BOLETIM DO INSTITUTO DE PESCA
ISSN 1678-2305 online version
Scientific Article

ON FEEDING OF THE FRESHWATER PRAWN LARVAE *Macrobrachium rosenbergii*

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Received: December 05, 2017
Approved: May 07, 2018

ABSTRACT

The hatchery of *Macrobrachium rosenbergii* is a successful activity that supports freshwater prawn farming operations worldwide, although feeding schedules require improvement. As *M. rosenbergii* is assumed to forage at night, *Artemia* nauplii (AN) are normally offered in the afternoon or at night. However, at present, there is neither consensus on the optimum schedule nor the amount of nauplii that should be provided daily during the larval phase. In the present study, two aspects of the provisioning of the *M. rosenbergii* larvae were tested experimentally – (i) the timing of the presentation of the *Artemia* nauplii (08:00 h and 20:00 h), and (ii) the density of the nauplii (5, 10, 20 AN mL^{-1}). The results showed that *M. rosenbergii* larvae feed *Artemia* nauplii preferentially during the daylight hours, and that provisioning during this period supports a 25% increase in productivity. The results also showed that it is unnecessary to provide *Artemia* nauplii at a density up to 5 Na mL^{-1}, not exceeding 10 AN mL^{-1}.

Key words: hatchery; feeding strategies; prey density; productivity.

SOBRE A ALIMENTAÇÃO DE LARVAS DO CAMARÃO DE ÁGUA DOCE *Macrobrachium rosembergii*

RESUMO

A larvicultura do *Macrobrachium rosenbergii* é uma atividade bem-sucedida que possibilita o cultivo dessa espécie em todo o mundo. Todavia, o manejo alimentar na fase larval é um aspecto que ainda pode ser otimizado. A oferta dos náuplios de *Artemia* (NA) ocorre no final da tarde ou a noite, pois é atribuído a essa espécie um comportamento trófico noturno. No entanto, até o momento, não há consenso acerca do período ideal de oferta, nem da quantidade de náuplios, na fase larval. No presente estudo, dois aspectos do manejo alimentar das larvas de *M. rosenbergii* foram testados experimentalmente - (i) o horário da oferta dos náuplios de *Atemia* (8:00h e 20:00h) e (ii) a densidade da oferta (5, 10 e 20 NA mL^{-1}). Os resultados indicam que as larvas de *M. rosenbergii* se alimentam preferencialmente de náuplios durante a fase clara do dia e que a oferta nesse horário promove aumento na produtividade de 25%. Além disso, a oferta de náuplios de *Artemia* deve ser em densidades superiores 5, não excedendo 10 Na mL^{-1}.

Palavras-chave: larvicultura; estratégia de alimentação; densidade de presas; produtividade.

INTRODUCTION

In recent years, a number of advances have been made in the technology used to cultivate the freshwater prawn *Macrobrachium rosenbergii* (De Man 1879), which is generally considered to be the most farmed freshwater prawn in the world (NEW, 2010). The hatchery stage is considered the most difficult step in this culture, one that requires advanced technology and well-designed management techniques, with an adequate supply of food (VALENTI *et al*., 2010; DHONT *et al*., 2010).

Feeding efficiency depends not only on the supply of an optimum amount of nutrients, but also the adequate timing of the feeds. However, there is no consensus on techniques or standardization of procedures, which vary considerably among the different production laboratories (NEW, 2002).

Many studies have recommended feeding the larvae of *M. rosenbergii* on *Artemia* nauplii only once a day (AQUACOP, 1983; VALENTI *et al*., 1998) or to divide feeding into 3–5 events (DANIELS *et al*., 1992; CARVALHO and MATHIAS, 1998; NEW, 2002; VALENTI *et al*., 2010). However, there is a general consensus that the larvae should be fed in the evening or early night, indicating a nocturnal feeding pattern in the larvae. However, there is no evidence that the larvae feed more at night, and in fact, daytime feeding appears to be the norm in the larvae of other *Macrobrachium* species, such as *M. equidens* (Dana 1852) and *M. amazonicum* (Heller 1862), even though the nauplii are supplied only at night (MACIEL *et al*., 2012; GOMES *et al*., 2014).

One other factor that may affect the larval development of *M. rosenbergii* is the density of the nauplii supplied as food. An adequate supply of food is very important, given that this item represents a major cost in the production of post-larvae (DHONT *et al*., 2010). Overfeeding may also increase labor costs for tank cleaning and the maintenance of water quality, while harming the health of the larvae (VALENTI *et al*., 2010; BARBIERI *et al*., 2016), whereas an inadequate diet may lead to an increase in cannibalism as well as an extension of the development time of the larvae. In both cases, a reduction in both survival and productivity is expected. In addition, as *M. rosenbergii* capture nauplii based on encounter rates, low densities of prey can increase the difficulty of finding food (MOLLER, 1978).

AQUACOP (1983) recommends the provision of 5 to 50 *Artemia* nauplii (AN) larvae^{-1}day^{-1}, depending on the development stage of the larvae, while DANIELS *et al*. (1992) recommend 10-100 AN larvae^{-1}day^{-1} based on higher estimates of consumption. BARROS and VALENTI (2003a) observed four levels of intensity of prey consumption in *M. rosenbergii*: larval stages II to IV, with a mean consumption of 40 nauplii per day; stages V and VI, with a mean of approximately 55 nauplii per day; stages VII to VIII, with a consumption of 80 to 100 nauplii per day; and stages IX through XI, when a dietary supplement is needed (BARROS and VALENTI, 2003).

The available feeding protocols diverge considerably on the optimal timing of feeds and the appropriate density of *Artemia* nauplii for *M. rosenbergii* hatcheries, which may interfere with survival rates and the productivity of the larval culture. Given these considerations, the present study aimed to determine whether daytime or nighttime feeding schedules (AN supplying) were more favorable to the development of the *M. rosenbergii* larvae, as well as the optimal density of the nauplii used to feed the larvae.

METHODS

Origin of the animal

Ovigerous female *M. rosenbergii* were collected from the wild in the Bragança region (01°042'9.1" S, 46°38'8.7" W) of northeastern Pará, Brazil. The species is an exotic invader, which has established wild populations in this region (IKETANI *et al*., 2016). The females were taken to the laboratory and the larvae were hatched in brackish (5 ppt), counted, and transferred to the culture tanks.

Culture system

The experiments were conducted in closed-dynamic-systems with water recirculation, constant temperature and biological filtering as described by VALENTI *et al*. (1998). The larvae were housed in black rectangular tanks with a capacity of 15 L. Tank stocking density was 100 newly hatched larvae L^{-1}. The physical-chemical conditions of the water were maintained within the parameters recommended for the species: temperature 28.8 ± 0.8 °C, salinity 12.7 ± 0.7, pH 8.1 ± 0.06, and a 12 h photoperiod (12h dark: 12 h light) (VALENTI *et al*., 2010). The temperature was verified twice a day (8:00h and 18:00h); other parameters (pH and salinity) only once a day (8:00h) aided by multiparameter probe (YSI Professional Plus); and the ammonia and nitrite levels by LabconTest (Table 1).

Experiments

Two experiments were developed: 1. Evaluation of the effects of the feeding schedule on larval development (Feeding Schedule), and 2. Evaluation of the effects of the density of *Artemia* nauplii on larval development (Food Density).

Experiment 1 (Feeding Schedule; FS): the feeding schedules (treatments) consisted of supplying the larvae with *Artemia* nauplii in the early morning (Daytime Feeding Schedule – DFS; 8:00h) or early night (Nighttime Feeding Schedule – NFS; 20:00h). The density of nauplii was adjusted to the intake of each larval development stage (Table 2) following VALENTI *et al*. (1998). The unconsumed nauplii were counted every 12 hours for both treatments in other to verify the feeding intake of nauplli during different day periods. These experiments had six replicates of each treatment, with a total of 12 tanks.

Experiment 2 (Food density; FD): three densities of *Artemia* nauplii (AN) were tested - FD1 – 5 AN mL^{-1}, FD2 – 10 AN

Table 1. Water quality parameters evaluated during larval culture in the two experiments (mean ± SD).

Experiments	Tratament	Total ammonia (mg L^{-1})	Nitrite (mg L^{-1})	Temperature (°C)	Salinity	pH
FS	DFS	0.13 ± 0.02	0.15 ± 0.03	29.6 ± 0.5	12.6 ± 0.7	8.0 ± 0.06
	NFS	0.12 ± 0.02	0.15 ± 0.01	29.8 ± 0.6	12.7 ± 0.7	7.9 ± 0.05
FD	FD1	0.03 ± 0.01	0.09 ± 0.02	28.7 ± 0.7	12.7 ± 0.7	8.2 ± 0.07
	FD2	0.07 ± 0.02	0.12 ± 0.02	28.9 ± 0.6	12.6 ± 0.8	8.1 ± 0.06
	FD3	0.04 ± 0.02	0.14 ± 0.03	28.9 ± 0.8	12.7 ± 0.7	8.0 ± 0.05

Abbreviations: FS = feeding schedule; FD = food density; DFS = daytime feeding schedule; NFS = nighttime feeding schedule; FD1 = food density 1; FD2 = food density 2 and FD3 = food density 3.

Table 2. Feeding table for the culture of *Macrobrachium rosenbergii* larvae (based on the values suggested by VALENTI *et al*., 1998).

Culture day	Dominant stage	*Artemia* (AN mL^{-1} Day^{-1})	Feed ‡ (g day^{-1})	Feed (g meal^{-1})
1-2	I	*	*	*
3-4	II	6	*	*
5-6	II	6	*	*
7-8	IV	6-8	*	*
9-10	V	6-8	*	*
11-12	VI	8	3	1.5
13-14	VII	8	3	1.5
15	VIII	8	3	1.5
16-18	IX	10	3	1.5
19-21	X	12	3	1.5
22-24	XI	14	3	1.5
25	XI-PL	14	3	1.5
26	PL	14	3	1.5

‡Feed (inert diet) proposed by MALLASEN and VALENTI (1998); * not fed.

mL^{-1}, and FD3 – 20 AN mL^{-1}. Twelve tanks were divided into four replicates of each treatment. Once detected the preferential feeding time by the larvae was identified (DFS; 8:00h) it was applied at the second experiment (FD).

Feeding management

In the FS experiment, the *Artemia* nauplii were introduced into each tank once a day, either in the early morning - DFS (Daytime Feeding Schedule - 8:00h) or the early night - NFS (Nighttime Feeding Schedule - 20:00h). The larvae were fed daily with newly hatched *Artemia* nauplii (AN). These schedules were supplemented with an inert diet (MALLASEN and VALENTI, 1998), 1.5 g for meal, from the 11th day of larval culture onwards (Table 2), at 10:00 and 12:00 am for all treatments.

In the FD experiment, the *Artemia* nauplii were supplied (at 8:00h a.m.) at the three fixed densities established for each treatment (see above). The number of nauplii consumed in each tank was counted at each 12 hours after feeding. The inert feed (MALLASEN and VALENTI, 1998) was offering (1.5 g for meal, for two meals at 10:00 and 12:00 am for all treatments), from the 11th day of larval culture onwards.

The Larval Stage Index (LSI) was recorded every two days by the examination of five larvae in each tank (both experiments) following MANZI *et al*. (1977). The larval stages were identified based on the characteristics described by UNO and KWON (1969).

Data analyses

The culture was finalized when most (80%) of the larvae had reached the juvenile stage. Experiment 1 was terminated on the 25th day of culture, and experiment 2 on the 27th day. At this moment, the number of larvae and post-larvae present in each tank was counted. Based on the number of larvae and post-larvae found in each tank, it is possible to calculate rates of (1) final survival, (2) coefficient mortality and (3) survival curve, based on the following equations (MACIEL *et al*., 2012):

$$S_f = N_T / N_0 \quad (1)$$

$$M = - lnS / T \quad (2)$$

$$Nt = N0 \cdot e^{-Mt} \quad (3)$$

where S_f = final survival; N_T = number of larvae and post-larvae taken at the final harvest; lnS = natural logarithm of survival; N_0 = number of larvae stored; M = coefficient of mortality; T = Culture time (days); N*t* = number of larvae present in the tank each day; *M* = coefficient of mortality; e = natural logarithm; and *t* = days of culture (1,2,...25). The T values were 25 and 27 for the experiments 1 and 2, respectively.

The individual consumption of prey (AN larva^{-1}day^{-1}) was obtained by dividing the total number of nauplii consumed per day by the number of *M. rosenbergii* larvae in the tank on that day (estimated by the application of the equations). The survival curve adopted was based on KREBS (1999) and by WINEMILLER and DAILEY (2002) for a single cohort.

This equation considers constant the mortality rate along the time and it is used in ecological population studies and also for fishery stock forecasting. This methodology has previously been applied for *M. amazonicum* and *M. equidens* larvae (MACIEL *et al*., 2012; GOMES *et al*., 2014).

At the end of the larval culture, the average fresh and dry weights of the post-larvae were calculated. Thus, 50 post-larvae were separated, removing the excess of salt by a quick wash with distilled water, followed of the absorption of water excess, made

quickly, using filter paper. Immediately, after this procedure, the larvae were placed in five pre-weighed cartridges of aluminum foil (5 post-larvae cartridge^{-1}) and weighted. To calculate the dry weight, the cartridges were placed in Petri dishes and transferred to an oven at 70 °C for 48 hours. The cartridges were then transferred to a desiccator for two-hours before being weighed on a digital scale (0.1 mg accuracy; SCIENTECH AS, model 210). This same procedure was followed in both experiments.

In both experiments, the experimental design was randomized, and the premises of normality (Shapiro-Wilk) and homoscedasticity (Brown-Forsythe) were confirmed to enable the application of parametric tests. In experiment 1 (FS), the mean consumption of nauplii per day was compared between daytime and nighttime feeds using the *t* test (for all parameters were used the t test as well). In experiment 2 (FD), differences between the means were tested using an analysis of variance (ANOVA) followed by Tukey's test (for al parameters). In both experiments, productivity was measured based on the density of post-larvae per liter of water at the end of the culture.

RESULTS

Experiment 1

The total feeding intake of nauplii in the period of 24-hour was similar for both treatments (DFS and NFS). No statistical difference between the means ($t = 2.06$; $P = 0.052$) were observed during whole rearing (Figure 1A and B). However, the results of this experiment indicate that the timing of the feeds affects the consumption rate of *Artemia* nauplii by daytime period (observed each 12 h). In DFS treatment, was observed a significantly higher intake by the *M. rosenbergii* larvae being recorded during the daytime than the nighttime ($t = 5.80$, $p < 0.0001$) (Figure 1A). In NFS treatment, the consumption of *Artemia* nauplii was similar at the night and daytime (Figure 1B). The larvae eaten half of the nauplii amount at night and the leftover of them were consumed in the daytime period, (in the clear phase of the day).

The two feeding schedules did not affect the larval stage indices (Figure 2), but that nighttime feeding (NFS) had a negative influence on final productivity, which was reduced by 25% (Table 3). The final weight of the post-larvae produced by the culture was not statistically different between treatments (Table 3).

Experiment 2

The intake rate of *Artemia* nauplii was significantly higher in the treatments in which 10 and 20 AN mL^{-1} were offered compared to that in which the density was 5 AN mL^{-1} ($P < 0.05$). The nauplii remaining in the tanks in the different treatments increased in proportion to the density offered (Table 4).

Except during the first days, the *M. rosenbergii* larvae were able to deplete the resource completely at the lowest density of nauplii (5 AN mL^{-1}), although depletion was not observed at the higher densities (10 and 20 AN mL^{-1}). In other words, as the density of prey increased, the intake did not increase

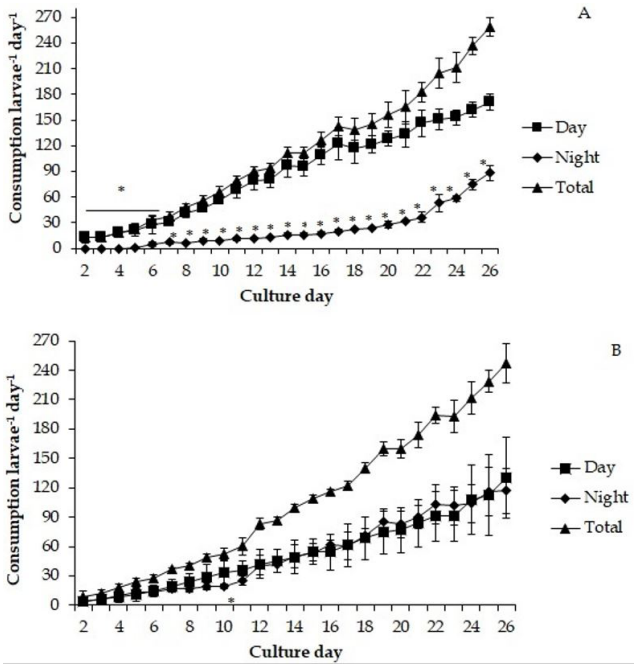

Figure 1. Daytime Feeding Schedule: consumption rate of *Artemia* nauplii by *M. rosenbergii* larvae during the diurnal and nocturnal periods (12 h after feeding) in the two treatments and, total consumption in 24 h. The number of larvae in the culture tanks at each day was obtained according to the mortality rate calculated daily. The asterisk (*) indicates the days on which diurnal consumption was statistical different compared to the night time period in each treatment. The vertical bars represent the standard deviation. (A) Feeding larvae in the early morning (Daytime Feeding Schedule; DFS); (B) Feeding larvae in the early night (Nighttime Feeding Schedule; NFS). For total consumption, in a 24-hour period, there was no difference between treatments DFS and NFS ($t = 2.06$, $P = 0.052$).

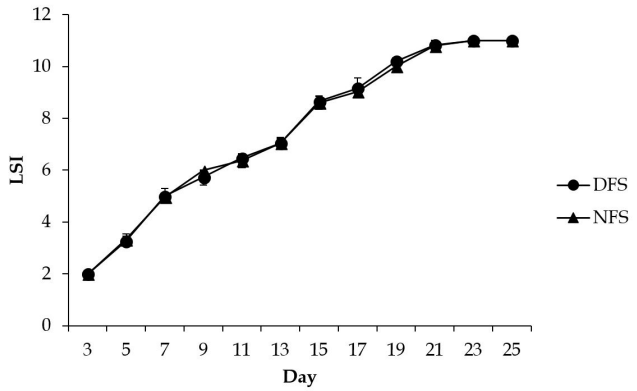

Figure 2. LSI (Larval Stage Indices) recorded in *M. rosenbergii* larvae during the feeding schedule experiment: supplying the larvae with *Artemia* nauplii in the early morning DFS (Daytime Feeding Schedule); supplying the larvae with *Artemia* nauplii in the early night NFS (Nighttime Feeding Schedule). The vertical bars represent the standard deviation.

proportionally, and large numbers of nauplii (3-8 AN mL^{-1}day^{-1}) were left over in the tanks.

The lowest density of prey (5 AN mL^{-1}) was inadequate because it resulted in a decrease in final productivity of 25% in comparison with treatment 2 and 20% compared with treatment 3 (Table 5). The higher density of nauplii (20 AN mL^{-1}) did not result in any significant increase in LSI (Figure 3) or productivity in comparison with the intermediate density of 10 AN mL^{-1} (Table 5). In addition, the final weight of the post-larvae did not vary significantly among treatments.

Table 3. Data (mean ± SD) on the survival, productivity, dry and fresh weight of the *Macrobrachium rosenbergii* larvae fed on diurnal (DFS) and nocturnal schedules (NFS) (experiment 1).

Treatments (%)		Survival (PL L^{-1})	Produtivity (mg)	Dry weight (mg)	Fresh weight
Feeding Schedule	DFS	52.2 (±2.5)	40.3 (±3.7)*	13.3 (±4.0)	55.3 (±5.5)
	NFS	45.3 (±3.7)	30.4 (±4.9)*	12.8 (±2.9)	52.7 (±4.2)
P		p>0.05	p = 0.03	p>0.05	p>0.05
t		ns	2.35	ns	ns

*There are significantly different between treatments (*t* test); Abbreviation: ns = not significant; P = value significance and t = t test.

Table 4. Consumption and leftover *Artemia* nauplii (AN larva^{-1} day^{-1}) during the culture of *Macrobrachium rosenbergii* larvae (24 h after suplly) under three prey densities (experiment 2).

Stage*	Consumption (AN Larvae^{-1} day^{-1})			Leftover (AN mL^{-1} day)		
	FD1	FD2	FD3	FD1	FD2	FD3
II	16 (±1.9)b	22 (±7.5)a	32 (±5.9)a	3.5 (±0.2)b	7.8 (±0.2)b	16.9 ±(0.87)a
III	24 (±4.3)b	33 (±9.6)a	49 (±13.7)a	2.7 (±0.1)b	6.9 (±0.5)b	15.4 (±0.46)a
III	24 (±2.9)b	33 (±8.0)a	49 (±14.6)a	2.7 (±0.3)b	6.9 (±0.4)b	15.4 (±0.8)a
IV	28 (±2.0)b	46 (±8.9)a	56 (±9.3)a	2.5 (±0.2)b	5.9 (±0.3)b	15.0 (±1.3)a
V	37 (±4.2)b	53 (±17.4)a	67 (±4.5)a	1.8 (±0.2)b	5.5 (±0.7)b	14.3 (±0.9)a
VI	44 (±5.1)c	65 (±19.5)b	81 (±15.8)a	1.3 (±0.2)b	4.7 (±0.9)b	13.5 (±0.9)a
VI	54 (±5.8)b	85 (±12.2)a	88 (±8.7)a	0.7 (±0.3)b	3.4 (±0.4)b	13.3 (±1.2)a
VII	62 (±3.7)b	99 (±9.1)a	99 (±8.6)a	0.2 (±0.0)b	2.7 (±0.5)b	12.7 (±1.8)a
VII	63 (±4.2)b	95 (±13.9)a	103 (±2.7)a	0.3 (±0.1)b	3.3 (±0.5)b	12.8 (±1.1)a
VIII	64 (±7.6)b	119 (±6.5)a	112 (±6.6)a	0.4 (±0.1)b	2.0 (±0.5)b	12.5 (±1.3)a
IX	68 (±5.5)b	126 (±6.0)a	133 (±8.4)a	0.4 (±0.0)b	1.9 (±0.5)b	11.5 (±1.3)a
IX	71 (±4.2)b	138 (±11.0)a	143 (±8.9)a	0.3 (±0.0)b	1.5 (±0.5)b	11.3 (±1.0)a
X	72 (±5.5)b	151 (±7.4)a	150 (±13.1)a	0.4 (±0.1)b	1.2 (±0.5)b	11.3 (±0.9)a
XI	79 (±6.6)b	164 (±1.3)a	159 (±10.0)a	0.1 (±0.0)b	0.8 (±0.1)b	11.2 (±0.8)a
PL	81 (±4.2)b	178 (±6.7)a	171 (±11.1)a	0.3 (±0.0)b	0.5 (±0.1)b	11.0 (±1.7)a

Parameters in the same line with different letters (a, b, c) are significantly different; FD1 = 5 AN mL^{-1} day^{-1}; FD2 = 10 AN mL^{-1}day^{-1}; FD3 = 20 AN mL^{-1}day^{-1}; *Dominant Stage; Abbreviations: FD1 = food density 1; FD2 = food density 2 and FD3 = food density 3.

Table 5. Data (mean ± SD) on the survival, productivity, dry and fresh weight of the *Macrobrachium rosenbergii* larvae fed different prey densities (experiment 2).

Treatments (%)		Survival PL L^{-1}	Produtivity (mg)	Dry weight (mg)	Fresh weight
Density Feeding	FD1	59.1 (±2.2)a	30.1 (±3.2)b	11.3 (±4.8)	48.0 (±1.6)b
	FD2	53.6 (±1.3)b	40.0 (±3.6)a	13.6 (±6.8)	56.3 (±1.8)a
	FD3	52.7 (±3.2)b	37.8 (±2.6)a	12.9 (±2.0)	55.7 (±0.6)a
P		p = 0.04	p = 0.004	p = 0.0006	p = 0.0001
F		4.37	10.25	11.55	16.9

Parameters in the same column with different letters (a, b) are significantly different (ANOVA; followed by Tukey's test); FD1 = 5 AN mL^{-1} day^{-1}; FD2 = 10 AN mL^{-1}day^{-1}; FD3 = 20 AN mL^{-1}day^{-1}; Abbreviations: FD1 = Food density 1; FD2 = Food density 2; FD3 = Food density 3; P = value significance and F = Fisher's F-test.

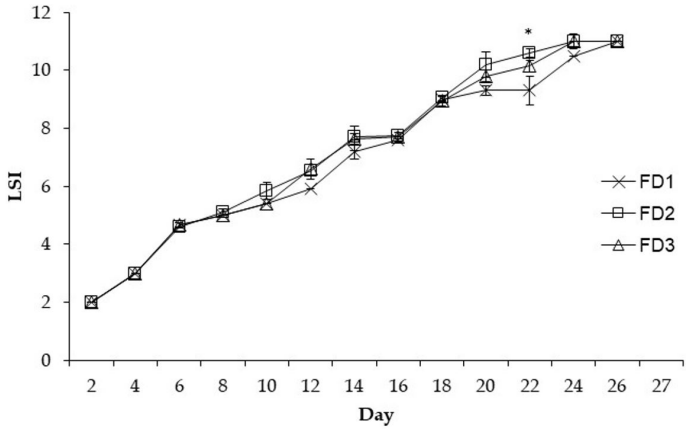

Figure 3. LSI (Larval Stage Indices) recorded in *M. rosenbergii* larvae during the feeding density experiment. FD1 = 5 AN mL^{-1}; FD2 = 10 AN mL^{-1}; FD3 = 20 AN mL^{-1}. The asterisk (*) indicates the days on which there was a significant reduction in the LSI of the larvae fed with 5 AN $mL^{-1}day^{-1}$; Abbreviations: FD1 = food density 1; FD2 = food density 2 and FD3 = food density 3.

DISCUSSION

The feeding schedule of *M. rosenbergii* larvae has been widely discussed, and most management schemes have emphasized and recommended nocturnal feeding (AQUACOP, 1983; VALENTI *et al*., 1998; LAVENS *et al*., 2000; NEW, 2002; DHONT *et al*., 2010), based on the assumption that the trophic patterns of the larvae would be similar to those of the adults. However, the results of the present study indicate that (in the DFS treatment, daytime food supply) the *M. rosenbergii* larvae are much more active in the capture of the prey during diurnal period, observed by the higher intake in this phase. In the nocturnal food supply (NFS), the larvae have shown a regular consume for both, diurnal and nocturnal periods, eating nauplius with poor yolk reserves in the 12 subsequent hours after the diurnal feeding. This greater consumption during the diurnal period in treatment DFS may be related to the increase in swimming activity in the presence of light, which leads to an increase in the exploration of the environment and, consequently, the chances of encountering a prey item (UTTIERI *et al*., 2008; SUI *et al*., 2009). In addition, molting tends to occur at night, and the larvae are unable to eat at this time, until the new exoskeleton has hardened (MACIEL *et al*., 2012; GOMES *et al*., 2014). The exuviae were observed every early morning on the edge of the tank suggesting that the same thing occur in *M. rosenbergii* larvae.

The intake of nauplii during the daytime may also be related to the use of visual cues by the *M. rosenbergii* larvae to detect and capture their prey. The larvae of *M. rosenbergii* have apposition-type eyes, which are adapted to well-lit environments (NILSSON, 1983). KAWAMURA *et al*. (2016) showed that the larvae of this species have color vision, and are able to perceive objects of different colours. MACIEL and VALENTI (2014) also showed that *M. amazonicum* larvae capture more nauplii in red and green tanks, emphasizing the importance of vision for the capture of prey. It is possible that in DFS treatment the color of the nauplii soon after hatching are more evident in the day time period due to the greater amount of yolk, making easier the visualization and the search for the prey and resulting in higher consumption. When they are supplied at 8:00 p.m., during the daytime, the yolk reserve has already been reabsorbed, making the nauplii less visible and less nutritious for the larvae. The use of visual cues to differentiate prey from non-nutrient particles may be highly advantageous to the larvae in the planktonic phase. Feeding during the diurnal period makes possible the larvae to forage more intensively, optimizing the intake of the yolk of the newly-hatched nauplii.

An increase in the intake of nauplii during the daytime has also been observed in the larvae of the freshwater prawns *Macrobrachium amazonicum* (MACIEL *et al*., 2012) and *M. equidens* (GOMES *et al*., 2014), as well as other crustaceans, such as *Ranina ranina* (MINAGAWA, 1994), *Lucifer faxoni* (VEGA-PÉREZ *et al*., 1996), *Clausocalanus furcatus* (UTTIERI *et al*., 2008), and *Eriocheir sinensis* (SUI *et al*., 2009).

A number of previous studies have indicated that when higher densities of nauplii are offered should facilitate their capture by the *Macrobrachium* larvae (MOLLER, 1978; ANGER, 2006; MACIEL *et al*., 2012). However, HENRIQUES *et al*. (2014) emphasized that the larvae of *M. rosenbergii* are born with sensory structures for the exploration of the environment, suggesting that they are less dependent on chance encounters with potential prey than was previously thought. An evidence of this hypothesis was observed in this experiment 2, in which, by the capacity of the larvae (from zoea VI) consumer the nauplius until this resource has been exhausted, even with little amount of *Artemia* have been offering (5AN/mL). The capture of prey in the dark has been observed in *Lysmata wurdemanni* (ZHANG *et al*., 1998) and *L. vannamei* (YOU *et al*., 2006).

In the present study, low density of nauplii (5 AN mL^{-1}) had not influence on the LSI or on the larval dry weight, but probably, did not guarantee amount of reserve enough to complete the metamorphosis. Thus, it is observed reduction the number of larvae able to carry out the transition into benthic phase, decreasing the productivity. According to ANGER (2001), decapod larvae show endotrophy in the early stages, due to yolk reserves. However, they need to accumulate reserves after initiating trophic activity to prepare for the metamorphosis into juvenile stage. In this case, the food offering in less density (FD1) was enough to maintaining live larvae (FD1), inclusive, achieving the best larval survival (~9%), but it did not affect in the reduction of the metamorphosed post- larvae, suggesting that it was not enough to promoting accumulation of nutritional reserve for the metamorphosis.

BARROS and VALENTI (2003a) identified an increase in the intake of nauplii by *M. rosenbergii* as a response to an increase in the density of prey, although the maximum density tested was 12 AN mL^{-1}. However, our data show that the larvae were able to exploit the resource to exhaustion even during the night (experiment 1) or at low prey densities (experiment 2; FD1). The increase in prey density (FD3) did not result in a proportional increase in intake, indicating that there is a limit to daily capture rates.

MACIEL *et al*. (2012) observed that, while consumption rates of *M. amazonicum* larvae increased at increasing prey densities, this did not result in higher productivity, indicating the occurrence of superfluous feeding, exceeding the actual nutritional needs of this species. A similar pattern was not observed in *M. rosenbergii*, however, with similar intakes being recorded at densities of 10 and 20 AN mL^{-1}, while a density of 5 AN mL^{-1} implicates on the decreasing of the methamorphosis. This indicates that prey densities of over 10 AN mL^{-1} for day are unnecessary. These findings are extremely relevant to the refinement of larval culture practices, given that most previous studies (AQUACOP, 1983; LAVENS *et al*., 2000; DHONT *et al*., 2010) have recommended increasing prey density in response to increasing intake, which would clearly be wasteful, as well as increasing the amount of wastes in the culture tanks.

CONCLUSION

Based on the findings of the present study, we conclude that *M. rosenbergii* larvae should be fed during the daytime. Given this we recommend offering the *Artemia* nauplii during the first hours of the morning (until 8:00 am). In addition, the nauplius supply should be offering at density up to 5 do not exceeding to 10 Na mL^{-1}. This management practice will optimize the use of resources, given that the larvae will consume the nauplii while they are still rich in yolk reserves, contributing to increase in productivity.

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