Pakistan J. Zool., vol. 49(3), pp 973-977, 2017. DOI: http://dx.doi.org/10.17582/journal.pjz/2017.49.3.973.977

Stomach Repletion Rhythms of the Caridean Shrimps, *Macrobrachium americanum* and *M. tenellum* (Crustacea: Decapoda) in a Caged-Pond System

Fermín Lopez-Uriostegui[1], Jesús T. Ponce-Palafox[2,*], Fabiola Lango-Reynoso[1], María del Refugio Castañeda-Chavez[1], Virgilio Eugenio Arenas-Fuentes[3] and Fernando Vega-Villasante[4]

[1]*Posgrado en Ciencias en Acuacultura, Instituto Tecnológico de Boca del Río, Veracruz, C.P. 94290.*

[2]*Lab. de Bioingeniería Costera, Escuela Nacional de Ingeniería Pesquera, Unidad Multidisciplinaria de Bahía de Banderas, Universidad Autónoma de Nayarit, Nayarit, México C.P. 63155.*

[3]*Instituto de Ciencias Marinas y Pesquerías, Universidad Veracruzana, Boca del Río, Veracruz, México C.P. 94290.*

[4] *Laboratorio de Calidad de Agua y Acuicultura Experimental, Universidad de Guadalajara, Puerto Vallarta Jalisco, México.*

Article Information
Received 27 September 2016
Revised 13 December 2016
Accepted 24 December 2016
Available online 09 May 2017

Authors' Contributions
JTPP, FLR and VEAF conceived and designed the experiments. FLU and MRCC performed the experiments. FVV analyzed the data. JTPP wrote the manuscript.

Key words
Feeding habits, Freshwater shrimp, Gut repletion.

ABSTRACT

The stomach repletion rhythms of the caridean shrimp *M. americanum* and *M. tenellum* in caged-pond system were studied. A total of 120 caridean shrimp (60 *M. americanum* and 60 *M. tenellum*) had their stomach repletion analysis. Samples were taken four-hly over a 24 h cycle. In general it was found that stomach repletion index showed both species feed 24 h, but forage activity differs in intensity in the two species. In *M. tenellum* repletion index was greatest during the day and *M. americanum* in the night.

INTRODUCTION

The main species of *Macrobrachium* widely exploited by artisanal fisheries in the American Pacific, which have great potential for aquaculture, few has been studied about their natural diet and feeding habits. Knowledge about aspects of feeding ecology in native caridean shrimp grown in ponds is essential to understanding nutrition requirements and how species interact with environment. However, the feed consumption diel behavior of the feed consumption of these species under pond systems is still poorly understood. The response of caridean shrimp to balanced food is critical to attain the maximum production with the lowest feed input during culture (Soares *et al*., 2005a). In general, these crustaceans are omnivorous with a wide trophic spectrum that ranges from algae and plant remains to insect larvae and even vertebrates (Collins *et al*., 2007). In this way, they can play a functional role as shredders and predators in aquatic eco-system. The feed consumption pattern of decapod crustaceans (shrimp, prawn and red claw) in pond culture varies among species and is influenced by many factors, such as temperature, molt stage, water quality and body size (Wasielesky *et al*., 2003), food availability, and diet composition (González-Peña *et al*., 2002). The feeding habits of most *Macrobrachium* species are related to changes in their life cycle (Guerao and Ribera, 1996), and circadian rhythms (Lima *et al*., 2014). Another parameter that is used to evaluate feeding in crustaceans is passing amount of food out of the stomach per unit time, called gut or rate of gastric evacuation. This can be affected by the time of gastric evacuation, and the measure used in the study is also easily and useful in assessing estimations of daily feeding rates (Loya-Javellana *et al*., 1995). The stomach repletion can be used to estimate mainly food consumption in time. Stomach repletion indices showed the proportion of food consumption by one species and suggests that the species is a more voracious or more adaptable to the food present in the pond. The amount and feeding rhythm occurs during the 24-cycle crustaceans-decapod, but its intensity may vary due to endogenous mechanisms such as the circadian rhythm or exogenous as the

* Corresponding author: jesus.ponce@usa.net
0030-9923/2017/0003-0973 $ 9.00/0

availability of items, intra and interspecific competition or threats from potential predators (Stenseth, 1983). In aquatic systems studies feeding rhythms and temporal activity closely related species have been few studied (Collins, 2005) and semi-controlled systems are unknown. The present study aimed to investigate the stomach repletion rhythms and foraging activity of *M. americanum* and *M. tenellum* reared in a caged-pond system.

MATERIALS AND METHODS

The experiment was carried out in a 1,422 m^2 earthen pond located at the San Cayetano Aquaculture Center, Fisheries Dept. Nayarit State Government, (21°27′24.23″N; 104°49′29.67″W), where 12 bottom cages, each with a capacity of 3 m^3 (L x W x H: 3 x 1 x 1 m), were introduced. The caged-pond system used is described in Lopez-Uriostegui *et al*. (2014) and Ponce-Palafox *et al*. (2014). Temperature, dissolved oxygen (Yellow Springs Instruments YSI-85) and pH (Bernauer F-1002) were measured every 4 hs over a 24-h cycle inside the cage at 30 cm water depth.

M. tenellum (n = 60; weight, 9.7 ± 2.9 g [mean ± SD]) and *M. americanum* (n = 60; weight, 19.8 ± 4.0 g [mean ± SD]) organism adults were stocked in 6 cages each at density of 4 prawns/m^3, respectively. Six replicates, randomly distributed in the central area of the pond, were used per treatment. Animals were fed twice daily (08:00 h and 17:00 h) with a commercial diet (Nutripec Camaronina XT, Agribrands, Purina, Mexico, Inc., 35% crude protein, 8% lipid and 12% moisture; size 2 to 2.5 mm x 6 to 7 mm). All caridean shrimp were collected in Ameca river (20°53'14.62" N; 105°08'04.12") and Boca Negra estuary (20º39'-20º42' N y 105º15'-105º17' W) in Mexican Pacific coast during April-July 2014, weighed to evaluate their growth and to adjust the amount of feed supplied. Ten organisms of each species were collected every 4 h during the 24 h cycle to determine their total weight (g), gut weight (g) and stomach contents (g), according to the criteria of Soares *et al*. (2005a), who contend that organisms take 4 - 5 h to complete stomach evacuation. Animals were fixed and preserved in a 70% ethanol solution for further analysis. The sampling period was 07:00 h to 03:00 h on the following day. All samples collected from 07:00 h to 15:00 h were considered as day times. Likewise, catches from 19:00 h to 03:00 h were considered as night times. A total of 120 organisms per sampling day were collected (*i.e.,* 10 caridean shrimp x 6 sampling times; for each species). Soft organisms were not used for analyses and were returned to the cage.

In the laboratory, the sample organisms were sexed, and their biometric parameters (wet weight, g and total length, cm) were measured. Animals were then dissected, and their proventriculus was removed. The estimate of the percentage of filled space in the gut was made according to the total volume of each stomach, and categorized as follows: Stomach repletion index (r_s) was estimated as a percentage of fullness as follows (adapted from Soares *et al*., 2005a): empty, 0%; ¼ full, 25%; ½ full, 50%; ¾ full, 75% and full, 100%. The stomach repletion rate (Rs; %) was calculated as: $Rs = r_s/N$, where r_s = the stomach repletion index for each organism and N = the total number of stomachs analyzed during the period.

The data obtained from each of the variables were analyzed for normality and homogeneity of variances. Comparison of the water parameter and stomach repletion each species was performed by numerical analysis using the Pearson product moment correlation. A paired t-test was used to compare differences of stomach repletion each species and day-night period in SPSS version 21 (IBM-SPSS-Statistics, NY, USA).

RESULTS

The 24-h cycle mean temperature, pH and dissolved oxygen were 27.1ºC, 8.3 and 6.2 mg/L, respectively. Higher temperatures (28.2°C) and dissolved oxygen (7.2 mg/L) concentrations were observed at 15:00 h but decreased progressively until sunrise 25.3°C and 5.5 mg/L, respectively. The pH was highest at 19:00 h (8.6) and declined to 7:00 h (8.1).

In *M. americanum,* feeding activity was intermittent over the 24-h sampling cycle (Fig. 1). A stomach repletion rate of 95.8% at 23:00 h was the highest value recorded during the experiment. The stomach repletion rate was significantly different ($P < 0.05$) between day (79.1%) and night (55.1%). However, in this species, food consumption was fluctuant throughout the light and dark period. In *M. tenellum*, stomach repletion was maintained at a high level over the 24-h sampling cycle (Fig. 1). A stomach repletion rate of 95.8% at 11:00 h was the highest value recorded during the experiment. The stomach repletion rate was not significantly different ($P > 0.05$) between day (Rs=83.2%) and night (Rs = 73.3%). In this species, food consumption was continuous throughout the day and night period.

The stomach repletion rhythms varied over time and between *M. americanum* and *M. tenellum*. *M. tenellum* stomach repletion rate (Rs: mean±SE = 79.9±4.3%) was higher than that of *M. americanum* (Rs: mean±SE = 67.1±11.1%), especially during the day period, indicating continuous and higher feeding intensity during the 24 h cycle. The difference between night and day food consumption was more evident in *M. americanum* (Rs-

D=79.2%; Rs-N=55.1% N) than in *M. tenellum* (Rs-D=83.2%; Rs-N=73.3% N). However, *M. americanum* had its maximum Rs at night (23:00 h), whereas *M. tenellum* had its maximum Rs during the day (11:00 h).

Overall, it was found that stomach repletion increases after approximately 6 hs from feeding in *M. americanum*. In addition, in *M. tenellum*, the stomach repletion increases immediately after feeding during the daytime though it does not during the nighttime.

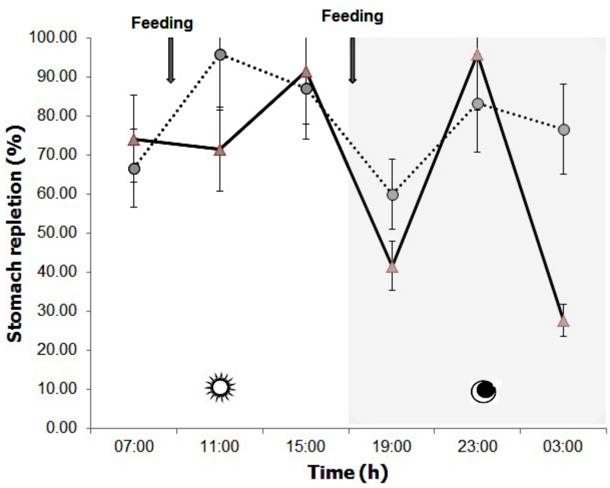

Fig. 1. Variation (mean ± SE) of stomach repletion rate (Rs) of *M. americanum* (continuous line) and *M. tenellum* (dotted line) during day and night.

DISCUSSION

Variations on *M. americanum* and *M. tenellum* repletion rate rhythms were observed during the experimental 24-h cycle rearing in a caged-pond system. The feeding rhythm recorded over the 24-h cycle showed more marked fluctuations in *M. americanum* than *M. tenellum*. During the experiment, *M. tenellum* showed continuous feeding regardless of light levels, whereas *M. americanum* showed major fluctuation in the night, having its maximum rate of repletion. It was determined differences in the rate of repletion of caridean shrimp depending on the size of organisms and species in ponds (Soares *et al*., 2005b; Carvalho *et al*., 2011). Wild shrimp appeared to feed over the entire 24-h cycle, but feeding intensity increased significantly during the night period (Ponce-Palafox *et al*., 2002). However, the offerings of feed pellets stimulate feeding activities of the caridean shrimps, which may encourage their food intake during the light period (Nunes *et al*., 1996). The response of the two species the supply of pellets in the light period also showed a higher consumption during the day to *M. tenellum* and *M. americanum* of 30.1% AND 9.1%, respectively. In this work, the more constant presence of stomach contents in *M. tenellum* than *M. americanum* is partly attributed to a higher differential digestibility of various items and its tendency feeding on detritus.

This observation likely accounts for the greater abundance of these two species in the study area. Additionally, the uniformity in the stomach repletion index recorded for these species appears to be a strategy that culminated in their comparative growth rates and the same breeding season for these species, which agrees with findings for fish by Offem *et al*. (2009). Differences in stomach repletion rhythms between these two species of caridean shrimp may be due to their feeding behavior and their different life strategies. Under caged-pond system conditions, *M. americanum* exhibited a multi-modal feeding rhythm, whereas *M. tenellum* showed a smooth feeding rhythm. The multi-modal rhythm observed in the two species and mainly in *M. americanum* may be the result of an ability to respond to competition and predation on an ecological time scale (Hut *et al*., 2012). However, the species rhythm peaks in the caged-pond system did not coincide with the crepuscular hs and occurred in the middle of the day (11:00-15:00 h) and at night (23:00 h). This finding is surprising in light of previous studies of decapod species from inland waters, which indicate a crepuscular feeding rhythm (Zimmermann *et al*., 2009). This has previously been reported in other species of Palemonidae under confined conditions (Carvalho *et al*., 2011), and that can be caused to the microclimatic conditions of the pond, water exchange, pellet supply, substrate conditions and prey availability.

In general it was found that stomach repletion index showed both species feed 24 h, but forage activity differs in intensity in the two species. In *M. tenellum* repletion index was greatest during the day and *M. americanum* in the night. Higher consumption was found to *M. tenellum* than by *M. americanum*, which suggests that the former species is a more adaptable to the food present in the pond and the other is clearly disadvantaged in ponds where there may be a limited variety of food sources compared with *M. tenellum*. Some reports support the hypothesis that detritus is the most important food source for *M. tenellum* (Ponce-Palafox *et al*., 2002, 2013). Instead, *M. americanum* tend to consume more vegetable matter and animals. The pellets should be supplied to *M. americanum* during the day-night cycle to improve their repletion rate rhythms in pond culture. For *M. tenellum*, it is sufficient to provide food during the day to maintain a continuous 24 h cycle of feeding activity.

CONCLUSIONS

Variations on *M. tenellum* and *M. americanum* stomach repletion rhythms were observed during the experimental rearing 24-h cycle. Daytime feeding activity was observed for wild caught and adapted to culture for 4 months *M. tenellum* and *M. americanum*, also appeared to feed over the entire 24 h cycle but feeding intensity increased significantly during the light and dark period, respectively. Thus, the offering of feed pellets during light period is recommended for *M. tenellum* and during light and dark period for *M. americanum* under earthpond culture, but the rates of feeding must be further investigated for the two species.

ACKNOWLEDGEMENTS

We thank the staff of the Centro Acuícola de San Cayetano, station Nayarit state, for their valuable help. We also thank Martin Alberto Arenas Pardo for her assistance with field and laboratory work.

Statement of conflict of interest

Authors have declared no conflict of interest.

REFERENCES

Carvalho, D.A., Collins P.A. and De Bonis C.J., 2011. Gut evacuation time of *Macrobrachium borellii* (Caridea: Palaemonidae) feeding on three types of prey from the littoral-benthic community. *J. Crust. Biol.,* **31**: 630-634. https://doi.org/10.1651/10-3446.1

Collins, P.A., 2005. A coexistence mechanism for two freshwater prawns in the Parana´ river floodplain, Argentina. *J. Crust. Biol.*, **25**: 219-225. https://doi.org/10.1651/C-2528

Collins, P., Williner V. and Giri, F., 2007. Trophic relationships in crustacean decapods of a river with a floodplain. In: *Predation in organisms a distinct phenomenon* (ed. A.M.T. Elewa), Springer Verlag, pp. 59-86. https://doi.org/10.1007/978-3-540-46046-6_5

Gonzalez-Peña, M.C., Gomes, S.Z. and Moreira, G.S., 2002. Effects of dietary fiber on growth and gastric emptying time of the freshwater freshwater prawn *Macrobrachium rosenbergii* (De Man, 1879). *J. World Aquacult. Soc.*, **33**: 441-447. https://doi.org/10.1111/j.1749-7345.2002.tb00023.x

Guerao, G. and Ribera, C., 1996. Locomotor activity patterns and feeding habits in the prawn *Palaemon serratus* (Pennant, 1777) (Decapoda, Palaemonidae) in the Alfacs Bay, Ebro delta, Spain. *Crustaceana,* **69**: 101-112. https://doi.org/10.1163/156854096X00132

Hut, R.A., Kronfeld-Schor, N., Van Der Vinne, V. and De La Iglesia, H., 2012. In search of a temporal niche: environmental factors. *Progr. Brain Res.,* **199**: 281-304. https://doi.org/10.1016/B978-0-444-59427-3.00017-4

López-Uriostegui, F., Ponce-Palafox, J.T., Arredondo-Figueroa, J.L., García-Ulloa, M., Castillo-Vargasmachuca, S. and Esparza-Leal, H.M., 2014. Effect of stocking density on growth and survival of prawn (*Macrobrachium tenellum*) cultured in caged-pond system. *N. Am. J. Aquacult.,* **76**: 164-169. https://doi.org/10.1080/15222055.2014.886646

Loya-Javellana, G.N., Fielder, D.R. and Thorne, M.J., 1995. Foregut evacuation, return of appetite and gastric fluid secretion in the tropical freshwater crayfish, *Cherax quadricarinatus*. *Aquaculture,* **134**: 295-306. https://doi.org/10.1016/0044-8486(95)00050-C

Lima, J., García, J.S. and Silva, T.C., 2014. Natural diet and feeding habits of a freshwater prawn (*Macrobrachium carcinus*: Crustacea, Decapoda) in the estuary of the Amazon River. *Acta Amaz.,* **44**: 235-244. https://doi.org/10.1590/S0044-59672014000200009

Nunes, A.J.P., Goddard, S. and Gesteira, T.V.C., 1996. Feeding activity patterns of the Southern brown shrimp *Penaeus subtilis* under semi-intensive culture in NE Brazil. *Aquaculture,* **144**: 371-386. https://doi.org/10.1016/0044-8486(96)01297-5

Offem, B.O., Samsons, Y.A. and Omoniyi, I.T., 2009. Trophic ecology of commercially important fishes in the cross river, Nigeria. *J. Anim. Pl. Sci.,* **19**: 37-44.

Ponce-Palafox, J.T., Arana-Magallón, F.C., Cabanillas-Beltrán, H. and Esparza-Leal, H., 2002. *Bases biológicas y técnicas para el cultivo de los camarones de agua dulce nativos del Pacífico Americano* Macrobrachium tenellum *(Smith, 1871) y* M. americanum *(Bate, 1968).* I Congreso IberoamericanoVirtual de Acuicultura, CIVA 2002 (http://www.civa2002.org), pp. 534-546.

Ponce-Palafox, J.T., López-Uriostegui, F., Benítez-Mandujano, M.A., Castillo-Vargasmachuca, S., Benítez-Valles, A., Gómez Gurrola, J. and Arredondo-Figueroa, J.L., 2013. Comparative growth performance of male and female freshwater prawn *Macrobrachium tenellum* (Decapoda: Palaemonidae) cultured in tropical earthen ponds.

Int. J. Fish. Aquacult., **5**: 26-28.

Ponce-Palafox, J.T., López-Uriostegui, F., Arredondo-Figueroa, J.L., Benítez-Mandujano, M. A., García-Ulloa, M., Esparza-Leal, H.M. and Spanopoulos-Hernández, M., 2014. Effect of stocking size on growth performance, biomass, production, yield and survival of freshwater prawn (*Macrobrachium americanum*) cultured in caged-pond system. *N. Am. J. Aquacult.,* **76**: 430-435. https://doi.org/10.1080/15222055.2014.936538

Soares, R., Wasielesky, R., Peixoto, S. and D'incao, F., 2005a. Food consumption and gastric emptying of *Farfantepenaeus paulensis. Aquaculture*, **252**: 534-544. https://doi.org/10.1016/j.aquaculture.2005.04.072

Soares, R., Peixoto, S., Wasielesky, W. and D'incao, F., 2005b. Feeding rhythms and diet of *Farfantepenaeus paulensis* under pen culture in Patos Lagoon estuary, Brazil. *J. exp. Mar. Biol. Ecol.,* **322**: 167-176. https://doi.org/10.1016/j.jembe.2005.02.019

Stenseth, N., 1983. A coevolutionary theory for communities and food web configurations. *Oikos,* **41**: 487-495. https://doi.org/10.2307/3544108

Wasielesky, W., Bianchini, A., Sanchez, C. and Poersch, L., 2003. The effect of temperature, salinity and nitrogen products on food consumption of pink shrimp *Farfantepenaeus paulensis*. *Braz. Arch. Biol. Technol.*, **46**: 135-141. https://doi.org/10.1590/S1516-89132003000100019

Zimmermann, B.L., Aued, A.W., Machado, S., Manfio, D., Scarton, L.P. and Santos, S., 2009. Behavioral repertory of *Trichodactylus panoplus* (Crustacea: Trichodactylidae) under laboratory conditions. *Zoologia*, **26**: 5-11. https://doi.org/10.1590/S1984-46702009000100002