ROTIFER PRODUCTION IN A SHALLOW ARTIFICIAL LAKE (LOBO-BROA RESERVOIR, SP, BRAZIL)

PELÁEZ-RODRÍGUEZ, M. and MATSUMURA-TUNDISI, T.

International Institute of Ecology São Carlos, Rua Bento Carlos, 750, CEP 13560-660, São Carlos, SP, Brazil

Correspondence to: Marlon Peláez-Rodrígues, International Institute of Ecology São Carlos, Rua Bento Carlos, 750, CEP 13560-660, São Carlos, SP, Brazil, e-mail: mapelaez@bol.com.br; tmt.iie@iie.com.br

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(With 3 figures)

ABSTRACT

Rotifer production in a shallow artificial lake (Lobo-Broa Reservoir) was studied for twenty consecutive days between August 25, 1995 and September 13, 1995, during the dry season. Two species were dominant, during this period namely *Filinia pejleri* and *Keratella americana*, contributing, respectively, 36% and 28% to total rotifer numbers. Production estimates of these species were, respectively, 41.93 and 80.70 µg dry weight.$m^{-3}.d^{-1}$, corresponding to 18.45 and 35.51 µgC$m^{-3}.d^{-1}$. The population of *F. pejleri* was numerically more abundant than that of *K. americana*, while the production of the former was less, as a result of lower egg to female ratios.

Key words: Rotifer, production, reservoir.

RESUMO

Produção de populações de Rotifera em um pequeno lago artificial (Reservatório do Lobo-Broa, SP, Brasil)

A produção de rotíferos da Represa do Lobo-Broa foi estudada durante o período de vinte dias consecutivos, no inverno (25/8/95 a 13/9/95). Amostragens diárias foram efetuadas com a finalidade de conhecer a influência das condições físicas e químicas do ambiente na dinâmica das populações de Rotifera em um curto intervalo de tempo. Duas espécies dominaram nesse período: *Filinia pejleri* e *Keratella americana*, as quais contribuíram com 36% e 28%, respectivamente, do total da densidade de Rotifera. A produção secundária dessas espécies foi calculada em 41,93 µgPeso-Seco.$m^{-3}.d^{-1}$ e 80,70 µgPeso-Seco.$m^{-3}.d^{-1}$, correspondendo a 18,45 e 35,51 µgC$m^{-3}.d^{-1}$, respectivamente. A população de *F. pejleri* foi mais abundante que a população de *K. americana*, porém, sua produção foi menor, devido a sua baixa razão ovo/fêmea.

Palavras-chave: Rotifera, produção, reservatório.

INTRODUCTION

Lobo-Broa Reservoir is a shallow, turbulent reservoir located in the center of São Paulo State (Fig. 1). It was constructed in 1936, initially for hydroelectric power supply. Today, besides being used for scientific experimental and applied research, Lobo-Broa Reservoir is used for recreation and sport fisheries. Limnological studies that have been carried out since 1971 show that it is a reasonably preserved environment from the human activities presenting low concentration of nutrients (nitrate 6.50 µg.L^{-1}, ammonium 23.10 µg.L^{-1} and orthophosphate 7.0 µg.L^{-1}); low chlorophyll *a* (4.5 µg.L^{-1}) and a well-oxygenated water column (7.6 mg.L^{-1}) (Rodríguez & Matsumura-Tundisi, 2000).

Trophic relationships studies were carried out by Tavares & Matsumura-Tundisi (1984) and Matsumura-Tundisi & Tavares (1986) involving experiments on feeding rates on phytoplankton by the copepod *Argyrodiaptomus furcatus*; the secondary production of this species was determined by Rocha & Matsumura-Tundisi (1984).

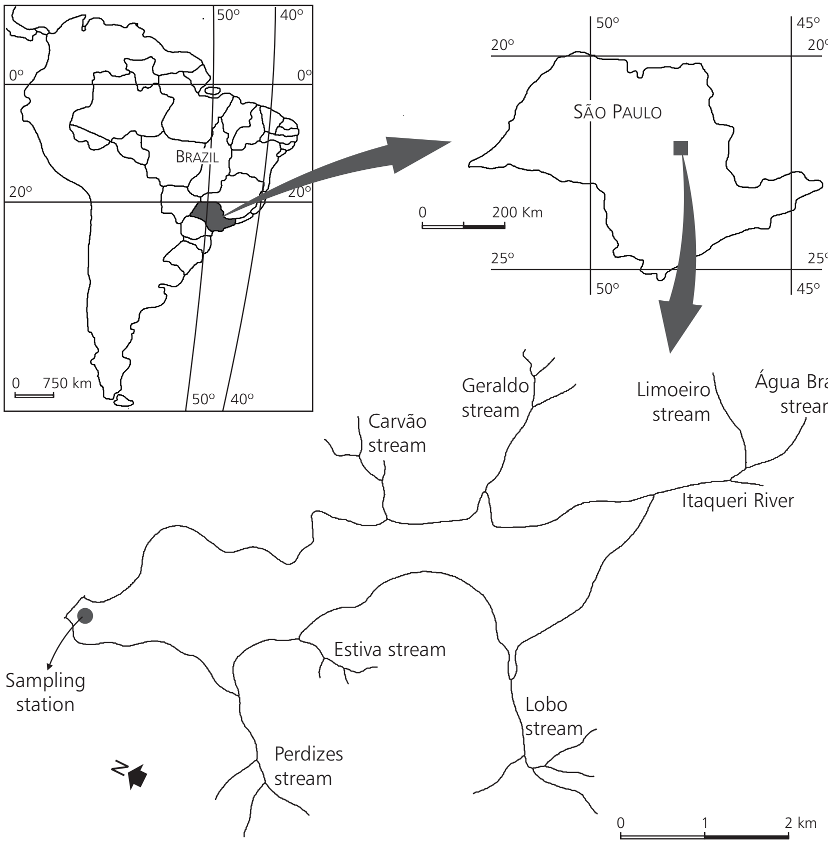


Fig. 1 — Map of Lobo-Broa Reservoir showing its location in São Paulo State and Brazil. Sampling station is also shown.

Of the zooplankton community of this reservoir, the Rotifera contribute about 80% of total abundance (Matsumura-Tundisi & Tundisi, 1976).

Rotifers are considered opportunistic organisms, showing high adaptive capacity, colonizing rapidly a wide variety of habitats and niches. They can constitute an important link in the food chain between the primary producers and secondary consumers, such as fish larvae and benthos (Nogrady *et al*., 1993). The role of the rotifers in energy flow is of great importance due to their high reproductive potential associated with their relatively short life cycles, implying an important conversion of organic matter via production (Winberg, 1971; Elser *et al.*, 1988). The rotifers also participate in recycling of nutrients, and, thereby, in freshwater ecosystem productivity. According to Makarewicz & Likens (1979), of the phosphorous annually incorporated by the zooplankton in Mirror Lake (USA), the rotifers were responsible for about one third.

Secondary production can be defined as the increase in biomass, including reproductive products, within a unit of time. According to Downing (1984), secondary production studies are important in elucidating the transfer of energy and material within the ecosystem, permitting the more rational management of aquatic resources.

Various works have been published with the aim of revising and systematizing concepts and techniques concerning the secondary production of zooplankton organisms (Winberg *et al.*, 1971; Edmondson, 1974; Bottrell *et al*., 1976; Downing & Rigler, 1984).

Estimates of rotifer production are generally carried out based on analyses of values for the finite birth rate and organism dry weight using the recruitment method, according to Elster (1954, 1955) or the method of Galkovskaya (1965) based on generation time (in Edmondson & Winberg, 1971).

The present work aimed in analysing secondary production of Rotifera of Lobo-Broa reservoir using the recruitment method, which is applied principally to organisms, which show slight (almost imperceptible) differences in size between new-born and adult individuals, and involves the direct measurement of the number of organisms and growth rates (Infante, 1988). Such information should provide insights into the productive potential of these organisms, as well as their functional role in the ecosystem.

MATERIAL AND METHODS

Daily samples were carried out at the fixed station of Lobo-Broa Reservoir, near the dam, at the deepest region, which is 10m deep, during the period of August 25 to September 13, 1995. The morphometry and the general characteristics of the reservoir are described in Tundisi *et al.* (1972 a, b).

Zooplankton samples were obtained using net plankton with 40 µm mesh size through the vertical hauls lowering the net to the bottom twice and obtaining approximately 1.3 m^3 of filtered water. The concentrated material was fixed with 4% formaldehyde.

The production of the dominant species of Rotifera during this period (*F. pejleri* and *K. americana*) was calculated using the recruitment method, according to Elster (in Edmondson & Winberg, 1971) based on the values for the finite birth rate and organism dry weight.

$$P = P_N \cdot W$$

where:

P = production in dry weight of organic matter
P_N = recruitment of new individuals
W = mean individual body dry weight

$$P_N = N_f \cdot B$$

where:

N_f = number of females
B = finite birth rate

$$B = \frac{E}{De} \qquad \text{(Edmondson, 1960)}$$

where:

E = proportion of eggs/female
De = egg development time

De was calculated using the formula of Bottrell *et al.* (1976):

$$\ln De = \ln a + b.\ln t + c.(\ln t)^2$$

where:

$\ln a$ = 2.7547; b = –0.2484; c = –0.2408;
t = temperature (°C)

Dry weight (W)

Rotifer dry weight was estimated using an indirect technique of bio volume calculation from body size measurements and application of approximate geometric formulae (Ruttner-Kolisko, 1977).

RESULTS

The production of rotifers of Lobo-Broa Reservoir in the period of August to September 1995 was estimated considering the two most abundant species that occurred in this period: *Filinia pejleri* and *Keratella americana* that performed 64% of rotifer populations (Rodríguez & Matsumura-Tundisi, 2000).

Table 1 shows the temperature, n. of females and n. of eggs for the populations of *Filinia pejleri* and *Keratella americana*. The egg development time (*De*), finite birth rate (*B*), recruitment of new individuals (P_N), necessary parameters to obtain the production (*P*) are presented in the Table 2. The data show that at temperatures between 20.4ºC and 22.2ºC, egg development time varied between 0.72 and 0.83 days, with a mean value of 0.8 days, which is equivalent to 19 hours and 13 minutes.

The bio volume technique used to calculate the dry weight of the two species considered is presented in the Table 3.

The geometric formula used for *F. pejleri* was an ellipsoid of revolution, with appendices (setae) representing 9% of the body volume, while the formula used for *K. americana* was a half cone. The body dimensions measured (in µm), the calculated bio volume (in μm^3), the conversion factor for transforming wet weight to dry weight, and the dry weight biomass (in µgDW). The calculated volume was converted to wet and then dry weight, using, for *F. pejleri* and *K. americana*, respectively, the estimates of dry to wet weight of 11% and 26% for *Filinia terminalis* and *Keratella cochlearis*, respectively, according to Pauli (1989).

TABLE 1

Data of temperature, n. of females.m^{-3} (N_f), n. of eggs.m^{-3} for *Filinia pejleri* and *Keratella americana* obtained in the period of August 25 to September 13, 1995.

Data 1995	Temperature ºC	Number of females.m^{-3} (N_f)		Number of eggs.m^{-3}	
		F. pejleri	*K. americana*	*F. pejleri*	*K. americana*
August, 25	20.7	2462	9615	222	2115
26	20.7	4615	17308	92	4846
27	20.5	1000	7846	0	2275
28	20.7	1231	5846	234	2163
29	21.0	2308	5000	531	1400
30	20.9	4692	3231	235	1066
31	21.5	11308	6692	2035	1673
September, 1	21.5	11769	6462	1412	1551
2	21.3	8462	8385	423	1174
3	22.2	21385	5462	2780	819
4	20.9	17154	12154	1544	2309
5	20.8	20385	20538	2242	4929
6	20.6	19000	17692	2090	2477
7	20.6	45692	15923	5026	2548
8	20.4	39615	26923	1188	4308
9	20.6	35692	31846	4283	7006
10	20.5	43462	33154	3477	5968
11	20.6	29769	25692	1786	5395
12	21.1	34692	47846	694	7655
13	20.4	85077	29769	3403	3572
Mean values	20.9	21988	16869	1979	3711

For *F. pejleri*, mean body length was 121 µm, and mean body width was 54 µm, giving a biovolume of 203,035 µm^3. Applying the wet weight – dry weight conversion factor of 11% gave a dry weight of 0.02 µgind^{-1}.

For *K. americana*, mean body length was 193 µm, and mean body width was 55 µm, providing a bio volume of 79,228 µm^3. Applying the wet weight – dry weight conversion factor of 26% gave a dry weight of 0.02 µgind^{-1}.

Relation between temperature and egg development time

Fig. 2 shows the relation between the water temperature and egg development time for both species considered.

TABLE 2
Data of *De, B, P_N* and *P* (mgDW.m^{-3}.d^{-1}) for two species of rotifers.

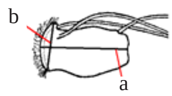
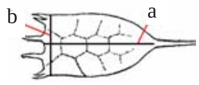
Data 1995	De	B		P_N		P	
		F. pejleri	*K. americana*	*F. pejleri*	*K. americana*	*F. pejleri*	*K. americana*
August, 25	0.81	0.12	0.28	295	2692	5.91	53.84
26	0.81	0.02	0.34	92	5885	1.85	117.69
27	0.83	0.00	0.36	0	2825	0.00	56.49
28	0.81	0.23	0.45	283	2631	5.66	52.61
29	0.79	0.29	0.35	669	1750	13.39	35.00
30	0.80	0.06	0.42	282	1357	5.63	27.14
31	0.76	0.24	0.33	2714	2208	54.28	44.17
September, 1	0.76	0.16	0.31	1883	2003	37.66	40.06
2	0.77	0.06	0.18	508	1509	10.15	30.19
3	0.72	0.18	0.22	3849	1202	76.99	24.03
4	0.80	0.11	0.24	1887	2917	37.74	58.34
5	0.81	0.14	0.30	2854	6161	57.08	123.23
6	0.82	0.13	0.17	2470	3008	49.40	60.15
7	0.82	0.13	0.20	5940	3185	118.80	63.69
8	0.83	0.03	0.19	1188	5115	23.77	102.31
9	0.82	0.14	0.27	4997	8598	99.94	171.97
10	0.83	0.10	0.22	4346	7294	86.92	145.88
11	0.82	0.08	0.26	2382	6680	47.63	133.60
12	0.78	0.03	0.20	1041	9569	20.82	191.38
13	0.83	0.05	0.14	4254	4168	85.08	83.35
Average	0.80	0.11	0.27	2419	4555	48.37	91.09

There is a relationship between temperature and egg development time for both species.

At lower temperatures (20.5ºC) the egg development time takes approximately 21 hours while at more high temperatures (22.5ºC) it takes 17 hours. The productions calculated for both populations of rotifers and their daily fluctuations can be observed in the Fig. 3. The average value of production of *Filinia pejleri* obtained during the consecutive twenty days (August 25 to September 13, 1995) analysed it was 41.93 µgDWm^{-3}.d^{-1} with a maximum value of 118.80 µgDWm^{-3}.d^{-1} while for *Keratella americana* the average value was 80.70 µgDWm^{-3}.d^{-1} with a maximum values of 191.38 µgDWm^{-3}.d^{-1}

The production of *F. pejleri* was low during the first few days of the study, with a tendency to increase, although in an irregular pattern. The production of *K. americana* was relatively high at the beginning of the study period, also tending to increase during the second half of the study. Production of the latter species was generally greater than that of the former.

TABLE 3
Geometric formulae used for the calculation of the body volume, the body dimensions measured (in µm), the calculated biovolume (in μm^3), the conversion factor for transforming wet weight to dry weight, and the dry weight biomass (in µgDW), for *Filinia pejleri* and *Keratella americana*.

Species	Geometric formula used	Measurement used for formula	Dimensions (µm)	Appendices in % of body volume	Biovolume (μm^3)	Factor (wet:dry)	Biomass ($\mu gDWm^{-3}ind^{-1}$)	Body: a = length b = width c = height
Filinia pejleri	Ellipsoid of revolution $\frac{4.\pi.r_1.r_2.r_3}{3}$	a = $2r_3$ b = $2r_1$ c = $2r_2$ b = c	a = 121 b = c = 54	16,767 = 9%	203,035 (μm^3)	11%	0.02	
Keratella americana	½ cone $\frac{\pi.r^2.h}{6}$	a = h b = 2r	a = 193 b = 55	–	79,228 (μm^3)	26%	0.02	

DISCUSSION

Studies carried out in reservoirs have indicated that one of the principal characteristics of such systems is the dominance of rotifers over other groups of zooplankton, when population density is considered. In terms of biomass, whether in dry weight or carbon content, the situation differs (Matsumura-Tundisi & Tundisi, 1986; Matsumura-Tundisi *et al.*, 1989), with the rotifers tending to become the group of least importance, and the Copepoda of most importance. Analysis of biomass gives estimates of the energy stored as organic matter by the population, and, if done for each trophic level, can assist the estimation of energy fluxes within the community and the productive potential of the system. However, the biomass of organisms present at any particular time does not necessarily reflect the rate of production of new matter or the rate of energy processing. Thus, among the zooplankton, the Rotifera can contribute less biomass when compared to such groups as the Cladocera and Copepoda, but have higher turnover times. Thus, when considering functional processes, the analysis of production offers a measurement, which is more realistic concerning the contribution in energetic and resource terms of each of the components of the community. Egg development time is directly related to temperature, with a value for rotifers in the tropics of about 20 hours. Okano (1994) obtained for the species *Brachionus falcatus*, *F. longiseta* and *K. cochlearis* in the reservoir of Monjolinho (SP), where mean water temperature was 20.4ºC, an egg development time of approximately 0.83 day (20 hours). The egg development time for *F. pejleri* and *K. americana* in the present study, where mean water temperature was approximately 20.9ºC, was calculated to be approximately 19 hours. The species from temperate region studied by Edmondson (1960) presented development times of 42 to 43 hours.

Despite the fact that the population of *F. pejleri* was numerically more abundant than that of *K. americana*, the former production was lower as a result of its lower egg ratio. The population size of *K. americana* was also affected by having a higher mortality rate than that of *F. pejleri*.

The Lobo-Broa Reservoir has been considered a nutrient-poor system with low concentrations of Nitrogen and Phosphate, and chlorophyll *a*, and a net primary production of around 0.155 $gCm^{-2}.d^{-1}$, which can be considered relatively, low (Tundisi & Matsumura-Tundisi, 1976, 1995; Rodríguez & Matsumura-Tundisi, 2000). With regard to the zooplankton community, Rocha & Matsumura-Tundisi (1984) calculated the mean annual production of *Argyrodiaptomus furcatus* (the dominant copepod in the reservoir) to be 1.43 $mgCm^{-3}.d^{-1}$ (assuming a carbon content of 38% of dry weight (Matsumura-Tundisi *et al.*, 1989). This is considerably greater than that measured for the rotifers in the present study. Nevertheless, the reservoir is becoming more eutrophic with the increase of human activities in the vicinity and recent data of nutrients have shown higher concentration of nitrate (797 $\mu g.L^{-1}$) and phosphate (36.7 $\mu g.L^{-1}$) in the discharge of the main tributaries (data of July, 2001). For a greater understanding of production in this reservoir, it would be desirable to analyse the other zooplankton groups, such as the Cladocera and Protozoa, and other species of Copepoda.

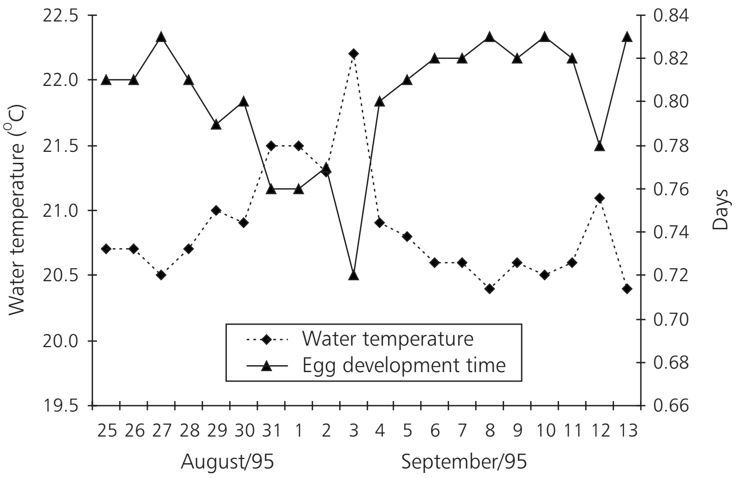


Fig. 2 — Daily variation in water temperature and egg development time during the period of August 25 to September 13, 1995, in the Lobo-Broa Reservoir.

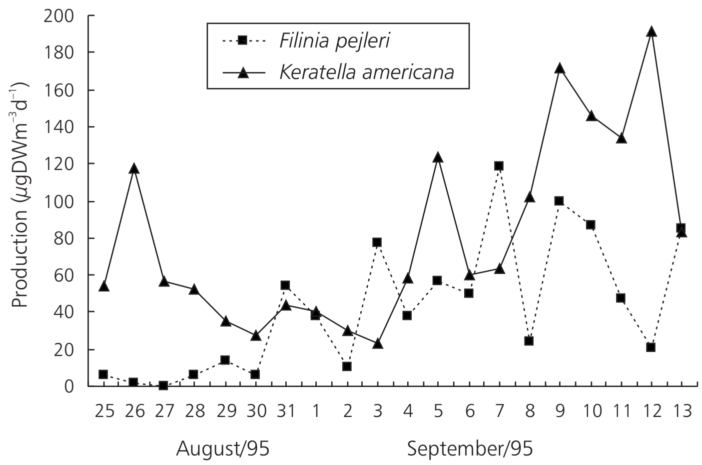


Fig. 3 — Daily variation in production (μgDWm^{-3} d^{-1}) of *Filinia pejleri* and *Keratella americana*, during the period of August 25 to September 13, 1995, in the Broa Reservoir.

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