R. Bras. Zootec., 48:e20180053, 2019
https://doi.org/10.1590/rbz4820180053

Aquaculture
Full-length research article

Revista Brasileira de Zootecnia

Brazilian Journal of Animal Science
ISSN 1806-9290
www.rbz.org.br

Effect of stock density of cultured Amazon Apple Snail *Pomacea dolioides* (Gastropoda: Ampullariidae) in Brazil

Amilcar Nogueira Pires-Júnior[1], Gustavo Yomar Hattori[1], Bruno Sampaio Sant'Anna[1*]

[1] Universidade Federal do Amazonas, Instituto de Ciências Exatas e Tecnologia, Itacoatiara, AM, Brasil.

***Corresponding author:**
brunusant@hotmail.com

Received: April 2, 2018
Accepted: October 30, 2018

How to cite: Pires-Júnior, A. N.; Hattori, G. Y. and Sant'Anna, B. S. 2019. Effect of stock density of cultured Amazon Apple Snail *Pomacea dolioides* (Gastropoda: Ampullariidae) in Brazil. Revista Brasileira de Zootecnia 48:e20180053.
https://doi.org/10.1590/rbz4820180053

ABSTRACT - This study evaluated the biomass gain, specific growth rate, absolute weight gain, and survival rate of the gastropod *Pomacea dolioides* cultivated in different stocking densities. To perform the experiment, samples were collected in March and June 2015. A total of 40 adult specimens were collected in the Jauary neighborhood (03°08'19.9"S, 58°27'32.5"W), municipality of Itacoatiara, AM, Brazil. They were kept in the laboratory for breeding to obtain the young *P. dolioides*, which were distributed into tanks containing 4 L of water and an aeration system, in three densities: 2.5 animals/L, 5 animals/L, and 10 animals/L, and were fed fish ration (34% gross protein). The specimens were measured for shell length and weight every fifteen days. The survival rate did not differ between treatments 2.5 and 5 animals/L (100%) and 10 animals/L (95.83%). The density with the best cultivation results was 2.5 animals/L, being most effective for the parameters of growth, weight gain, specific growth rate, and percentage weight gain, when compared with the other treatments after 225 days of the experiment. For future cultivation of this species, a density of 2.5 animals/L should be used to improve handling performance.

Keywords: aquaculture, growth, mollusk, stock enhancement

Introduction

Mollusk cultivation in Brazil has developed since 1990 in Santa Catarina and then in other regions. In the last decade, most coastal states have mollusk research or production activity (Cavalli and Ferreira, 2010). The cultivation is evidenced in various parts of the world, such as in Japan (Itami et al., 1963), Chile (Campalans and Lohrmann, 2009), Taiwan (Chen, 1984), French Polynesia (Coeroli et al., 1984), Mexico (Cardenas, 1984), United Kingdom (Laing and Spencer, 2006), France and Spain (Magdalena et al., 2003), China (Yan et al., 2006), and in other places, as an important economic and social activity. In Trinidad, *Pomacea urceus* (Müller, 1774), is captured from nature and sold in local markets (Lum-Kong and Kenny, 1989). In the Brazilian countryside, freshwater mollusks are consumed by the poorer populations (Barboza and Romanelli, 2005).

There are several factors such as temperature (Seuffert and Martín, 2010), food availability (Tamburi and Martín, 2016), and others that are not taken into consideration as much, such as lighting, genetic variability, stocking density, dimorphism, and gender ratio (Estebenet and Martín, 2002), which directly influence the development of the apple snails species. However, the stocking density affects growth, breeding, and survival. This negative dependency caused by the density usually contributes to the instability of a population (Yoshida et al., 2013). Such instability has been reported in a study with *Pomacea paludosa* (Say, 1829) in Florida USA, in which the presence of adult individuals causes a reduction in the growth of young ones, and increased mortality (Conner et al., 2008) due to competition for food and mating (Souza Júnior et al., 2013).

Tanaka et al. (1999), studying *Pomacea canaliculata* (Lamarck, 1819) in rice fields, found that the population size was relatively density-dependent, causing reductions in oviposition frequency and size of the egg masses. The same situation was described by Posch et al. (2012), in a study with *P. paludosa*, whose lower density promoted higher egg production and more young individuals per female. The effect of density was also observed with the snail *Helix aspersa* (Muller, 1774). Higher densities cause a reduction of the final adult size and increase mortality (Lazaridou-Dimitriadou et al., 1998). Regarding biology and culture of *Pomacea dolioides* (Reeve, 1856), only the recent study of Melo et al. (2017) investigated the reproduction, including fecundity, embryonic development, and substrate selection for oviposition, and Pires-Júnior et al. (2017) addressed aspects associated with growth and weight gain, analyzing different diets and feeding frequency.

Although *P. dolioides* does not have economic interest, several species of apple snails of the similar size are used for human or animal feeding (Santos, 1982; Ruiz-Ramírez et al., 2005; Vázquez-Silva et al., 2011; Chimsung and Tantikitti, 2014), with the development of research on meat yield (Barbosa and Romanelli, 2005), nutritive compound (Luo et al., 2012), time of ensiling (Phonekhampheng et al. 2009), among other applied research. Thus, the objective of this study was to analyze the culture of *P. dolioides* in different stocking densities.

Material and Methods

To develop the cultivation experiment, the gastropods were collected between March and June 2015. Forty adult gastropods were collected in the Jauary neighborhood (03°08'19.9" S, 58°27'32.5" W). To perform the collection, hand sieves and dip nets were used. The animals were placed in plastic boxes with water and aeration and later transported to the laboratory, where they were identified according to Simone (2006) (Figure 1) and kept in a circular 310-L capacity PVC tank with a closed recirculation system with 180 L/h water renewal and external biological filter. The animals were kept under these conditions until the cultivation experiment.

The sampled gastropods were kept alive in the laboratory for twenty days. They were acclimated and underwent a river ebb and flood simulation in the tank to induce breeding. After mating and oviposition, three egg masses from different females were collected and transported to floating surfaces in PVC containers (5 L capacity) with water and aeration, until hatching, which occurred after eighteen days of embryonic development.

Bar = 1 cm.

Figure 1 - Morphology of *Pomacea dolioides* shell.

The young individuals were cultivated for twenty days in plastic boxes (26 × 36 × 11 cm) with 4 L of water and an aeration system and were fed *ad libitum* fish ration (34% gross protein), with the following compounds: ground whole corn, wheat bran, soybean meal, protenosis, fish meal, meat and bone meal, vitamins (A, D3, E, K3, B1, B2, B6, B12, folic acid, niacin, pantothenic acid, choline chlorate), copper sulphate, iron sulphate, manganese monoxide, zinc oxide, iodate calcium, selenite sodium, cobalt sulfate, DL-methionine, and ethoxyquin. After the 20-day period, the total shell length was measured using a digital caliper (0.01 mm) and the snails were weighed using an analytical scale (0.0001 g). They were then transferred to plastic boxes (26 × 36 × 11 cm) and fed 10% of biomass per day, with the food amount adjusted every fifteen days according to the biometric data and mortality.

Each day, 25% of the tank water was siphoned off to remove excreta and food leftovers. Replenishment was performed from a clean water reservoir with aeration and a biological filtration system. The photoperiod during the experiment was kept constant with 12 h of light and 12 h of darkness.

The experiment lasted 225 days, and three stocking density treatments were tested: 2.5 animals/L, 5 animals/L, and 10 animals/L. Each treatment was triplicated, resulting in a total of nine boxes, considering the young individuals coming from different females as a treatment replica.

The water and air temperature (°C) and relative humidity (%) were measured with a digital thermometer and a thermohygrometer, respectively. The dissolved oxygen content (mg/L) in water was recorded with an oximeter and pH, with a portable pH meter. The contents of nitrite and ammonia (mg/L) were measured with colorimetric tests from samples taken from the treatments (Table 1). To maintain water calcium levels, 0.3 g of calcium carbonate ($CaCO3$) was added twice a week for each replica. Voucher specimens were deposited in the Malacological Collection of Instituto Oswaldo Cruz (CMIOC 10552) and identified by Prof. Dr. Silvana Carvalho Thiengo.

The biomass gain (BG) was evaluated according to the following formula: BG = (Fw × Fn) − (Iw × In), in which Fw = final weight, Fn = final number of gastropods, In = initial number of gastropods, and Iw = initial weight. For the analysis of growth, the specific growth rate (SGR) was calculated using the following formula: SGR = (Log Fw − Log Iw) × 100 / T, in which T = time elapsed. The absolute weight gain (AWG) was calculated from the equation: AWG = Fw − Iw. Percentage weight gain (PWG) was calculated from the equation: PWG = Fw − Iw × 100 / Iw. The survival rate (SR) was evaluated according to the equation: SR = (Fn × 100) / In.

Shell length, weight, BG, SGR, AWG, and PWG data of individuals were subjected to the Shapiro-Wilk test for normality. The normal distribution data were subjected to one-way analysis of variance (ANOVA), complemented by the Tukey test for means comparison. For non-normal data, the Kruskal-Wallis test was used, complemented by Dunn's test for treatment comparison. The chi-square test was used to analyze survival data in contingency table format. The size and weight gain of gastropods in relation to growth time were investigated by analysis of covariance and F test. For all statistical analyses used in this study, we adopted a significance level of $P<0.05$.

Table 1 - Minimum, maximum, mean, and standard deviation values of water quality parameters during the experiment

Treatment	Water Temperature (°C)	pH Min/Max		Nitrite (mg/L)	Ammonia (mg/L)	Dissolved oxygen (mg/L)
2.5 animals/L	28.06±0.37	7.13	7.73	0.04±0.10	0.006±0.002	5.26±0.17
5 animals/L	28.09±0.32	6.93	7.66	0.08±0.12	0.007±0.001	5.31±0.21
10 animals/L	28.07±0.36	6.87	7.59	0.21±0.10	0.009±0.001	5.28±0.18

Results

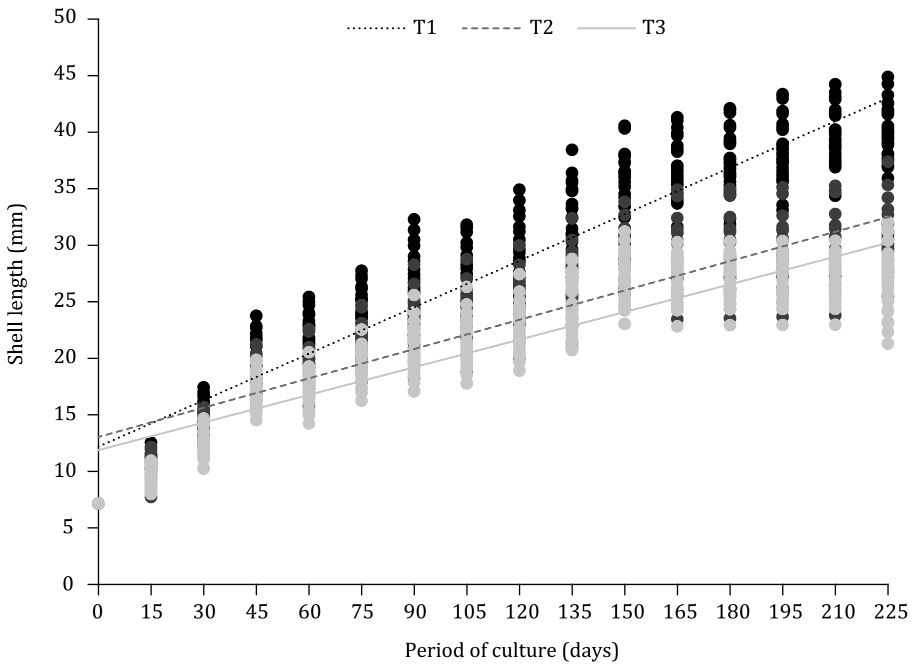
The treatment with the lowest culture density (2.5 animals/L) showed significantly higher gain for growth (F = 103.8464; DF = 2; P<0.0001), weight (H = 60.0887; DF = 2; P<0.0001), absolute weight (H = 60.0887; DF = 2; P<0.0001), specific growth rate (F = 109.5193; DF = 2; P<0.0001), and percentage weight gain (H = 60.0887; DF = 2; P<0.0001), in relation to the other treatments (5 and 10 animals/L) after 225 days of cultivation (Table 2). As for biomass gain, there was no significant difference between densities 2.5 and 5 animals/L, differing only for 10 animals/L (H = 49.2701; DF = 2; P<0.0001). The recorded survival rate showed no significant difference between treatments (X^2 = 3.841; DF = 2; P = 0.1465) (Table 2).

In the comparison between the lines of the shell length and days of cultivation ratio treatment with 2.5 animals/L was significantly different among the tested densities (ANCOVA; F = 68.75; DF = 2; P<0.0001) (Figure 2), showing increased gastropod growth. The slope of the lines for

Table 2 - Performance parameters of the culture of *Pomacea dolioides* under three stock density treatments

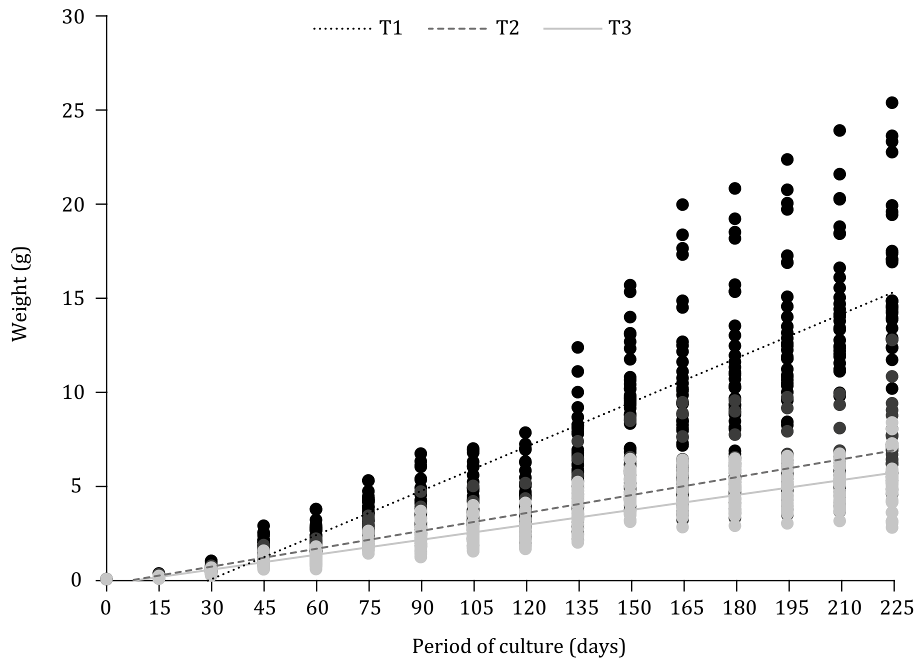
Variable	Treatment		
	2.5 animals/L	5 animals/L	10 animals/L
SL (mm)	40.05±2.25a	30.28±2.56b	26.98±2.70c
Weight (g)	16.10±3.86a	7.04±1.78b	5.05±1.39c
BG (g)	480.80±115.88a	314.24±72.94b	521.53±111.22a
SGR (%/day)	1.54±0.07a	1.31±0.07b	1.21±0.08c
AWG (g)	16.02±3.86a	6.96±1.78b	4.97±1.39c
WGP (%)	21,199.60±5109.6a	9,218.70±2354.80b	6,580.70±1840.90c
SR (%)	100±0.00	100±0.00	95.83±3.82

SL - shell length; BG - biomass gain; SGR - specific growth rate; AWG - absolute weight gain; WGP - percentage weight gain; SR - survival rate.
Means followed by different letters in the same row are significantly different (P<0.05). Kruskal-Wallis test and one-way analysis of variance complemented by Dunn and Tukey, respectively, and SR analyzed by chi-square.



T1: 2.5 animals/L; T2: 5 animals/L; T3: 10 animals/L.

Figure 2 - Relationship between the period of culture (days) and shell length (mm) of *P. dolioides* in three different stocking densities.



T1: 2.5 animals/L; T2: 5 animals/L; T3: 10 animals/L.

Figure 3 - Relationship between period of culture (days) and weight gain (g) of *P. dolioides* subjected to three different stocking densities.

the relationship of period of culture to weight gain differed significantly between treatments (ANCOVA; F = 170.8; DF = 2; P<0.0001). Treatment with 2.5 animals/L provided greater weight gain for gastropods (Figure 3).

Discussion

In this study, the survival rate was not affected by stocking density at the tested levels, as reported for other species of gastropods by Souza Júnior et al. (2013), for *Pomacea lineata* (Spix, 1827), *P. bridgesii* (Reeve, 1856), and *P. paludosa* by Garr et al. (2011). However, for *P. canaliculata*, the density effect caused a decrease in the survival of individuals (Tanaka et al., 1999), as also observed for other gastropod species of other genera such as the *Littorina irrorata* (Say, 1822) (Stiven and Kuenzler, 1979).

The treatment with 2.5 animals/L was superior for size and weight gain of *P. dolioides* when compared with the highest densities, which agrees with Conner et al. (2008), in which lower densities had higher performance results, and the higher the density, the lower growth of young *P. paludosa* individuals. The density also negatively influenced the size of *P. canaliculata* (Yoshida et al., 2013) and other species of gastropods such as *L. irrorata* (Stiven and Kuenzler, 1979), and pulmonary species such as *Helix aspersa* (Muller, 1774) and *Bulimulus tenuissimus* (d'Orbigny, 1835), with an inversely proportional relationship between density and growth (Mayoral et al., 2004; Meireles et al., 2010). Almeida and Bessa (2001a) pointed out that, for *Leptinaria unilamellata* (d'Orbigny, 1835), individuals that are kept isolated reach larger shell length than individuals in a group, but in this species, grouped individuals become sexually mature earlier, as observed for *Bradybaena similaris* (Férussac, 1821) (Almeida and Bessa, 2001b). As for individuals of *Balea perversa* (Linnaeus, 1758) held at high densities, their size is reduced and, consequently, their sexual maturity is delayed; however, their reproductive rate does not differ among different densities (Baur and Baur, 1994). For *Pomacea dolioides*, within the same treatment, there was great variation in size, even though in treatments with higher density, individuals had less growth. Pires-Júnior et al. (2017), who cultured *P. dolioides* in different conditions of food and feeding frequency, observed the same result.

Gastropods at densities of 5 and 10 animals/L had lower SGR. Garr et al. (2011) reported that a monospecific diet and high densities over time are detrimental to the development of young *Pomacea paludosa*, causing low growth rates, which can be minimized with the use of a wider variety of feeds at lower densities, so that young individuals reach larger sizes and sexual maturity faster. Alves et al. (2006) noted that, for *P. lineata* and *P. bridgesii*, SGR did not differ between species in a 16-week period, but, at a lower density than in our study, the gains were higher than for *P. dolioides*.

The biomass gain was highest in treatment 10 animals/L, probably due to the larger number of individuals in the treatment. As for the absolute weight gain, treatment with 2.5 animals/L had the highest increases, reaching more than 43% than the other two treatments, corroborating Souza Júnior et al. (2013), who found that the increase in density reduced the weight gain of individuals of the two investigated *Pomacea* species, probably due to social factors. Hence, it can be inferred that intraspecific competition may have aspects such as territoriality or hierarchy, which affect the development of individuals. However, for freshwater snails, it has not been established whether these individual differences are caused by competitive interactions such as competition for exploration, environmental factors, or other factors such as genetics. They do not grow uniformly, which implies that factors such as interaction between individuals partially affect their development (Kawata and Inaba, 1992).

Based on studies on the effect of density on the growth of different species of the *Pomacea* genus, Conner et al. (2008) stated that this gastropod seems to be quite sensitive to initial density increases compared to other species, confirming our findings with *P. dolioides*. Increasing the number of individuals per area tends to make the performance drop, even under similar conditions of water and food. Species of the genus *Pomacea* is not yet commercially explored in the Amazon region, but it can be considered an alternative protein source to supplement human food and feeding of other animals of husbandry interest. Thus, in laboratory conditions, *P. dolioides* showed higher gains with lower density (2.5 animals/L) treatments, and the mentioned densities are recommended in association with a rate of food at least three times a day, as suggested by Pires-Júnior et al. (2017), when seeking to adapt other techniques, to explore the full potential of still unknown cultivations.

Conclusions

The density with the best cultivation results is 2.5 animals/L, being most effective for the parameters of growth, weight gain, specific growth rate, and percentage weight gain, when compared with other treatments after 225 days of the experiment. For future cultivation of this species, a density of 2.5 animals/L should be used to improve handling performance.

Acknowledgments

The authors wish to thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), for the scholarship granted to Pires Júnior, A. N., and Conselho Nacional de Desenvolvimento Científico e Tecnológico, for the grant provided to Sant'Anna, B. S. (CNPq#409910/2016-3). We would also like to thank Prof. Dr. Silvana Carvalho Thiengo, for helping with the identification of gastropods; the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), for the collection license (46230-2); George William Siple, for the English revision of the text; and the anonymous reviewers for their suggestions and comments to our manuscript.

References

Almeida, M. N. and Bessa, E. C. A. 2001a. Estudo do crescimento e da reprodução de *Leptinaria unilamellata* (d'Orbigny) (Mollusca, Subulinidae) em laboratório. Revista Brasileira de Zoologia 18:1107-1113. https://doi.org/10.1590/S0101-81752001000400009

Almeida, M. N. and Bessa, E. C. A. 2001b. Estudo do crescimento e da reprodução de *Bradybaena similaris* (Férussac) (Mollusca, Xanthonychidae) em laboratório. Revista Brasileira de Zoologia 18:1115-1122. https://doi.org/10.1590/S0101-81752001000400010

Alves, T.; Lima, P.; Lima, S. F. B.; Ferri, A. G.; Barros, J. C. and Machado, J. 2006. Growth of *Pomacea lineata* and *Pomacea bridgesii* in different stock densities. Thalassas 22:55-64.

Barboza, S. H. R. and Romanelli, P. F. 2005. Rendimento de carcaça e composição centesimal do músculo dos moluscos escargot (*Achatina fulica*) e aruá (*Pomacea* lineata). Alimentos e Nutrição 16:77-82.

Baur, A.; Baur, B. and Fröberg, L. 1994. Herbivory on calcicolous lichens: different food preferences and growth rates in two co-existing land snails. Oecologia 98:313-319. https://doi.org/10.1007/BF00324219

Chimsung, N. and Tantikitti, C. 2014. Fermented golden apple snails as an alternative protein source in sex-reversed red tilapia (*Oreochromis niloticus* x *O. mossambicus*) diets. Agricultural Technology and Biological Sciences 11:41-49.

Campalans, M. and Lohrmann, K. B. 2009. Histological survey of four species of cultivated molluscs in Chile susceptible to OIE notifiable diseases. Revista de Biología Marina y Oceanografia 44:561-569. https://doi.org/10.4067/S0718-19572009000300004

Cardenas, E. B. 1984. Status of molluscan aquaculture on the Pacific coast of Mexico. Aquaculture 39:83-93. https://doi.org/10.1016/0044-8486(84)90260-6

Cavalli, R. O. and Ferreira, J. F. 2010. O futuro da pesca da aquicultura marinha no Brasil: a maricultura. Ciência e Cultura 62:38-39.

Chen, H. C. 1984. Recent innovations in cultivation of edible molluscs in Taiwan, with special reference to the small abalone *Haliotis diversicolor* and the hard clam *Meretrix lusoria*. Aquaculture 39:11-27. https://doi.org/10.1016/0044-8486(84)90256-4

Coeroli, M.; De Gaillande, D. and Landret, J. P. 1984. Recent innovations in cultivation of molluscs in French Polynesia. Aquaculture 39:45-67. https://doi.org/10.1016/0044-8486(84)90258-8

Conner, S. L.; Pomory, C. M. and Darby, P. C. 2008. Density effects of native and exotic snails on growth in juvenile apple snails *Pomacea paludosa* (Gastropoda: Ampullariidae): a laboratory experiment. Journal of Molluscan Studies 74:355-362. https://doi.org/10.1093/mollus/eyn024

Estebenet, A. L. and Martín, P. R. 2002. *Pomacea canaliculata* (Gastropoda: Ampullariidae): life-history traits and their plasticity. Biocell 26:83-89.

Garr, A. L.; Lopez, H.; Pierce, R. and Davis, M. 2011. The effect of stocking density and diet on the growth and survival of cultured Florida apple snails, *Pomacea paludosa*. Aquaculture 311:139-145. https://doi.org/10.1016/j.aquaculture.2010.11.017

Itami, K.; Izawa, Y.; Maeda, S. and Nakai, K. 1963. Notes on the laboratory culture of the octopus larvae. Nippon Suisan Gakkaishi 29:514-519.

Kawata, M. and Inaba, M. 1992. Individual differences in growth and access to food in the freshwater snail, *Physa acuta*. Journal of Ethology 10:75-79. https://doi.org/10.1007/BF02350189

Laing, I. and Spencer, B. E. 2006. Bivalve cultivation: criteria for selecting a site. Science Series Technical Reports of Centre for Environment Fisheries and Aquaculture Science 136:1-28.

Lazaridou-Dimitriadou, M.; Alpoyanni, E.; Baka, M.; Brouziotis, T. H.; Kifonidis, N.; Mihaloudi, E.; Sioula, D. and Vellis, G. 1998. Growth, mortality and fecundity in successive generations *Helix asersa* Müller cultured indoors and crowding effects on fast medium and slow growing snails of the same clutch. Journal of Molluscan Studies 64:67-74. https://doi.org/10.1093/mollus/64.1.67

Lum-Kong, A. and Kenny, J. S. 1989. The reproductive biology of the ampullariid snail *Pomacea urceus* (Müller). Journal of Molluscan Studies 55:53-65. https://doi.org/10.1093/mollus/55.1.53

Luo, D.; Mu, X. D.; Song, H. M.; Gu, D. E.; Yang, Y. X.; Wang, X. J.; Luo, J. R.; Hu, Y. C. and Zhang, J. E. 2012. Nutritional components and utilization values of golden apple snails (*Pomacea canaliculata*) in different habitats. Chinese Journal of Ecology 8:0-19.

Magdalena, A. B.; Lehane, M.; Krys, S.; Fernández, M. L.; Furey, A. and James, K. J. 2003. The first identification of azaspiracids in shellfish from France and Spain. Toxicon 42:105-108. https://doi.org/10.1016/S0041-0101(03)00105-3

Mayoral, A. G.; Garcia, A.; Perea, J.; Martin, R.; Martos, J.; Acero, R. and Pena, F. 2004. Effect of population density on size of edible snail *Helix aspersa* Muller. Archivos de Zootecnia 53:379-382.

Meireles, L.; Da Silva, L. C.; Junqueira, F. O.; Lopes, J. F. S. and Bessa, E. C. 2010. Influência da densidade populacional sobre crescimento e fecundidade de *Bulimulus tenuissimus* (d'Orbigny, 1835) (Mollusca, Bulimulidae). Revista Brasileira de Zoologia 12:51-58.

Melo, I. B.; Hattoi, G. Y. and Sant'Anna, B. S. 2017. Reproduction and substrate selection for oviposition of the gastropod *Pomacea dolioides* (Reeve, 1856). p.89-108. In: Amazonian apple snails. Sant'Anna, B. S. and Hattori G. Y., eds. NOVA Science Publishers, New York.

Phonekhampheng, O.; Hung, L. T. and Lindberg, J. E. 2009. Ensiling of golden apple snails (*Pomacea canaliculata*) and growth performance of african catfish (*Clarias gariepinus*) fingerlings fed diets with raw and ensiled golden apple snails as protein source. Livestock Research for Rural Development 21, article #207.

Pires-Júnior, A. M.; Hattori, G. Y. and Sant'Anna, B. S. 2017. Effects of diet and feeding frequency on culture of juveniles of apple snail *Pomacea dolioides*. p.67-88. In: Amazonian apple snails. Sant'Anna, B. S. and Hattori G. Y., eds. NOVA Science Publishers, New York.

Posch, H.; Garr, A. L.; Pierce, R. and Davis, M. 2012. The effect of stocking density on the reproductive output of hatchery-reared Florida apple snails, *Pomacea paludosa*. Aquaculture 360:37-40. https://doi.org/10.1016/j.aquaculture.2012.07.007

Ruiz-Ramírez, R.; Espinosa-Chávez, F. and Martínez-Jerónimo, F. 2005. Growth and reproduction of *Pomacea patula catemacensis* Baker, 1922 (Gastropoda: Ampullariidae) when feed *Calothrix* sp. (Cyanobacteria). Journal of the World Aquaculture Society 36:87-95. https://doi.org/10.1111/j.1749-7345.2005.tb00134.x

Santos, E. 1982. Os moluscos (vida e costumes). Itatiaia, Belo Horizonte.

Seuffert, M. E. and Martín, P. R. 2010. Dependence on aerial respiration and its influence on microdistribution in the invasive freshwater snail *Pomacea canaliculata* (Caenogastropoda, Ampullariidae). Biological Invasions 12:1695-1708. https://doi.org/10.1007/s10530-009-9582-5

Simone, L. R. L. 2006. Land and freshwater mollusks of Brazil. EGB/FAPESP, São Paulo.

Souza Júnior, E.; De Barros, J. C. N.; Paresque, K. and De Freitas, R. R. 2013. The effect of stocking density on the growth of apple snails native *Pomacea bridgesii* and exotic *Pomacea lineata* (Mollusca, Gastropoda). Anais da Academia Brasileira de Ciências 85:753-760.

Stiven, A. E. and Kuenzler, E. J. 1979. The response of two salt marsh molluscs, *Littorina irrorata* and *Geukensia demissa*, to field manipulations of density and *Spartina litter*. Ecology Monograph 49:151-171. https://doi.org/10.2307/1942511

Tamburi, N. E. and Martín, P. R. 2016. Effects of absolute fasting on reproduction and survival of the invasive apple snail *Pomacea canaliculata* in its native range. Current Zoology 62:369-375. https://doi.org/10.1093/cz/zow023

Tanaka, K.; Watanabe, T.; Higuchi, H.; Miyamoto, K.; Yusa, Y.; Kiyonaga, T.; Kiyota, H.; Suzuki, Y. and Wada, T. 1999. Density-dependent growth and reproduction of the apple snail, *Pomacea canaliculata*: a density manipulation experiment in a paddy field. Research in Population Ecology 41:253-262. https://doi.org/10.1007/s101440050029

Vázquez-Silva, G.; Castro-Barreta, T.; Castro-Mejía, J. and Mendonza-Martínez, G. D. 2011. Los caracoles del género *Pomacea* (Perry, 1810) y su importancia ecológica y socioeconómica. ContactoS 81:28-33.

Yan, X.; Zhang, G. and Yang, F. 2006. Effects of diet, stocking density, and environmental factors on growth, survival, and metamorphosis of Manila clam *Ruditapes philippinarum* larvae. Aquaculture 253:350-358. https://doi.org/10.1016/j.aquaculture.2005.07.030

Yoshida, K.; Hoshikawa, K.; Wada, T. and Yusa, Y. 2013. Patterns of density dependence in growth, reproduction and survival in the invasive freshwater snail *Pomacea canaliculata* in Japanese rice fields. Freshwater Biology 58:2065-2073. https://doi.org/10.1111/fwb.12191