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Short Communication

Effect of shelters on the growth and cultivation performance of the endemic snail, *Pomacea patula catemacensis*, cultured in a recirculating system during its grow-out

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ABSTRACT. This study describes the process of *Pomacea patula catemacensis* grow-out in outdoor tanks. Experimental juvenile snails (1.5-2 months old) obtained from wild breeding snails were reared using a recirculating aquaculture system (RAS). The present study focused on increasing the surface area of growth tanks to be used by snails without affecting their growth and survival by adding shelters throughout the water column, which also worked to harbor snails. Two treatments were tested; T1: shelters made with curved clay tiles, T2: curved PVC shelters, and control (without shelters) in triplicate. The stocking density was set at 420 ind m^{-2} in tanks with 1 m^3 total volume, and the culture period was 150 days. The final weight of the snails was significantly higher in control and PVC shelter groups (9.14 ± 2.2 and 8.83 ± 2.31 g, respectively), with PVC shelters showing the highest productivity in total biomass (12.03 ± 0.86 kg $tank^{-1}$, $P < 0.05$). Final survival (%) was not significantly different among treatments (56.49 ± 1.62 to 58.05 ± 0.62).

Keywords: *Pomacea patula catemacensis*; snail fattening; artificial substrates; gastropod aquaculture; outdoor aquatic systems; Lake Catemaco

The snail *Pomacea patula catemacensis*, known commonly as "tegogolo", is an endemic species from Lake Catemaco located in Los Tuxtlas, Veracruz, Mexico (Naranjo-García 2003); its fishery represents economic regional value (Calderón-Villagómez et al. 2001, NOM-041-PESC-2004). Unfortunately, its population has sharply declined from 280 t in 2007 to 12 t in 2013 and 82 t in 2020 (CONAPESCA 2023), reflecting the broader trend that freshwater species are among the most threatened taxa in the world (Dudgeon et al. 2006). Several factors could be related to the vulnerable status of aquatic species in Lake Catemaco, including the decrease in tegogolo populations, such as water contamination associated with pesticides (Calderón-Villagómez et al. 2001), biotoxins (Berry et al. 2012) and pressures like overfishing, inter-specific competition and predation from exotic species (Jelks et al. 2008), e.g. the tilapia (*Oreochromis* spp.) (Lorán-Nuñez et al. 2013) and the translocated fish *Mayaheros urophthalmus* (Jiménez-García & Suárez-Morales 2017). In this regard, conserving endangered species and endemism requires controlled cultivation throughout their life cycles (Haryono et al. 2022). Prior research has demonstrated the feasibility of cultivating

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Figure 1. Process of the cultivation phases of *Pomacea patula catemacensis*.

P. p. catemacensis in captivity (Fig. 1) (Espinosa-Chávez & Martínez-Jerónimo 2005, Ruiz-Ramírez et al. 2005, Meyer-Willerer & Santos-Soto 2006, García-Ulloa et al. 2008, Vázquez-Silva et al. 2012, Jiménez et al. 2013). Such authors have successfully managed tegogolos in relatively small containers. Small-scale tegogolo grow-out attempts in Veracruz state have been made in concrete or fiberglass tanks of 1000 L or more (*unpubl. obs.*). However, the space occupied by the water in such tanks results in a large spatial area being misused for culturing benthic species, such as the tegogolo snail. This study addressed this problem by setting up shelters throughout the tank's water column in a recirculating aquaculture system (RAS) and testing different shelters to increase the surface of tegogolo cultivation.

An experiment was conducted to study the effect of shelters on the growth and culture performance of *P. p. catemacensis* during its grow-out. The experiment was designed with two treatments, curved clay tiles (T1) and curved PVC substrates (T2), implemented for 150 days. A control group without substrates was also included. The experiment was performed in triplicate. Nine experimental units were randomly placed. Each unit consisted of a concrete tank filled with 800 L of water connected to a RAS. The area of the control tanks was 5.63 m^2 each, which increased to 7.13 m^2 in T1 and T2 due to shelters (1.5 m^2 of internal plus external faces). Based on the stocking density of 420 ind m^{-2}, the total number of juvenile snails (1.5 to 2 months old) per tank was 2377 for T1 and T2 and 1747 for control tanks. According to Souza et al. (2013), the initial feeding of snails was 15% of biomass. The feeding percentage was gradually decreased to 3% by the end of the study based on their consumption. The growth of snails was evaluated every 15 days. Despite previous studies sampling between 10 and 30% of relatively small tegogolo populations (Iriarte-Rodríguez & Mendoza-Carranza 2007, De Jesús-Navarrete et al. 2023), we opted to sample 3% (51 snails/control replica and 71 snails/treatment replica), as recommended by Yogev et al. (2020) for high-density fish culture. Before each sampling, the snails of tank walls and shelters were mixed, and random samples were taken. The total length of the shell was measured using a digital vernier caliper (Ultratech H-7352) with a precision of 0.01 mm. Weight was obtained with a digital balance (Ohaus) with an accuracy of 0.01 g. The following response variables were calculated: 1) daily length gain (DLG), 2) daily weight gain (DWG), 3) final biomass per tank, and 4) survival at the end of the study. The performance of the RAS was monitored daily by measuring temperature and dissolved oxygen using a YSI-55 multi-parameter probe; pH nitrites, nitrates, hardness, and ammonia were measured weekly using colorimetric kits. From day 30, 100% water exchanges were conducted every 10 days to maintain optimal conditions in the RAS. The effect of treatments on the growth performance and biomass was evaluated using a one-way variance analysis after transforming the values to a $\log_{10}$ (x+1) scale to get data homoscedasticity. Finally, *post-hoc* Tukey tests were applied.

The effect of treatments on the percentage of final survival was analyzed with Chi-square tests. The significance between treatments was established at $P < 0.05$ using Statistica software v.7.0 StatSoft Inc. 2004.

The average values of environmental variables were: water temperature 27.36 ± 0.10°C in the rainy months (July to September) and 26.04 ± 1.04°C in the winter season (October and November). Dissolved oxygen remained between 5.4 and 6.1 mg L^{-1}, and pH fluctuated between 7.45 and 7.92. Ammonia levels mostly stayed below 1 mg L^{-1}.

During the first 120 days of cultivation, the growth of the organisms was steady; later, it halted between days 120 and 135 (Fig. 2), which coincided with the lowest values in water temperature. All treatments yielded snails reaching minimum commercial size (32 mm shell length) (NOM-041-PESC-2004) by day 150, with spawning beginning after day 105. Table 1 shows the response variables (growth and cultivation performance) between the control and substrate treatments (PVC and clay). The highest increase in snails' final length (F = 14.23, $P < 0.0001$) and weight (F = 25.900, $P < 0.00001$) was registered in the control treatment and the PVC shelters. The final average biomass per tank was significantly higher in the treatments with PVC shelters (12.03 ± 0.86 kg $tank^{-1}$); the treatments did not affect the snail survival ($P > 0.05$) (Table 1). The correlations between the weight and length of snails during their grow-out indicate a good fit to a potential model for the control and PVC shelters treatment ($y = 0.0007x^{2.7145}$; $y = 0.0005x^{2.8305}$, respectively); however, in the case of clay tile, fit better to a quadratic model ($y = 0.0166x^2 - 0.3339x + 2.297$) (Fig. 3).

During the tegogolo growth period, oxygen levels were adequate (5 to 8 mg L^{-1}), with pH slightly lower than Lake Catemaco (7.3 ± 0.09 *vs*. 8-9), as per Lorán-Nuñez et al. (2013). Nitrate concentration stayed below 1 mg L^{-1}. Water temperature varied between 28-29°C, dropping to 23.7°C in colder months (Appendini et al. 2018), coinciding with reduced snail growth between days 120 and 135. In Lake Catemaco, temperatures range 19.8-30°C, pH is 8-9, oxygen levels are 6-10 mg L^{-1} (Soto 1979, Torres-Orozco & Zanatta 1998, Komárková & Tavera 2003), and nitrogen concentrations 0.2-1.21 µg L^{-1} (Lind et al. 2016).

The tegogolo snails in our research thrived on commercial 35% crude protein (CP) tilapia feed, mirroring the findings of Vázquez-Silva et al. (2012), who conducted their study in aquariums under controlled conditions. They reported a 74% survival rate using tilapia feed; the survival rates in our RAS ranged from 54 to 59%. These rates are comparable to the 63% survival registered by Iriarte-Rodríguez & Mendoza-Carranza (2007) for *Pomacea flagellata* under similar conditions to our study. Commercial tilapia pellets (35% CP) were used with stocking densities ranging from 2 to 3 ind L^{-1}, exceeding the 1 ind L^{-1} reported by Iriarte-Rodríguez & Mendoza-Carranza (2007). Reported stocking densities for *Pomacea* vary, typically ranging between 0.5 and 5 ind L^{-1} (García-Ulloa et al. 2008, Vázquez-Silva et al. 2012, Jiménez et al. 2013, De Jesús-Navarrete et al. 2023).

In our RAS with PVC shelters, tegogolos aged 6-8 weeks and weighing around 0.7 g reached 8.83 ± 2.31 g at 150 days, at a density of approximately 3 ind L^{-1}. Comparable to the findings of Vázquez-Silva et al. (2012) for the same species using tilapia feed at a den-

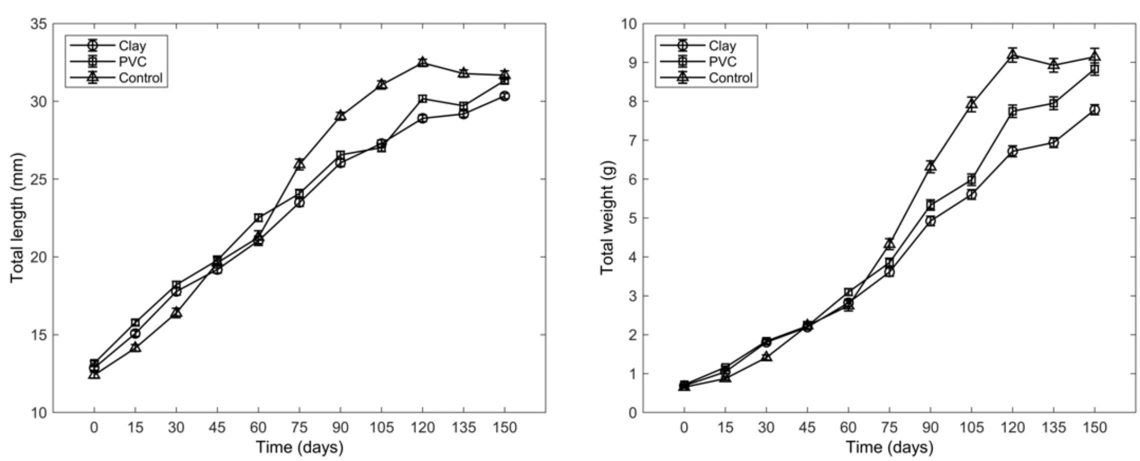

Figure 2. Increase of total length and weight of *Pomacea patula catemacensis* during 150 days of grow-out in control (N = 51 individuals/sampling) and clay and PVC treatments (N = 71 individuals/sampling). Vertical bars denote 95% confidence intervals.

Table 1. Growth and cultivation performance during the grow-out of *Pomacea patula catemacensis* (150 days). Different superscripts indicate differences between treatments.

Parameter	Control	PVC	Clay
Water volume	800	800	800
Stocking density (ind m^{-2})	420	420	420
Total stocked individuals	5,241	7,131	7,131
Initial length (mm)	12.40 ± 2.53[a]	13.17 ± 2.10[a]	12.87 ± 2.19[a]
Initial weight (g)	0.67 ± 0.24[a]	0.71 ± 0.31[a]	0.69 ± 0.33[a]
Final length (mm)	31.67 ± 2.78[a]	31.33 ± 2.85[a]	30.33 ± 2.48[b]
Final weight (g)	9.14 ± 2.2[a]	8.83 ± 2.31[a]	7.78 ± 1.88[b]
Daily length gain (mm d^{-1})	0.13 ± 0.006[a]	0.12 ± 0.002[a]	0.11 ± 0.004[b]
Daily weight gain (g d^{-1})	0.05 ± 0.003[a]	0.04 ± 0.003[a]	0.04 ± 0.001[b]
Final biomass (kg $tank^{-1}$)	9.26 ± 0.67[a]	12.03 ± 0.86[b]	10.34 ± 0.87[a]
Survival (%)	58.05 ± 0.62[a]	57.31 ± 0.53[a]	56.49 ± 1.62[a]

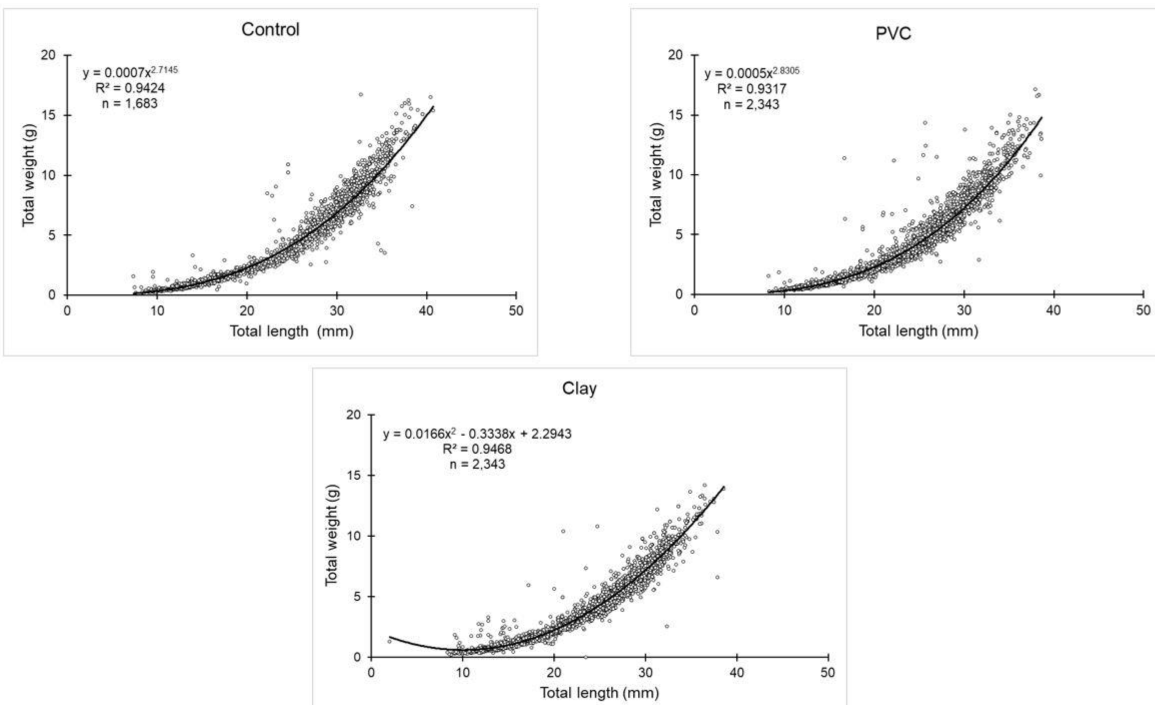

Figure 3. Correlation between the length and weight of *Pomacea patula catemacensis*.

sity of 0.5 ind L^{-1}. Both experiments concluded with snails at approximately 210 days of age. Notably, our records showed the highest DLG (0.13 ± 0.006 mm) and DWG (0.05 ± 0.003 g) in the control tanks (2.1 ind L^{-1}). In contrast, higher-density conditions (5 ind L^{-1}) resulted in a lower DWG of 0.01 ± 0.002 g (Jiménez et al. 2013), significantly less than the value reported by Vázquez-Silva et al. (2012) of 0.042 g. For the larger species *P. flagellata*, growth rates were 0.515 ± 0.07 mm d^{-1} (DLG) and 0.25 g d^{-1} (DWG) (Iriarte-Rodríguez & Mendoza-Carranza 2007), while De Jesus-Navarrete et al. (2023) recorded a DLG of 0.31 mm d^{-1}. These differences are notably higher compared to *P. p. catemacensis* raised at a density of 0.5 ind L^{-1}, with a DLG of 0.012 ± 0.02 mm and a DWG of 0.042 g (Vázquez-Silva et al. 2012) and our findings.

The relationship between the weight and size of *P. p. catemacensis* during their control growth and PVC shelters followed an exponential model. García-Ulloa et al. (2008) observed rapid growth but found a linear relationship during broodstock growth, attributing variations to genetics and sex. In our study, the growth of snails (males+females) in clay shelters followed a quadratic equation. A notorious difference between the kinds of shelters used in our study is that the light penetration is practically zero in the clay tile at the difference of PVC. Therefore, the snails occupying the inferior side of the curved shelters did not receive solar light. Although snails exhibit negative phototaxis (Linton-Izquierdo 2019), the light effect in the growth of gastropods is a subject that should be studied because it potentially impacts shell production (Rossbach et al. 2019).

Mejía-Ramírez et al. (2020) conducted a study that showed the potential profitability of *P. p. catemacensis culture*. However, there is still a concern about the sustainability of the culture and the decline of wild populations. A gradual approach is necessary to ensure the profitability of this culture, with support from local groups such as fishers, artisan women, and youth learning snail cultivation, as Renn & Weirowski (2011) suggested, which requires trans-disciplinary research in species conservation, ecosystem restoration, and improved tegogolo management. The process should begin with small-scale aquaculture, promoting the welfare of the snails.

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