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Seasonal dynamics of *Callibaetis willineri* (Ephemeroptera, Baetidae) associated with *Eichhornia azurea* (Pontedericeae) in Guaraná Lake of the Upper Paraná River, Brazil

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Abstract

Nymphs of the *Callibaetis willineri* Navás, 1932 colonize *Eichhornia azurea* in Guaraná Lake, a várzea (floodplain) lake of the Upper Paraná River. The plants were sampled monthly from October 1997 to October 1998. Higher abundances of *C. willineri* coincided with months of higher dissolved oxygen concentrations in the water, suggesting that the nymphs were sensitive to variations in dissolved oxygen. The presence of different size classes and the predominance of small specimens suggest that this species has asynchronous development.

Introduction

Aquatic macrophytes increase the productivity of lakes by increasing niches and food resources (Newman, 1991), shelter (Delariva et al., 1994), and sites for egg deposition and emergence for some species of macroinvertebrates (Monahan & Caffrey, 1996). Aquatic plants are not directly eaten by invertebrates (Hynes, 1970), but their roots act as a net and promote the input of detritus (Da Silva et al., 1994), an important food source for nymphs of Ephemeroptera.

The life cycles of the ephemeropteran have been extensively studied in temperate regions (Sweeney & Vannote, 1981; Ward & Stanford, 1982; Clifford, 1982; Giberson & Rosenberg, 1992; Tabacchi et al., 1993; Sweeney et al., 1995; Gibbs & Siebenmann, 1996; Kukuła, 1997). Investigations in the tropics are sparse (Smock, 1988; Jacobi & Benke, 1991), especially in floodplains (Stagliano et al., 1998). In Brazil, the few studies on ephemeropteran life cycles include those of Ferreira & Froelich (1992), Melo et al. (1993), and Da Silva (1997, 1998).

The surface of Guaraná Lake, a floodplain lake in the Upper Paraná River valley, is extensively covered by aquatic macrophytes (Souza & Stevaux, 1997), including *Eichhornia azurea* (Schwartz) Kunth. Nymphs of *Callibaetis willineri* Navás, 1932 colonize *E. azurea*. The objective of the present study, the first on *C. willineri* associated with *E. azurea*, was to analyze the density temporal variation of nymphs in relation to changes in abiotic factors (temperature, dissolved oxygen, conductivity, pH, transparency and depth) in Guaraná Lake.

Study area

The study was carried out in a lentic environment in the floodplain of the Upper Paraná River, state of Paraná, Brazil. Guaraná Lake (22° 43′ 26″ S; 53° 18′ 03″ W) is located in the várzea (floodplain) on the right bank of the Baía River, with which it communicates by a permanent lateral channel. The surrounding vegetation is composed of mainly Poaceae and *Polygonum*, and *Eichhornia azurea* dominates the littoral zone of the lake (Fig. 1).

The level of the Paraná River influences Guaraná Lake. According to the daily hydrological level of the Paraná River, two phases were established: high water phase from November to March 1998 and May to

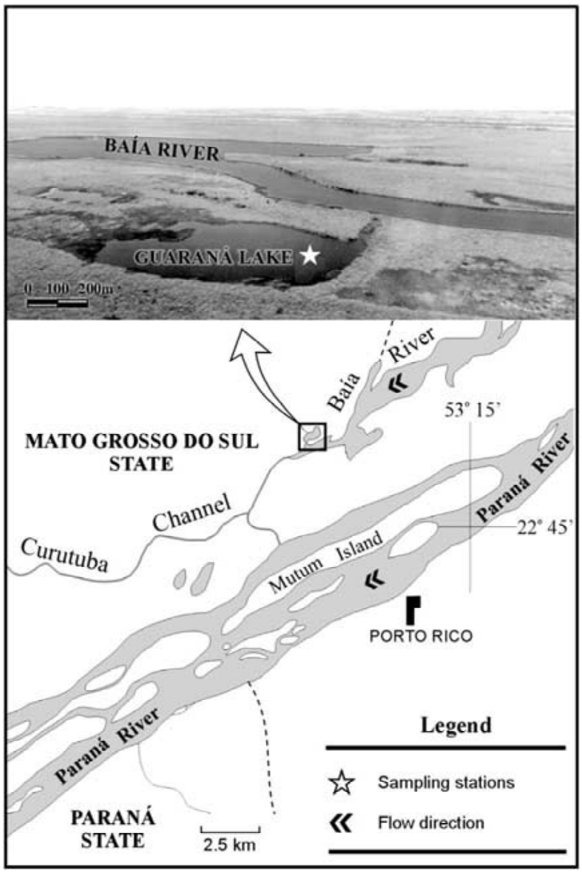

Figure 1. Study area and location of the sampling sites.

October 1998; and low water phase for the remaining months (Fig. 2).

Data for the Paraná River level were taken at Porto São José, state of Paraná, and furnished by ANEEL (Agência Nacional de Energia Elétrica). Monthly means for water level were used in the data analyses.

Materials and methods

Collections of *Eichhornia azurea* were made monthly from October 1997 through October 1998. The plant stolon was pulled out of the water by the floating leaf stalk, until nearly all the root cluster was exposed, and was collected in three different segments. Each segment (root and stalk) was conditioned in a polyethylene flask and preserved in 80% methanol. Next, the plant parts were scraped and washed with 80% methanol to remove adherent particles, and the root and stalk portions were oven-dried at 60 °C. The density of nymphs was calculated per 100 g plant dry weight.

At each collecting site, water transparency (by Secchi disc), depth (m), and temperature (°C) were measured. Water samples were collected with a Van Dorn bottle from surface, middle, and near-bottom depths for laboratory determinations of pH and electrical conductivity (μS cm^{-1}) by portable digital potentiometer and conductivity meter respectively. Dissolved oxygen (mg l^{-1}) was measured by the Winkler method as modified by Golterman et al. (1978).

In the laboratory, the nymphs were sorted, identified, and counted using a stereoscopic microscope. The interocular distance (distance between the eyes) and body length (tip of the head to the tip of the last abdominal segment) were measured to determine the monthly changes in the different size classes. The monthly data for interocular distance were grouped at 0.1 mm intervals, which resulted in eight length classes. Nymphs with interocular distance less than 0.3 mm were considered 'small'.

To aid in the identification of the nymphs, adults were collected monthly in the same area. The winged forms were collected at night using a light trap during about 1 h. Adults of *C. willineri* were found just in August, September and October 1998. Body size length of all adults was measured.

Linear regression analysis was used to evaluate the relationship between interocular distance and body length. To establish the monthly difference in nymph sizes, analysis of variance with repeated measurements (ANOVA) with the STATISTICA program, version 5.0, was used.

Results

Water temperatures were higher during the high water phase. Water transparency was greater during low water, because the water was less turbid. However, dissolved oxygen was low during high water, and approached anoxia in March and April. The pH remained slightly acid throughout the study period (Table 1).

The nymphs reached their greatest density in June (820 ind. 100 g d.w.$^{-1}$). No individuals were found in March and April (Fig. 3). Small nymphs predominated in most months (Fig. 4).

The regression analysis demonstrated a linear relationship between interocular distance and body length ($R^2 = 0.80$; $p<0.001$). The regression formula for

Table 1. Mean values of the physical and chemical variables

Months	Water temperature (°C)		Dissolved oxygen (mg l^{-1})		Conductivity (μS cm^{-1})		pH		Transparency (m)	Depth (m)
	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	$\bar{x}$
October	**29**	0	**6.60**	0.28	**23**	0	**6.4**	0	**0.55**	**1.55**
November	**28**	2.0	**1.72**	1.36	**28**	4.93	**5.8**	0.08	**0.65**	**2.10**
December	**29**	0	**1.45**	1.62	**23**	0.58	**5.8**	0.05	**0.50**	**2.15**
January	**33**	0.57	**3.44**	0.90	**22**	0.61	**5.8**	0.05	**0.65**	**1.80**
February	**29**	1.0	**1.60**	0.96	**23**	1.35	**5.3**	0.04	**0.95**	**1.80**
March	**27**	0	**0.57**	0.19	**29**	0.35	**5.2**	0.15	**0.65**	**3.00**
April	**24**	1.0	**0.63**	0.37	**34**	7.21	**5.5**	0.27	**0.45**	**3.00**
May	**23**	1.52	**1.96**	1.49	**17**	1.14	**5.2**	0.18	**0.95**	**2.00**
June	**21**	0.29	**7.29**	0.12	**17**	0	**5.4**	0.14	**0.90**	**1.20**
July	**23**	0	**5.31**	0.49	**17**	0	**5.9**	0.05	**1.10**	**1.50**
August	**24**	0.58	**3.55**	0.65	**23**	1.0	**5.8**	0.02	**0.85**	**1.80**
September	**21**	1.0	**3.65**	0.79	**22**	0.70	**5.6**	0.01	**0.70**	**2.50**
October	**27**	1.0	**1.61**	1.09	**19**	1.0	**5.4**	0.12	**0.95**	**2.50**

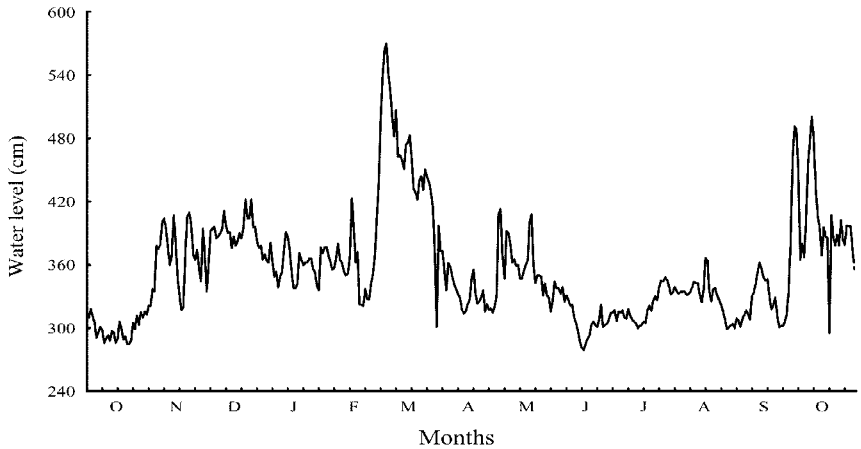

Figure 2. Monthly water level variation of the Paraná River at Porto São José (Paraná).

body length was:

$$L_t = 0.54 + 9.23^* L_h,$$

where L_t = body length, and L_h = interocular distance.

The analysis of variance showed a significant difference in interocular distance between months ($p<0.01$).

Despite the adults sampling was qualitative (total of 15 individuals), the body size length of adults varied among months. The mean ($\bar{x}$) and standard deviation (sd) in August was 0.77 and 0.08, respectively, and in September the means was 0.75 and standard deviation 0.05, and October $\bar{x}$= 0.49; sd = 0.01.

Discussion

In subtropical floodplains, river level strongly influences the concentration of dissolved oxygen. In floodplain lakes, dissolved oxygen concentrations decrease during the high water phase (Takeda et al., 1991; Thomaz et al., 1997). Irmler (1975) established that in Amazonian floodplains, oxygen depletion is a stress factor for aquatic invertebrates and causes decreased abundance.

In Guaraná Lake, the hypoxic conditions in March and April were probably responsible for the complete absence of *Callibaetis willineri* from the stands of *Eichhornia azurea*, suggesting that the nymphs are sensitive to low dissolved oxygen. Moreover, the

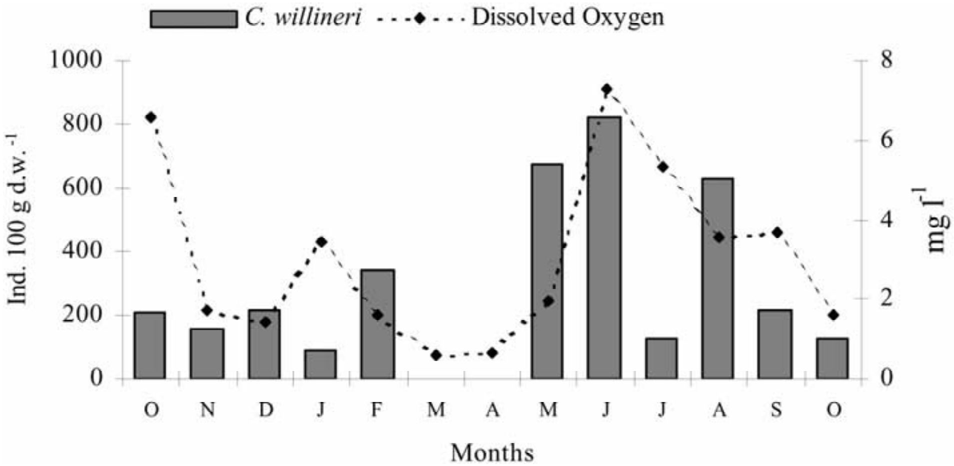

Figure 3. Variation monthly in density of *Callibaetis willineri* in relation in relation to dissolved oxygen concentration.

peak abundance of this species coincided with the months of highest dissolved oxygen concentrations. *Callibaetis montanus* in a small lake (Kolar & Rahel, 1993) and *Cloeon* sp. (Samways et al., 1996) also did not tolerate hypoxic conditions. Brittain (1982) established that low dissolved oxygen concentration was critical in limiting the survival of certain Baetidae.

In temperate regions, temperature is the main factor influencing the nymphs life cycle (Ward, 1992). Most immature aquatic insects show well defined size classes, in synchrony with the seasons of the year. Temperature directly influences development as well as food supply (Rader & Ward, 1989; Brittain, 1990; Takemon, 1990; Benke et al., 1992; Giberson & Rosenberg, 1992; Kukuła, 1997). Gibbs & Siebenmann (1996) established that the life cycle of *Siphlonisca aerodromia* at the edge of the floodplain of the Tomah River (U.S.A.) was adapted to the seasonal cycle of the river: the nymphs migrated from the river to the floodplain in search of locations with higher temperatures (in winter) for emergence of subimagoes, and shelter from predation in the submerged vegetation.

Cressa (1986) suggested that the life cycle of several nymphs was adapted to environmental changes in order to guarantee their survival. During the flood stage, the nymphs of *C. willineri* are able to attach themselves to the aquatic plants by means of their long claws, which guarantees their survival the strong currents. Although eggs were not found in the present study, first instar nymphs were present in most months, suggesting frequent oviposition.

Nymphs have several types of life cycle (Clifford, 1982). The non-seasonal polyvoltine cycle cycle is characterized by the presence of nymphs in several size classes (nymphal cohort) during the year, and by asynchronous development. The observations on *C. willineri* reported here also show the non-seasonal life cycle with emergence throughout the year.

According to Clifford (1982), it is important to distinguish cohorts among generations and one criterion often used to distinguish the two generations is that the adults of the summer generation are often much smaller than the winter generation adults. In this research, adults of August and September were relatively larger than October. The October nymphs may indicate another generation. In March and April, hypoxic conditions with complete absence of nymphs of C. *willineri* were probably responsible for the absence or very few numbers of adults in following months.

In the tropics, seasonality is marked by variation in annual rainfall, and the hydrological regime is highly dynamic (Poi de Neiff & Carignan, 1997). High temperatures favor rapid development of ephemeropterans, in multivoltine asynchronous life cycles (Cowell & Vodopich, 1981; Jacobi & Benke, 1991). Growth and emergence may occur at any time of year (Jacobi & Benke, 1991). Oliveira & Froehlich (1997) also noted that in tropical regions, adult and juvenile insect forms, including nymphs, occur year-round in a non-seasonal cycle.

It can be concluded from the distribution of the several size classes during the study period, that nymphs of *C. willineri* in the floodplain lake have polyvoltine development, with main emergence in the late of winter and during spring.

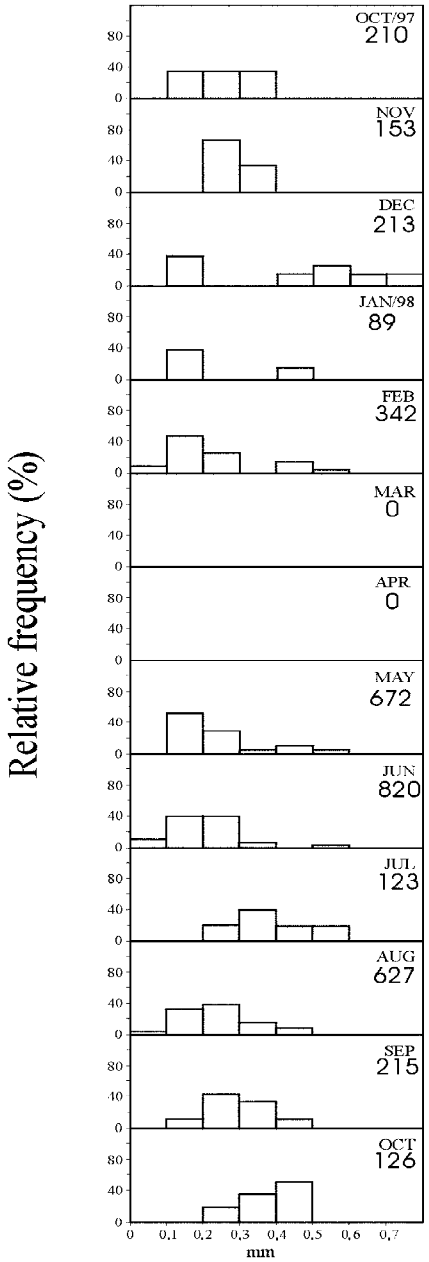

Figure 4. Interocular distance frequency distribution and total density of *Callibaetis willineri* nymphs in Guaraná Lake, Brazil.

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References

Brittain, J. E., 1982. Biology of mayflies. Ann. Rev. Ent. 27: 119–147.

Brittain, J. E., 1990. Life history strategies in Ephemeroptera and Plecoptera. In: Campbell, I. C. (ed.), Mayflies and Stoneflies. Kluwer Academic Publishers, Dordrecht, The Netherlands: 1–12.

Benke, A. C., F. R. Hauer, D. L. Stites, J. L. Meyer & R. T. Edwards, 1992. Growth of snag-dwelling mayflies in a black-water river: the influence of temperature and food. Arch. Hydrobiol. 125: 63–81.

Clifford, H. F., 1982. Life cycles of mayflies (Ephemeroptera), with special reference to voltinism. Quaestiones Entomologicae 18:15–90.

Cowell, B. C. & D. S. Vodopich, 1981. Distribution and seasonal abundance of benthic macroinvertebrates in a subtropical Florida lake. Hydrobiologia 78: 97–105.

Cressa, C., 1986. Variación estacional, distribuición espacial y balance energético de *Campsurus* sp. (Ephemeroptera, Polymitarcyidae) en el lago Valencia, Venezuela. Acta Cient. Venez. 37: 572–579.

Da Silva, C. J., F. Nogueira & F. A. Esteves, 1994. Composição química das principais espécies de macrófitas aquáticas do lago Recreio pantanal matogrossense (MT). Rev. Bras. Biol. 54: 617–622.

Da Silva, E. R., 1997. A alimentação de ninfas de *Callibaetis guttatus* Navás, 1915 (Ephemeroptera, Baetidae) em um brejo temporário do litoral do Estado do Rio de Janeiro. Rev. Bras. Ent. 41: 53–55.

Da Silva, E. R., 1998. Estratégias de adaptação das espécies de Ephemeroptera às condições ambientais da restinga de Maricá, estado do Rio de Janeiro. In Nessimian, J. L. & A. L. Carvalho (eds), Ecologia de Insetos Aquáticos. UFRJ, Rio de Janeiro: 29–40. Série Oecologia Brasiliensis, 5.

Delariva, R. L., A. A. Agostinho, K. Nakatani & G. Baugartner, 1994. Ichthyofauna associated to aquatic macrophytes in the upper Parana river floodplain. Revista UNIMAR, Maringá 16: 41–60.

Ferreira, M. J. N. & C. G. Froehlich, 1992. Estudo da fauna de Ephemeroptera (Insecta) do Córrego do Pedregulho (Pedregulho, SP, Brasil) com aspectos da biologia de *Thraulodes schlingeri* Traver & Edmunds, 1967. Rev. Bras. Entom. 36: 451–458.

Gibbs, E. K. & M. Siebenmann, 1996. Life history of the rare mayfly *Siphlonisca aerodromia* Needham (Ephemeroptera: Siphlonuridae). J. n. am. Benthol. Soc. 15: 95–105.

Giberson, D. J. & D. M. Rosenberg, 1992. Effects of temperature, food quantity, and nymphal rearing density on life-history traits of a northern population of *Hexagenia* (Ephemeroptera: Ephemeridae). J. n. am. Benthol. Soc. 11:181–193.

Golterman, L., R. S. Clymo & M. A. M. Ohmstad, 1978. Methods for Physical and Chemical Analysis of Fresh Waters. Blackwell Scientific, Oxford: 215 pp.

Hynes, H. B. N., 1970. The ecology of stream insects. Ann. Rev. Ent. 15: 25–42.

Irmler, U., 1975. Ecological studies of the aquatic soil invertebrates in three inundation forests of Central Amazonia. Amazoniana 3: 337–409.

Jacobi, D. I. & A. C. Benke, 1991. Life histories and abundance patterns of snag-dwlling mayflies in a blackwater Coastal Plain river. J. n. am. Benthol. Soc. 10: 372–387.

Kolar, C. S. & F. J. Rahel, 1993. Interaction of a biotic factor (predator presence) and an abiotic factor (low oxygen) as an influence on benthic invertebrate communities. Oecologia 95: 210–219.

Kukuła, K., 1997. The life cycles of three species of Ephemeroptera in two streams in Poland. Hydrobiologia 353: 193–198.

Melo, S. M., A. M. Takeda & N. C. Büttow, 1993. Life history of nymphs of *Campsurus violaceus* Needham & Murphy, 1924 (Ephemeroptera, Polymitarcyidae) in the Baía River (MS-Brasil). Revista UNIMAR, Maringá 15: 95–107 (in Portuguese with English abstract).

Monahan, C. & J. M. Caffrey, 1996. The effect of weed control pratices on macroinvertebrate communities in Irish Canals. Hydrobiologia 340: 205–211.

Newman, R. M., 1991. Herbivory and detritivory on freshwater macrophytes by invertebrates: a review. J. n. am. Benthol. Soc. 10: 89–114.

Oliveira, L. G. & C. G. Froehlich, 1997. The Trichoptera (Insecta) fauna of a 'cerrado' stream in southeastern Brazil. Naturalia 22: 183–197.

Poi de Neiff, A. & R. Carignan, 1997. Macroinvertebrates on *Eichhornia crassipes* roots in two lakes of the Paraná river floodplain. Hydrobiologia 345: 185–196.

Rader, R. B. & J. V. Ward, 1989. Influence of impoundments on mayfly diets, life histories, and production. J. n. am. Benthol. Soc. 8: 64–73.

Samways, M. J., R. Osborn & I. Van Heerden, 1996. Distribution of benthic invertebrates at different depths in a shallow reservoir in the KwaZulu-Natal Midlands. Koedoe 39: 69–76.

Smock, L. A., 1988. Life histories, abundance and distribution of some macroinvertebrates from a South Carolina, U.S.A. coastal plain stream. Hydrobiologia 157: 193–208.

Souza-Filho, E. E. & J. C. Stevaux, 1997. Geologia e geomorfologia do complexo rio Baía, Curutuba, Ivinheima. In Vazzoler, A. E. A. M., A. A. Agostinho & N. S. Hahn (eds), A Planície de Inundação do alto rio Paraná: Aspectos Físicos, Biológicos e Socio-econômicos. State University of Maringá: 3–46.

Stagliano, D. M., A. C. Benke & D. H. Anderson, 1998. Emergence of aquatic insects from 2 habitats in a small wetland of the southeastern U.S.A.: temporal patterns of numbers and biomass. J. n. am. Benthol. Soc. 17: 37–53.

Sweeney, B. W. & R. L. Vannote, 1981. *Ephemerella* mayflies of white clay creek: bioenergetic and ecological relationships among six coexisting species. Ecology 62: 1353–1369.

Sweeney, B.W., J. K. Jackson & D.H. Funk, 1995. Semivoltinism, seasonal emergence, and drift size variation in a tropical stream mayfly (*Euthyplocia hecuba*). J. n. am. Benthol. Soc. 14: 131–146.

Tabacchi, E., H. Décamps & A. Thomas, 1993. Substrate interstices as a habitat for larval *Thraulus bellus* (Ephemeroptera) in a temporary floodplain pond. Freshwat. Biol. 29: 429–439.

Takeda, A. M., G. Y. Shimizu, G. M. Shulz & A. C. M. Silva, 1991. Zoobentos de quatro lagoas de várzea do alto rio Paraná (MS-Brasil). Influência do regime hidrológico sobre a comunidade. Revista UNIMAR, Maringá 13: 365–387.

Takemon, Y., 1990. Timing and synchronicity of the emergence of *Ephemera strigata*. In Campbell, I. C. (ed.), Mayflies and Stoneflies. Kluwer Academic Publishers, Dordrecht, the Netherlands: 61–70.

Thomaz, S. M., M. C. Roberto & L. M. Bini, 1997. Caracterização limnológica dos ambientes aquáticos e influência dos níveis fluviométricos. In Vazzoler, A. E. A. M., A. A. Agostinho & N. S. Hahn (eds), A Planície de Inundação do Alto rio Paraná: Aspectos Físicos, Biológicos e Socio-econômicos. State University of Maringá: 73–102.

Ward, J. V. & J. A. Stanford, 1982. Thermal responses in the evolutionary ecology of aquatic insects. Ann. Rev. Ent. 27: 97–117.

Ward, J. V., 1992. Aquatic Insect Ecology. 1. Biology and Habitat. John Wiley & Sons, Inc., New York: 438 pp.