig. 5 — Distributions of *Thermocyclops* species in São Paulo State. a) *Thermocyclops decipiens*, b) *Thermocyclops minutus*, c) *Thermocyclops iguapensis* n. sp., d) *Thermocyclops inversus*.

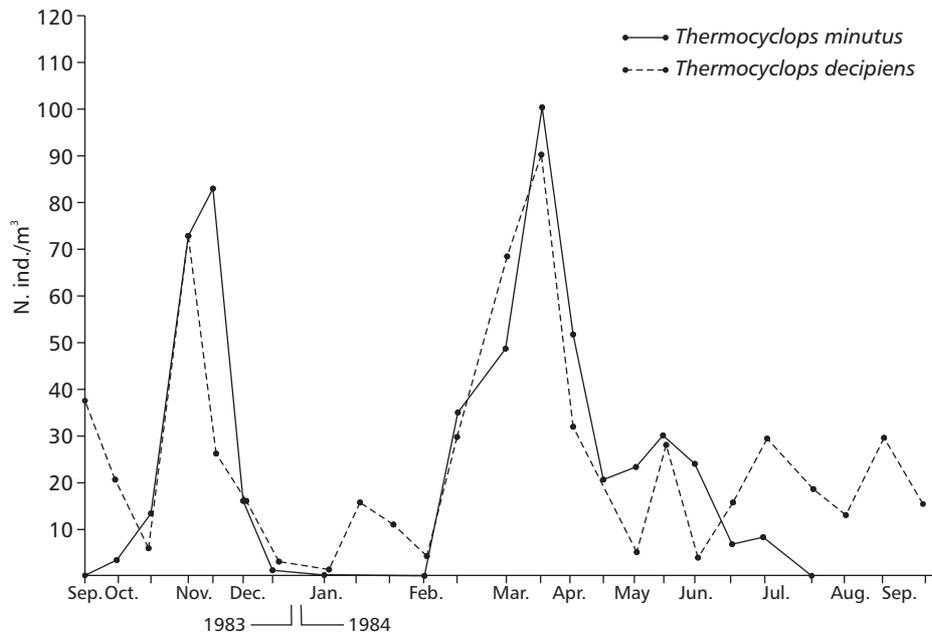


Fig. 6 — Seasonal fluctuation of *Thermocyclops decipiens* and *Thermocyclops minutus* in Barra Bonita Reservoir.

Seasonal fluctuation of Thermocyclops populations in Barra Bonita Reservoir

Barra Bonita Reservoir is the first of six reservoirs constructed in cascade in the Middle Tietê River Basin (Fig. 1). The reservoir receives from the Tietê River all the domestic and industrial sewage produced in the metropolitan area of São Paulo, SP, as well as pollution from the Piracicaba River, another tributary. The reservoir presents eutrophic characteristics with high concentrations of phosphorus, nitrogen, and chlorophyll, and frequent presence of cyanobacterial blooms. The abundances in this reservoir of two species of *Thermocyclops*, *T. decipiens*, and *T. minutus*, from September 1983 to September 1984, were analyzed at a time when the reservoir was meso-eutrophic. Both populations showed high abundances during the same periods (November-December and March-April). However, while *Thermocyclops minutus* disappeared completely in some periods (the end of July to October), *Thermocyclops decipiens* occurred throughout the period (Fig. 6).

DISCUSSION

Thermocyclops iguapensis n.sp. was found only in two basins of São Paulo State: the Ribeira do Iguape and Paraíba do Sul. Sendacz & Kubo (1982) found it in the water bodies of those basins, but identified the species as *Thermocyclops minutus*. *T. iguapensis* n. sp. as well as *T. inversus* have narrow geographical distributions, being restricted to the hydrographic basins in the eastern part of São Paulo State.

The most frequent species, *Thermocyclops decipiens*, has wide geographical distribution occurring in many types of water bodies in all of the hydrographic basins, whereas *Thermocyclops minutus* is less widely distributed, thus indicating more restrictive ecological requirements. The occurrence of these two species in Barra Bonita Reservoir (which this time was meso-eutrophic) with similar abundances in some periods of the year and complete disappearance of *Thermocyclops minutus* in other periods (mainly in the winter and spring) indicates that the two species probably present some different ecological requirements. Much evidence shows that *Thermocyclops minutus* is common in

oligotrophic and mesotrophic environments (Matsumura-Tundisi & Tundisi, 1976; Tundisi *et al.*, 1997). Silva & Matsumura-Tundisi (2002) recorded clear patterns of dominance of *Thermocyclops minutus* over *Thermocyclops decipiens* in oligo-mesotrophic reservoirs and dominance of *T. decipiens* over *T. minutus* in eutrophic reservoirs.

The co-occurrence of *Thermocyclops inversus* and *Thermocyclops decipiens* in some eutrophic water bodies of the Ribeira do Iguape Basin (Iporanga and Jurupará reservoirs) showed that *Thermocyclops inversus* outnumbered *Thermocyclops decipiens* (Table 1). Thus, the former species probably has better adaptive strategies than does *Thermocyclops decipiens* in eutrophic systems.

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REFERENCES

- DUMONT, H. J. & DECRAEMER, W., 1977, On the continental Copepod fauna of Morocco. *Hydrobiologia*, 52(2-3): 257-278.
- MARGALEF, R., 1983, *Limnología*. Ediciones Omega, Barcelona.
- MATSUMURA-TUNDISI, T. & TUNDISI, J. G., 1976, Plankton studies in a lacustrine environment. *Oecologia* (Berl.), 25: 265-270.
- MATSUMURA-TUNDISI, T. & SILVA, W. M., 1999, Crustáceos Copépodos planctônicos. In: C. A. Joly & C. E. M. Bicudo (orgs.), Biodiversidade do Estado de São Paulo, Brasil. 4. *Invertebrados de Água Doce*. FAPESP, São Paulo, pp. 91-100.
- REID, J. W., 1989, The distribution of species of the genus *Thermocyclops* (Copepoda Cyclopoida) in the Western Hemisphere, with description of *T. parvus*, new species. *Hydrobiologia*, 175: 149-174.
- ROCHA, C. E. F. & BOTELHO, M. J. C., 1998, Maxillopoda-Copepoda. Cyclopoida. In: P. S. Young (ed.), *Catalogue of Crustacea of Brazil*. Museu Nacional, Rio de Janeiro, pp. 129-166 (Série Livros N.6).
- ROCHA, O., SENDACZ, S. & MATSUMURA-TUNDISI, T., 1995, Composition, biomass and productivity of zooplankton in natural lakes and reservoir. In: J. G. Tundisi, C. E. M. Bicudo & T. Matsumura-Tundisi (eds.), *Limnology in Brazil*. ABC/SBL, Rio de Janeiro.

- SENDACZ, S. & KUBO, E., 1982, Copepoda (Calanoida e Cyclopoida) de reservatórios do Estado de São Paulo. *Boletim do Instituto de Pesca* 9 (único), pp. 51-189.
- SILVA, W. M. & MATSUMURA-TUNDISI, T., 2002, Distribution and abundance of Cyclopoida populations in a cascade of reservoirs of the Tietê River (São Paulo State, Brazil). *Verh. Internat. Verein. Limnol.*, 28: 667-670.
- TUNDISI, J. G., MATSUMURA-TUNDISI, T., FUKUARA, H., MITAMURA, T., ROCHA, O., GULLEN, S. M., HENRY, R., CALIJURI, M. C., IBANEZ, M. S. R., ESPÍNDOLA, E. L. G. & GOVONI, S., 1997, Limnology of fifteen lakes. In: J. G. Tundisi & Y. Saijo (eds.), *Limnological studies on the Rio Doce Valley Lakes*. ABC, USP, CRHEA, pp. 265-274.