Biologia Geral e Experimental

Universidade Federal de Sergipe

Biol. Geral Exper., São Cristóvão, SE 8(2):21-28 02.viii.2008

DIEL CHANGES IN THE SIZE STRUCTURE OF A *MOINA MINUTA* HANSEN, 1899 POPULATION (ANOMOPODA: MOINIDAE) IN AN AMAZONIAN FLOODPLAIN LAKE.

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ABSTRACT

In this study we analyzed the size structure of a *Moina minuta* population in order to verify the possible effects of predation pressure on a population of a small bodied cladoceran species. During two days in November of 1998 we collected samples at 1200, 1500, 2100, 0300 and 0900 hours in lago Camaleão, a Central Amazonian, island, floodplain lake of the Amazon River, near Manaus, Amazonas. At this time the water level of the river was at the lowest level of the annual hydrological cycle. The frequency of the six size classes encountered changed from day to night. During the day immature size classes made up between 71% and 80% of the population and at night the mature size classes made up between 65% and 72% of the population. This marked change in the size structure of the *M. minuta* population is attributed to size-selective predation by vertebrates during the day and by invertebrates during the night. The implications of this diurnal selective predation for studies on the population dynamics of small bodied tropical cladocerans are discussed.

Key words: population, size structure, *Moina minuta*, cladocera, Central Amazon Basin.

RESUMO

Neste estudo analisamos a estrutura de tamanho dos indivíduos de uma população de *Moina minuta*, um pequeno cladócero, para verificar a ocorrência de pressão de predação sobre esta população. Durante dois dias em novembro de 1998 coletamos amostras às 1200, 1500, 2100, 0300 e 0900 horas no lago Camaleão, um lago de várzea da Amazônia Central no rio Amazonas, região de Manaus, Amazonas. Nesta época, o nível de água do rio estava no seu nível mais baixo do ciclo hidrológico anual. A freqüência das seis classes de tamanho encontradas variou durante o dia e a noite. Durante o dia, as classes de fêmeas imaturas compuseram entre 71% e 80% da população e durante a noite as classes de fêmeas maduras compuseram entre 65% e 72% da população. Esta variação marcante na estrutura de tamanho da população de *M. minuta* é atribuída a predação seletiva, por vertebrados durante o dia e por invertebrados durante a noite. São discutidas as implicações desta predação seletiva diurna sobre os estudos da dinâmica de populações de pequenos cladóceros tropicais.

Palavras-chave: populações, estrutura de tamanho, *Moina minuta*, cladócera, Amazônia Central.

INTRODUCTION

Compared to pelagic communities in temperate zones, pelagic communities in the tropics are made up of smaller cladoceran species. Sarma *et al*. (2005) recently discussed the ecological implications of these smaller bodied communities, particularly with respect to the life history strategies of the different species. In the pelagial of lakes in the Brazilian Amazon the most common dominant cladoceran species are the small *Bosminopsis deitersi, Ceriodaphnia cornuta,* several species of *Bosmina*, *Moina minuta*, the little larger *Moina reticulata* and the still larger *Diaphanosoma* species and *Daphnia gessneri* which in itself is a small daphnid. Sarma *et al*. (2005) suggested that while vertebrate and

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invertebrate predation can have a profound effect on the population dynamics and demographic characteristics of temperate cladoceran species, in the tropics, fish are probably the most important predators. We suggest that, in the tropics, the smaller bodied cladoceran species are very likely to be subject to invertebrate predation and even both, invertebrate and vertebrate predation. In this study we examined this possibility by analyzing the diel population size structure of a small bodied cladoceran in the field.

MATERIAL AND METHODS

Study area: Zooplankton and limnological data were collected at one sampling station in lago Camaleão (3°15'S, 59°57'W), located on the island of Marchantaria, Amazon River (Figure 1). A comprehensive overview of the limnology and ecology of floodplain in general, lago Camaleão in particular, can be found in Junk (1997). It should be mentioned, however, that lago Camaleão has changed over the years principally due to sandbank formations at the mouth of the lake (N-Barbosa *et al.*, 2007). Consequently, during low water period, the lake remains isolated from the river for a longer period of time and also does not dry out completely as it once did.

Samples: On November 12 and 13 of 1998 physical and chemical parameters of the water and zooplankton samples were collected in lago Camaleão at 1200, 1500, 2100, 0300, and 0900 hours. Water transparency was measured with a Secchi disc and temperature, dissolved oxygen, pH and conductivity were measured *in situ*, at half meter or one meter intervals, with portable WTW ProfiLine OXi197, pH197 and LF197 sensors attached to a cable. The plankton samples were collected by towing a 55 µm plankton net from the bottom to the surface several times. Buffered formalin was added to the plankton samples to a final concentration of 6%.

The composition of the zooplankton community was determined by examining subsamples from each sample in a ruled volumetric chamber with an Olympus CBA 43306 microscope. The first 3000 or so organisms in each sample were identified and counted, except for *Chaoborus* larvae. These were not counted. The population size structure of the dominant Cladocera species was determined by examining subsamples from each sample with the Olympus microscope. The first 1200 specimens were measured with an ocular micrometer at a 40x magnification. The length of the specimens was measured in a straight line from the top of the head to the middle of the posterior carapace. The preliminary results of these analyses were presented as an abstract at the VIII Congresso Brasileiro de Limnologia (Robertson *et al.*, 2001)

RESULTS

Limnological variables

In November of 1998 lago Camaleão was 2.5 meters deep, the physical and chemical data has been compiled in Table 1. The Secchi disc readings were the same during the two sampling days, 0.75 meters, and the euphotic zone extended to 2.0 meters. The mean temperature of the water column varied little, between 30.6°C (0900 hours) and 31.6°C (1200 hours) during the two-day sampling period. The pH value of the water column varied between 6.78 (0900 hours) and 7.13 (2100 hours) and the mean value of electrical conductivity in the water column was almost always 161µS/cm. The water column was well oxygenated and often supersaturated during the two-day study period.

Zooplankton

The zooplankton community was made up of testate amoebae, rotifers, cladocerans and copepods, represented almost entirely by cyclopoid nauplii and, only in the night samples, *Chaoborus* sp. larvae. Four species of Cladocera were found: *Moina minuta, M.*

Figure 1. Island of Marchantaria and the lago Camaleão (3°15'S, 59°57'W – red mark), Amazon River. Landsat 7 ETM+.

reticulata, Diaphanosoma birgei and *D. spinulosum,* but *Moina minuta* was clearly the dominant cladoceran, occurring with a frequency of 96% of all Cladocera.

Moina minuta

The *M. minuta* population was made up of parthenogenetic females only: no males or ephipial females were found. Six size classes were detected: neonates measuring 256.0 µm, two classes of immature females measuring 281.6 µm and 307.2 µm, primiparas measuring 332.8 µm, and two classes of mature females measuring 358.4 µm and 384.0 µm. The frequency of the size classes changed markedly from day to night (Figure 2). During the day, at 1200 and 1500 hours, on November 12 and again at 0900 hours on November 13, the immature size classes together made up 80%, 74% and 71% of the total population. At night, at 2100 hours on November 12 and 0300 hours on November 13, the contribution of the immature size classes diminished markedly and the mature size classes made up 72% and 65% of the total population. The mature females were carrying from 2 to 5 eggs or embryos.

Table 1. Limnological parameters in the Camaleão lake, November of 1998.

	depth (m)	1200 h	1500 h	2100 h	0300 h	0900 h
SD	-	0.75	0.75	not taken	not taken	0.75
EZ	-	2.03	2.03	not taken	not taken	2.03
	0.0	31.8	32.1	31.4	30.9	30.7
	0.5	31.8	32.0	31.5	30.9	30.6
TºC	1.0	31.8	31.1	31.4	30.9	30.6
	1.5	31.6	31.6	31.4	30.9	30.6
	2.0	31.2	31.4	31.4	30.9	30.5
	2.5	31.1	31.0	31.0	30.9	30.4
	0.0	6.93	7.07	6.94	6.82	6.78
pH	1.0	7.03	7.08	7.07	7.01	6.93
	2.0	7.01	7.08	7.13	7.03	6.93
	2.5	7.01	7.01	7.05	7.02	6.96
	0.0	160.0	160.0	161.1	162.1	161.0
EC	1.0	159.8	159.8	160.7	162.3	161.5
	2.0	161.1	161.1	160.8	162.5	161.3
	2.5	161.1	161.6	162.7	162.2	161.5
	0.0	9.2	7.7	10.0	8.1	5.5
	0.5	8.4	7.7	8.6	8.2	5.9
O_2	1.0	8.2	7.1	8.5	8.0	8.2
	1.5	7.6	6.9	9.0	7.8	6.5
	2.0	6.4	5.5	8.6	7.7	7.4
	2.5	6.4	4.3	5.4	7.6	7.4

SD, Sechi disc (m) TºC, temperature O_2, dissolved EC, electrical
EZ, euphotic zone (m) oxygen (mg/L) conductivity (μS_{25}/cm)

DISCUSSION

Invertebrate and vertebrate predators

The change in the size structure of the *M. minuta* population from day to night most probably is the result of size-selective predation by both vertebrate and invertebrate predators. That is, the result of fish preying on the larger individuals during the day and *Chaoborus sp*. larvae feeding on the smaller animals during the night. It should be mentioned that we did not observe any *Chaoborus* specimens in our day samples, and if not for the night samples, it would be tempting to presume there were none. It may be that the lago Camaleão *Chaoborus* larvae species does not just lie at the bottom of the lake, but like the *Chaoborus flavicans* larvae, buries itself in the mud (Gosselin & Hare, 2003).

As with most Amazonian floodplain lakes, a large number of fish species can be found in lago Camaleão (Junk *et al*., 1997). Bayley (1983), for

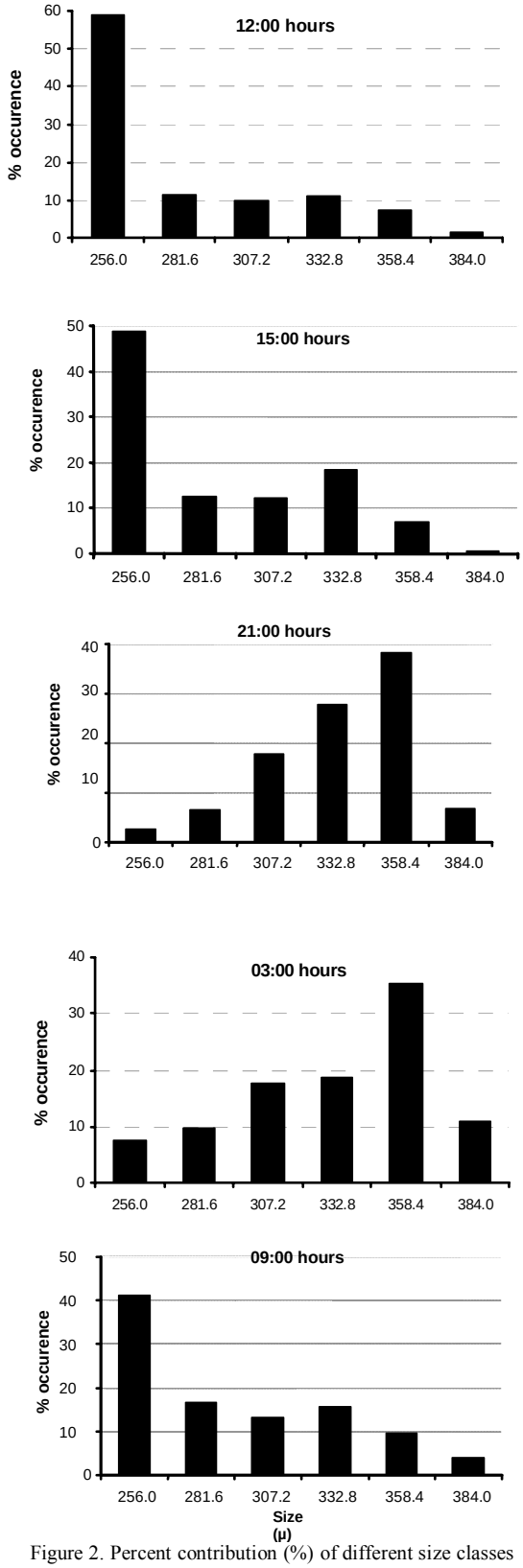

Figure 2. Percent contribution (%) of different size classes of a *Moina minuta* population during the low water period in lago Camaleão during the day and at night.

example, recorded more than 226 species in his study of the fish community at the mouth of the lake. Not all occur year round, but at all times there are adults, juveniles and larvae of fish in Amazonian floodplain lakes (Leite, 2000; Chu Koo, 2000; Valente da Silva, 2004).

At the same time as our study, in November of 1998, Chu Koo (2000) recorded 19 species of small 15-120 mm fish inhabiting the aquatic macrophyte stands in lago Camaleão. Almost all species were observed performing daily lateral migrations. They left the macrophyte stands for the open water between 0600 and 0900 hours and migrated back between noon and 1800 hours. Of these reported fish species, seven were feeding on pelagic zooplankton. Similar, but less detailed, diurnal changes in the size structure of a *Daphnia gessneri* and *Ceriodaphnia cornuta* population was observed in lago Calado by Caraballo & Hardy (1995), who also attributed the changes to size selective invertebrate and vertebrate predation.

Population dynamics

A diel changing population structure of tropical zooplankton species has important implications in studies based on exponential population growth model, births rate and mortality across age classes (Taylor & Slatkin, 1981; Taylor, 1988). Taylor & Slatkin (1981) suggested that "because birth rate estimates depend on the properties of the age or stage distributions this suggests that these properties could be used to test whether a population satisfies the assumption of an exponential model", and that "the stability of the age distribution can be tested by comparing the proportions of an animal in particular stages for successive samples taken at short intervals of time. The egg ratios or proportions of animals in any other stage can be used. If the proportions change, the age distribution is not stable". This certainly was the case of the *M. minuta* population we studied: age distribution, egg ratios and consequently birth rates and mortality were not uniform or stable over a 24-hour period.

Obviously, not all tropical zooplankton populations are as unstable over a 24-hour period. In tropical Lake Lanao, Lewis Jr. (1979) did not find any significant differences between the day and night samples for any of the Cladocera or rotifer species. He also comments that there was only a small amount of fish predation and that the mortality of the zooplankton was probably almost entirely due to *Chaoborus* predation.

In the Venezuelan floodplain lake, Laguna la Orsinera, Twombly & Lewis Jr. (1989) studied five cladoceran species, including *Moina minuta*, in order to target factors controlling population dynamics. Sampling was intense, four days a week, but all samples were collected during the day, between 0900 and 1200 hours. However, in discussing potential sources of error, the authors mention that with regards to unstable stage distribution, "Taylor & Slatkin (1981) have shown that egg ratio estimators, and particularly Paloheimo´s formula, are robust when stages or age structure departs from stability". In Laguna la Orsinera all five cladoceran species had consistent high birth rates, but also high death rates, which restricted populations to small sizes during most of the study period. On the other hand, the authors attributed the occasional brief maximum to an increase in birth and population growth rates, and hatching from resting eggs. The high birth rates and small population sizes indicated that mortality controlled cladoceran dynamics in Laguna la Orsinera and this mortality was attributed to intense fish and *Chaoborus* larvae predation.

If sampling should to be undertaken in intervals smaller than the generation time for the study of zooplankton population dynamics in general (e.g. Bottrell *et al*., 1976), we would like to reiterate what Caraballo & Hardy (1995) suggested, particularly for the tropics. They proposed that where nocturnal events can change the population size structure, this period must be carefully examined, as to not implicate presumptions, calculations and considerations based only on daytime population size structure.

Body size at different stages

We were interested as well in knowing if and how the size spectrum of the lago Camaleão *M. minuta* population was affected by the intense day and night predation. The size spectrum of a *M. minuta* population studied by Melo (1998) in the black water lago Cristalino, was 250 - 507 µm, with large females carrying up to 6 eggs. He used Stibor & Lampert´s (1993) method to determine primiparas in the field and these fell into his 0.3 mm size class category. Keppeler & Hardy (2002) studied *M. minuta* populations during the low water and high water period in lago Amapá. The size of the primiparas during the low water and the high water phases was 330 µm and 340 µm, which agree well with Melo´s (1998) and our measurements for *M. minuta* primiparas (Table 2).

Keppeler & Hardy (2002) also observed a mean size of ovigerous females of 501 µm during the low water season and 533 µm during the high water season, which agrees quite well with Melo´s (1998) largest females. Keppeler & Hardy (2002) give two sizes of neonates, 150 µm and 250 µm. One, 250 µm, is the same size as that found in the lago Cristalino and the lago Camaleão *M. minuta* populations. The largest female found in the lago Camaleão population measured 384 µm, while the largest females in lago Cristalino and lago Amapá measured 507 µm and 595 µm, respectively. It appears that *M. minuta* populations tend to have neonates in the range of 250 µm and primiparas in the range of 330 µm, but under the duress of intense daily and nocturnal predation, lose a substantial part of the large end of the size range.

Final considerations

The marked diel change in the population size structure of *M. minuta* observed in lago Camaleão may be the result of a particular combination of variables in the lake at the time of our study. For example, the high water temperatures and consequently, the high metabolic rates. The water temperature in lago Camaleão at the time of our study was in the range of

Table 2. *Moina minuta* populations, lakes Amapá, Cristalino and Camaleão.

Size of Neonate (µm)	Size of Primipara (µm)	Size of individuals (µm)	Mean size of ovigerous females (µm)	Maximum number of eggs	Lake	Source
150-250	330-340	150 –595	501-533	4.41-4.84	lago Amapá	Kepppeler & Hardy (2002)
250	300	250 –507		6	lago Cristalino	Melo (1998)
256	332.8	256-384		5	lago Camaleão	This study

The Amapá lake was sampled once during the high water period and once during the low water period, hence the size ranges.

30°C. As for the water transparency, it is not often that white water floodplain lakes have a 2.0-meter euphotic zone during the peak low water period. Also, that both kinds of predators, vertebrate and invertebrate, were present. This may not be the case throughout the year. For example, for reasons that are not entirely clear, when the turbid Amazon River water flows into the lakes, the zooplankton diminishes and sometimes disappears (Brandorff & Andrade, 1978; Hardy *et al*, 1984).

On the other hand, as the inflow of the river water lessens, the suspended material precipitates and, at the peak high water period, transparency can again increase to 2.0 meters (Furch & Junk, 1997). Also temperatures tend to be high year round; so one would not expect Amazonian zooplankton species to have very different metabolic rates at different times during the year. And, except when the lakes dry up completely, small fish predators are always present. Overall there is almost no information with respect to invertebrate predators preying on zooplankton and very little on the *Chaoborus* species larvae in floodplain lakes in particular. However, there is some evidence that *Chaoborus* larvae are present not only during the low water period, but also during the high water period in lago Camaleão.

Chu Koo (2000) who studied the small fish fauna associated with aquatic macrophyte stands in November of 1998 repeated the study in April of 1999, during the high water period. He reported that eighteen species of fish were identified during the low water period and nineteen during the high water period, but only 6 species overlapped. Also that during the high water period the species performing lateral migrations were moving out of the macrophyte stands, between 1500 and 2100 hours, and returning between 0600 and 1500 hours. Four of these fish species were feeding on pelagic zooplankton and two were feeding almost exclusively on *Chaoborus* larvae. This suggests that, throughout most of the year, vertebrate and invertebrate predation in lago Camaleão are the main biotic factors influencing the population dynamics of zooplankton species.

However, white water floodplain lakes come in all shapes and sizes (Melack, 1984) and the timing and impact of the inflow of the river water depends on the nature and extent of the connection of the river to the lakes (Robertson & Hardy, 1984). It is probable that both vertebrate and invertebrate predators are not present at all times. We postulate, however, that even if there is only one kind of predator, when predation pressure is intense there will still be a significant change in the population size structure of the prey between night and day. This remains to be seen. Nevertheless, for studies on the population dynamics of small bodied tropical zooplankton we strongly recommend: i) sampling must be intense, practically on a daily basis, ii) nocturnal predation events must be considered, iii) sampling programs must necessarily include taking samples at night.

Acknowledgments: Dr. Gerd-Oltmann Brandorff and Dr. Edinaldo Nelson dos Santos Silva, for their valuable suggestions. Msc. Thiago Morato de Carvalho provided the image of the study area, and Nupélia´s (Universidade Estadual de Maringá, Paraná) zooplankton laboratory and associated scientists, in particular Dr. Fabio Amodeo Lansac-Tôha, for the opportunity to analyze the plankton samples.

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Aceito: 15.6.2008