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COMPARISON OF DIFFERENT *Moina minuta* POPULATIONS DYNAMICS ECLODED FROM RESTING EGGS IN A SEMI-ARID REGION IN BRAZIL.

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ABSTRACT:

This work analysed the different population dynamics of *Moina minuta* hatched from ephippia in different dry environments (reservoirs and river) after rain, in a semi-arid region in Paraíba state, Brazil. All the environments were lentic, because the amount of rain water was not enough to flow the river, and it only remained with a little lagoon. Percentage of ephippia females, parthenogenetic females, males and juveniles in populations were analysed. Biometric measures were also developed, comparing body length in ephippial and parthenogenetical females in the reservoirs and the river studied. Results obtained in cladoceran populations were correlated with environmental chemical variables. In Soledade reservoir a high proportion of females produced ephippia, while in the other reservoirs and river the percentage of ephippial females was much lower.

Key words: cladocera, resting eggs, population dynamics, semi-arid.

INTRODUCTION

In semi-arid regions as well as in extremely cold regions, animals need to have special adaptations to survive extreme environments. In Branchiopoda diapause has been observed in fossils since geological periods. These resting eggs enabled them to live in temporary ponds and in extremely cold habitats, thus allowing them to counter adverse conditions and to act as dispersal agents (4). According Hairston & Cáceres (7), crustaceans found in inland water bodies, especially those that ocasionally become dry, are more likely to possess a diapausing stage than those living in open oceans. This happens due to selection pressure exerted on crustacean species by the environments where they live, and as result of their phylogenetic history. Still according the same authors, resting egg duration time is very variable, depending on each species, but in the calanoid *Onychodiaptomus sanguineus* the duration of diapause can be 70 years. Cladoceran eggs, however, can be viable for 55 years (7) and those of rotifers 35 years (3) though this is not the rule.

Arbaciauskas & Gasiunaité (2) observed that life history traits of ephippial and parthenogenetic generations of *Daphnia* differ substantially. Daphniids hatching from resting eggs grow faster and their body sizes are bigger than those hatching from subitaneous eggs. Because this they mature a few days earlier than parthenogenetic females. Fecundity of the ephippial generation is markedly higher.

In temperate regions the environmental cue to produce resting eggs is the photoperiod (8; 9), the population density (8; 9), the decrease in food quantity (5) and in some cladocerans by the presence of predators (11).

In northeast Brasil, severeral dams were constructed to decrease the impact of drought on humans. During normal years, these dams, especially the bigger ones, keep water during dry season, although their water levels strongly decrease. In especially dry years, these environments become completely dry, including some rivers. Little dams almost always dry out during the drought season. This happened during 1998 in Taperoá Basin, a semi-arid region in northeast Brasil, where 3 dams and a river completely dried. After first rain, *Moina minuta* was the first cladoceran species to appear. This study compared the different population dynamics of *M. minuta* ecloded from ephippial eggs in 3 dams and in one river, that spent some months completely dry. In most environments water remained for all hydrological cycle, after rain fall, but in Soledade Dam, it only remained for approximately 20 days. Nevertheless in

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all environments *M. minuta* disappeared from water column, staying only as diapause stages, in epphippia. The aim of this work was to compare the different densities, fecundities, percentage of male, juveniles, ephhippial females and corporal length of the different populations and to detect which environmental cues are responsible for the formation of epphippial eggs in *M. minuta*.

STUDY SITES

Taperoá River - Is a temporary river in a semi-arid region in Paraíba state, in the northeast of Brazil. It was dry for more than a year. After the first rain, some pools appeared on its sandy bed. As rain was not abundant, the river waters did not run and the environment remained lentic. *M. minuta* was collected 15 days after rain. This species only was present during 2 weeks after the first sample. Later, only copepods and rotifers were present.

Soledade Dam - Soledade is also located in Taperoá River Basin, but in a dryer region. This dam has maximum capacity of 27 058 000 m3 and was completely dry for 3 years. The first sample was done a week after rain fall. The next week this species disappeared and one week after the dam was completely dry again.

Taperoá Dam - This is a very large dam in the same Basin. Water remained in the dam during the dry period until a month before the rain. After that, only a litle pond remained with water, on the deeper site. This water was hypereutrophic with a bloom of Euglena sp. and the only zooplankters present were 3 species of rotifers, being *Brachionus urceolaris* the more abundant. The rain was very abundant, and after 3 days the dam was full. The first sample was taken 2 weeks after rain, when *M. minuta* was present in high densities, but one week later none were observed.

State Dam - This dam is about 3 Km from Taperoá Dam, and is very small (100 m x 30 m). It was completely dry before the rain, and received water when the others did. Nevertheless, as this dam is located downstream of the other, received less water. In this dam the first sample was collected two weks after the rain and *M. minuta* remained here one week more than in Taperoá Dam.

MATERIAL AND METHODS

Samples were first collected 7 and 15 days after the beggining of rain. This difference occurred because the rain period was not the same in all environments.

Samples were taken by filtering 40 liters of litoral water through a 50 µm mesh filter. In each environment three replicates were collected. Material was preserved with a 4% formol solution, satured with sugar. Enumeration and length measurements were done using a binocular microscope with a micrometric ocular.

Data analysis:

One way ANOVA was used to compare measurements of body length in adults and juvenile of *M. minuta*. Males were not included. To discriminate between juveniles and adults, we measured adult ovigerous females's length and considered all lower values as juveniles.

Densities represent the mean of 3 replicates.

Pearson correlation was used to correlate densities, and percentage of stages and sex proportion in populations with physical and chemical parameters in the environments. Only the first sample was suitable for correlation analysis as in later samples *M. minuta* was not found in Soledade Dam and Taperoá Dam.

Analysis of fecundity and growth rates were also performed. Fecundity was estimated from the following equation, $F = \frac{E}{A} \times (A+)$, where E is medium number of eggs, A is adult females and (A+) is adult females with eggs/embryos. Growth rate was obtained by the equation: $r = \frac{Ln\,N1 - Ln\,N0}{t1 - t0}$, where N1 is the final population density and N0 is the initial one, t1 is the final time and the t0 the initial time.

Chemical variables were analysed following standard methods: Total phosphorus and chloride (1); sulphate (6); silicate, nitrite and amonium (10); nitrate (12) and dissolved oxygen (6).

RESULTS

After the start of the rain in the semi arid region studied, water remained in ponds and in the river, until the rest of the season, except in Soledade Dam, where the rainfall was less and about 20 days after rain fall, all water disappeared.

The active life-cycles of *M. minuta* were very short. In the four environments analysed, supposing that this species hatched as soon as it rained, *M. minuta* was present in the water column less than 40 days. 12 days after ephippial eggs be produced, M. minuta was not seen again. In Soledade Dam and Taperoá Dam, epphippia were produced approximately 7 and 15 days respectively after rain fall. In State Dam and Taperoá River, ephippia were produced aproximately on day 27.

In State Dam, *M. minuta* population dynamics changed during the time this species was actively present in water column. Fecundity values, percentage of juveniles and percentage of males decreased from day 15 to day 27. Ephippial eggs were observed only on day 27 (Table I). Density slightly increased from

day 15 to day 27, as well the percentage of these individuals in the zooplankton community. In the next sample, 14 days later, M. minuta was not observed anymore. The active cycle of this species in the water of this dam was at least 27 and no more than 41 days.

In Taperoá Dam, *M. minuta* was detected in the first sample, on day 15, but not later (day 27). The active life cycle in this population was shorter than in State Dam. Fecundity values, percentage of juveniles and males were lower than those observed at State Dam. On the other hand, densities and percentage of *M. minuta* in the zooplankton community were higher, compared to State Dam, but lower than in the other environments.

In Soledade Dam, ephippial female percentage was the highest of all environments. *M. minuta* was observed only in the first sample, 7 days after raining. In this pond there was little water, at about 40 cm depth, and it completely disappeared few days after rain (aproximatelly 19 days). The active life-cycle was quicker in this pons, less than 19 days. The percentage of *M. minuta* in the community was higher than in the other environments, and density values were only exceeded by those of Taperoá River on day 27 (Table I).

	STATE DAM		TAPEROÁ DAM		SOLEDADE DAM		TAPEROÁ RIVER	
	day 15	day 27	day 15	day 27	day 7	day 19	day 15	day 27
Fecundity (F)	2.69	0.21	1.19		0.23		10.63	0.89
%juveniles	53.61	10.17	22.89		60.15		28.70	82.52
% male	13.30	0	0.65		3.77		2.21	3.37
% ephippial fem.	0	1.89	1.69		41.18		0	5.88
growth rate (r)		0.07		-0.79		-0.93		0.18
Density (ind/l)	9.90	11.80	133.30	0	664.90	0	115.48	1243.67
% of *Moina* in the community	2.26	4.34	32.18	0	61.96	0	27.19	8.30

Tabela 1. - Populational parameters in M. minuta in the four environments analysed

In Taperoá River the fecundity value on the first sample was the highest in all study, F = 10.63, resulting in the percentage of juvenile of the second sample being highest of all samples in the study. Male percentage was similar to those in Soledade Dam, and lower than that observed at State Dam. Densities showed here the highest values on day 27, although the percentage of this species in the community was low. This is due to the presence of the colonial rotifer *Conochilus* sp., present in high densities. *M. minuta* was the second most abundant species.

Analysing the body length of *M. minuta* in the four environments by ANOVA, we detected significant differences between adult females of Taperoá Dam and all of the other environments ($p<0,001$) (Table II), being body length always shorter in Taperoá Dam. Significant differences were also observed between Soledade Dam and Taperoá River ($F1,107 = 12.81$, $p<0,001$), being *M. minuta* bodies larger in Taperoá River. In the two environments where was possible to compare body length over time (Taperoá River and Taperoá Dam), there were no signifficant differences among populations. Juveniles showed different patterns in body length. The only environments that showed no significant differences in juveniles's body length were Taperoá River and Taperoá Dam, all other pairs of environments presented significant differences (Table II). The mean body length values of juveniles were higher in State Dam (0.534 mm), followed by values of Soledade Dam juveniles (0.495 mm). The lower mean value was obtained at Taperoá Dam (0.438 mm). Comparing body length of ovigerous females and ephippial females in Soledade Dam (the only one with both kind of females in sufficient quantity to compare), ovigerous females were significantly larger (Table II).

ANOVA

Sites	length (µm)	N	F	p
adults				
State Dam / Taperoá Dam	731.8 / 586.3	40 / 59	79.34	< 0.001
State Dam / Soledade Dam	731.8 / 701.6	40 / 51	3.00	n.s.
State Dam / Taperoá River	731.8 / 764.4	40 / 56	2.40	n.s.
Taperoá Dam / Taperoá River	586.3 / 764.4	59 / 56	108.83	< 0.001
Taperoá Dam / Soledade Dam	586.3 / 701.6	59 / 51	76.27	< 0.001
Soledade Dam / Taperoá River	701.6 / 764.4	51 / 56	12.81	< 0.001
juveniles				
State Dam / Taperoá Dam	534.0 / 438.5	52 / 42	115.04	< 0.001
State Dam / Soledade Dam	534.0 / 495.2	52 / 56	15.99	< 0.001
State Dam / Taperoá River	534.0 / 442.5	52 / 53	65.01	< 0.001
Taperoá Dam / Taperoá River	438.5 / 442.5	42 / 53	0,11	n.s.
Taperoá Dam / Soledade Dam	438.5 / 495.2	42 / 56	33.53	< 0.001
Soledade Dam / Taperoá River	495.2 / 442.5	56 / 53	20.25	< 0.001
Soledade Dam - females				
Ephippial / ovigerous	673.1 / 748.2	57 / 50	68.91	< 0.001

Tabela 2. Coeficientes de correlação entre os seis primeiros eixos da ordenação por componentes principais e os descritores ambientais.

Positive correlations were found between density and ephippial female percentage, amonium, nitrate and cloride. Ephippial females percentage showed positive correlations with the same variables (Table III).

	fec	%juv	%mal	ephi	dens	PT	silicate	SO4	NO3	NO2	NH4	Cl-	O2	clo a	phae
fec	1.00														
%juv	-0.457	1.00													
%mal	-0.131	0.641	1.00												
ephi	-0.507	0.666	-0.144	1.00											
dens	-0.437	0.534	-0.306	**0.985***	1.00										
PT	-0.488	-0.551	-0.463	-0.218	-0.161	1.00									
silicate	0.915	-0.440	-0.436	-0.190	-0.080	-0.449	1.00								
SO4	-0.610	-0.046	-0.683	0.630	0.704	0.575	-0.266	1.00							
NO3	-0.348	0.543	-0.293	**0.978***	**0.994****	-0.253	0.007	0.640	1.00						
NO2	-0.259	-0.739	-0.556	-0.379	-0.294	**0.969***	-0.235	0.471	-0371	1.00					
NH4	-0.623	0.637	-0.163	**0.988***	**0.972***	-0.079	-0.307	0.710	0.949	-0.257	1.00				
Cl-	-0.511	0.684	-0.121	**1.000****	**0.981***	-0.230	-0.200	0.616	0.974	-0.393	**0.988***	1.00			
O2	0.031	0.269	0.911	-0.533	-0.668	-0.239	-0.361	-0.802	-0.662	-0.264	-0.533	-0.513	1.00		
Clo a	0.038	0.576	-0.124	0.835	0.835	-0.642	0.318	0.257	0.894	-0.694	0.742	0.835	-0.491	1.00	
phae	-0.124	0.689	-0.035	0.902	0.902	-0.598	0.148	0.304	0.926	-0.691	0.826	0.904	-0.433	**0.985***	1.00

Table III - Pearson's correlation analysis among M. minuta populational parameters and chemical factors. N=4 * means $p < 0.05$. ** means $p < 0.01$.

	State Dam	Taperoá Dam	Soledade Dam	Taperoá River
Total P (mg/l)	0.15	0.49	0.15	0.09
Silicate (mg/l)	28.00	36.57	42.60	94.83
Sulfate (µg/l)	6.38	66.09	69.04	18.88
Nitrate (µg/l)	241.33	423.00	1549.67	539.67
Nitrite (µg/l)	19.41	131.48	12.34	26.31
Amonium (µg/l)	499.50	674.50	1813.25	374.50
Chloride (mg/l)	172.85	198.46	1901.34	134.44
Dissolv. oxygen (mg/l)	7.89	2.87	1.97	3.31

Table IV - Chemical parameters in all environments analysed

Chemical parameters showed some differences among environments, particularly in Soledade Dam, where values for nitrate, amonium and chloride were the highest (Table IV).

DISCUSSION

In all environments *M. minuta* ecloded from ephippia, since all of them were completely dry before rain fall. Nevertheless, their life history was different among the dams and the river. This species only was present in the water for 19 (Soledade Dam) and 27 days

(other dams and in the river). To know which environmental or biological factors were responsible for the disappearence of the organisms from the environment we correlated biological with environmental parameters. This shows that the formation of sexual eggs was positively correlated with nitrate, amonium and chloride concentrations. Density was also positively correlated with ephippia percentage, showing that crowding induced ephippia formation as well as occurs in *Daphnia* (9). Once ephippia were produced, population densities began to decline and about 10 days later the populations completely disappeared.

As in Soledade Dam, the water remained less time than in the other environments analysed, and the water presented more salts the induction of ephippia production in the females in the population was high. Nevertheless, in this dam were produced the higher amout of juveniles and the population reached higher densities on first sample. This show that the environmental condition can induce more or less the answer of *M. minuta* dynamics. All the environments but Soledade Dam remained with water and *M. minuta* disappeared from the water column, so other factors beyond chemical parameters must be involved in. Probably food, or other biotic factors can be involved in *M. minuta* disappearence. Decreases in food quantity induces resting egg formation in rotifers (5), this could happen in the study sites after rain. Phytoplankton populations probably highly increased from diapause stages, allowed *M. minuta* to increase population densities, and collapsed due to overgrazing by cladocerans and other organisms in the environments. When densities of *M. minuta* reached high values the kind of eggs were changed from parthenogenetical to ephippia. We will do further research to find answers.

When body length of ovigerous and ephippial females was compared, significantly differences were obtained, being ephippial females smaller than the others. This could mean that the females spent more energy producing ephippia than producing normal eggs or that ephippial females were youngers than the others. As comparations were done in the same dam and at the same time, food did not influenced this body length. Experimental tests must be developed to find out why ephippial females were shorter, than the others.

To conclude, when ephippia began to be produced asexual fecundity values strongly decreased in all sites and consequently the percentage of juveniles, resulting in the complete disappearence of the species few days later. This species presented a short active life cycle in all study sites and was negatively affected by population densities, amonium, nitrate and chloride concentrations.

RESUMO

Comparação de diferentes dinâmicas populacionais de *Moina minuta* eclodidas de efípios numa região semi-árida do Brasil. Este trabalho analisou as diferentes dinâmicas populacionais de Moina minuta eclodidas de efípios em diferentes ambientes secos (açudes e rio), após o início das chuvas, na região semi-árida da Paraíba-Brasil. Todos os ambientes foram lênticos porque a quantidade de água da chuva não foi o suficiente para o rio correr, produzindo apenas uma pequena lagoa. A percentagem de fêmeas efipiais, fêmeas partenogenéticas, machos e juvenis na população foram analisados. Medidas biométricas também foram realizadas, comparando o comprimento do corpo em fêmeas afipiais e partenogenéticas nos açudes e no rio analisados. Os resultados obtidos nas populações de cladóceros foram correlacionados com parâmetros químicos ambientais. No Açude de Soledade uma maior proporção de fêmeas produziu efípios, enquanto nos outros açudes e no rio essa percentagem foi menor.

Palavras chave: cladocera, ovos de resistência, dinâmica populacional, semi-árido

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