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Original

Growth and survival of *Cryphiops caementarius* in coculture with *Oreochromis niloticus* at different densities

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ABSTRACT

Objective. To evaluate the growth and survival of *Cryphiops caementarius* in coculture with *Oreochromis niloticus* at different densities. **Materials and methods.** Male prawns (5.86 cm and 7.65 g) and reverse tilapia fingerlings (5.65 cm and 2.61 g) were used. Nine aquariums (55 L) were used. Six containers were installed in each aquarium, where one prawn was stocked per container (32 prawn/m^2), and in the remaining water, tilapia was stocked at densities of 100, 200 and 300 fish/m^3. Balanced feed was used. The daily ration for prawns was 6% and for tilapia, it was 5% of the total biomass. The experiment lasted 90 days**. Results.** In prawns, the length (6.46 cm), weight (9.37 g), percentage gains in length (10.01% at 10.45%) weight (19.24% a 25.41%), and survival (88.89% to 94.44%) were similar ($p<0.05$) between treatments. The effect of molting death syndrome is discussed. In tilapia, the length (9.25 cm), weight (12.90 g), absolute growth rate (0.040 cm/day; 0.114 g/day), specific growth rate (0.55% length/day; 1.759% weight/day) and percentage gain (64.21%; 389.48%) were greater ($p<0.05$) at 100 and 200 fish/m^3. Tilapia survival was similar (86.11%) between treatments. **Conclusions.** Prawn growth and survival were affected by molt death syndrome but not by the presence of tilapia in the system. In contrast, greater growth of tilapia was obtained with 100 fish/m^3, although survival was similar between treatments.

Keywords: Intensive culture; biomass; polyculture; prawn; tilapia. (*Source: CAB*).

RESUMEN

Objetivo. Evaluar el crecimiento y la supervivencia de *Cryphiops caementarius* en cocultivo con *Oreochromis niloticus* a diferentes densidades. **Materiales y métodos.** Se utilizaron camarones machos (5.86 cm y 7.65 g) y alevines revertidos de tilapia (5.65 cm y 2.61 g). Se emplearon nueve acuarios (55 L). En cada acuario se instalaron seis recipientes donde se sembró un camarón por recipiente (32 camarones/m^2) y en el agua restante se sembraron tilapias a 100, 200 y 300

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alevines/m^3. Se empleó alimento balanceado. La ración diaria para camarones fue del 6% y para tilapia fue del 5% de la biomasa total. El experimento duró 90 días. **Resultados.** En el camarón, la longitud (6.46 cm), peso (9.37 g), las ganancias porcentuales en longitud (10.01% a 10.45%) peso (19.24% a 25.41%), y la supervivencia (88.89% a 94.44%) fueron similares ($p<0.05$) entre tratamientos. El efecto del síndrome de muerte por muda es discutido. En tilapia, la longitud (9.25 cm), peso (12.90 g), tasa de crecimiento absoluto (0.040 cm/día; 0.114 g/día), tasa de crecimiento específica (0.55% longitud/día; 1.759% peso/día) y la ganancia porcentual (64.21%; 389.48%) fueron mayores ($p<0.05$) a 100 y 200 alevines/m^3. La supervivencia de tilapia fue similar (86.11%) entre tratamientos. **Conclusiones.** El crecimiento y la supervivencia del camarón fueron afectados por el síndrome de muerte por muda, más no por la presencia de tilapia en el sistema. En cambio, mayor crecimiento de tilapia se obtuvo con 100 alevines/m^3 y la supervivencia fue similar entre tratamientos.

Palabras clave: Cultivo intensivo; biomasa; policultivo; camarón; tilapia. (*Fuente: CAB*).

INTRODUCTION

Coculture is similar to polyculture due to the combination of species but differs in the way in which they are separated within the aquatic environment. In polyculture, organisms, due to their different feeding habits and spatial distribution, maximize production, where one species is the main species and the other is not but are considered in the yield (1). In coculture, two or more species occupy the same body of water, but there is a physical separation between them; for example, a species cultivated in cages within a pond where another species is cultivated (2), and in this case, the species are important in management and production.

In coculture of *Homarus gammarus* in compartments within tanks with *Idotea emarginata*, the latter uses the waste generated in the system (3). In coculture of *Clarias batrachus* in cages within ponds with *Macrobrachium rosenbergii*, higher growth and productivity were obtained (4). Likewise, in coculture of *Oreochromis niloticus* in cages within ponds with *M. rosenbergii*, both species show higher growth and yield, as there is no physical interaction (5). However, coculture of *Cryphiops caementarius* in individual compartments within aquariums with different densities of *O. niloticus* has not been investigated.

The Nile tilapia *O. niloticus* is omnivorous but feeds on microalgae found in the water column and in the substrate (6). Furthermore, this species of tilapia is resistant and fast growing in different management systems but with adequate stocking densities. Tilapia at 50 fish/m^3 show a higher final weight and specific growth rate than at higher densities (7), and between 100 and 450 fish/m^3, growth and yield are not affected (8,9,10). In *O. mossambicus*, an increase from 429 to 1716 fish/m^3 causes a decrease in growth due to the social hierarchy that causes small fish not to feed due to the dominance of the larger ones (11).

Prawn *C. caementarius* inhabit the rivers from Lambayeque in Peru to Valparaíso in Chile (12), but there is a high population density of these prawn in rivers of Arequipa, Peru, where the water temperature varies between 18.4 to 26.8°C (13). This prawn species has economic and commercial importance, as 997 t (14) have entered the Lima, Peru market at present. Prawn farming has not been established due to the aggressiveness of male specimens, which leads to interaction and cannibalism. However, an alternative method of improving growth, survival and productive performance is through the use of individual containers, where the culture is at a high density (32 prawn/m^2) (15). In cultures of aggressive crustaceans in individual compartments, there is no cannibalism, growth is greater, and high survival is maintained even at very high densities (>142 prawn/m^2), as in *Cherax quadricarinatus* (16) and *H. gammarus* (17).

Consequently, according to advances in the cultivation of temperate climate crustaceans (*C. caementarius*) and tropical fish (*O. niloticus*), the objective was to evaluate the growth and survival of *C. caementarius* in coculture with *O. niloticus* at different densities.

MATERIALS AND METHODS

Organisms. Male prawn were collected from the Pativilca River (10°39'53.6" S - 77°40'23.2" W) near the population center of Huayto (Lima, Peru), and for transportation, each prawn was placed in a plastic cup (250 mL) with holes and were conditioned in containers with water from the same river (45 L) and with aeration (15). The transport density was 50 prawn per container. Land transportation lasted 5 h, and there was no mortality. Prawn were acclimatized for one week in the same transport system and fed a balanced formulation (30% crude protein, 5% total fat, 10% ash and 5% fiber) (15). The *C. caementarius* species was recognized with a taxonomic key (18), and the male sex was verified by the presence of gonophores in the coxopodites of the fifth pair of pereopods (19).

Sexually reversed 20-day-old male *O. niloticus* fry came from the Estación Pesquera Ahuashiyacu (6°30'55.83" S - 76°19'50.65" W) (Tarapoto, Perú). Fish were transported in polyethylene bags with 10 L of water (25 fish/L) and pure oxygen under pressure. The bags with the fish inside were packed in 20 L plastic buckets. Land transportation lasted 30 h, and there was 5% mortality. Fish were acclimatized for one week in fiberglass tanks (240 L) to 200 fish/m^3 and they were fed to satiety.

Coculture. The coculture system used (15) consisted of nine glass aquariums (0.60 m long, 0.31 m wide, 0.35 m high, 0.186 m^2 and 55 L), each with an air-type water recirculation system-water-lift (1.5 L/min) and with a biological trickling filter (2.5 L), whose filter bed was crushed shells and gravel, in equal proportions. Inside each aquarium, six plastic containers were installed (19 cm diameter, 8 cm height and 284 cm^2) that were arranged in two groups of three levels. The containers had holes (3 cm long by 0.5 cm wide) on the sides to allow the flow of water. In addition, a tube (½" Ø PVC) was attached that protruded the water level and through which the feed granules were distributed (Fig. 1). The six installed containers occupied 15 L, and the remaining volume of the aquarium was 40 L. Drinking water was aerated for 72 h to remove the chlorine.

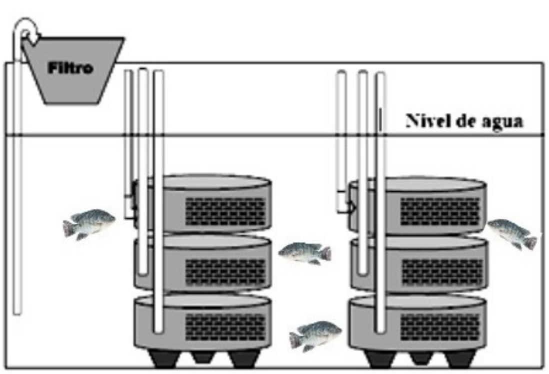

Figure 1. *C. caementarius* coculture system with *O. niloticus* in aquarium.

Stocking. One prawn was stocked in each culture container, which was equivalent to six prawn per aquarium (32 prawn/m^2). Fifty-four prawn (5.86±0.12 cm and 7.65±0.26 g) were used that had complete cephalothoracic appendages and did not show signs of lacerations on the body and appendages. In addition, 4, 8 and 12 tilapia fish were stocked in each aquarium, which equaled 100, 200 and 300 fish/m^3, respectively. Seventy-two healthy-looking fish (5.65±0.03 cm and 2.61±0.08 g) were used.

Food. The prawn and tilapia were fed only with the formulation that was prepared for prawn (15) supplemented with 3% *Saccharomyces cerevisiae* (20) and which had 30% crude protein, 8.1% total lipids and 4.6% fiber, with 2600 kcal/g. The daily ration (08:00 and 18:00 h) for prawn was 6% of wet weight, and for tilapia, it was 5%. The prawn feed was distributed through the feeder tubes of each container; the tilapia feed, through the aquarium water surface.

Zootechnical parameters. Sampling of prawn and tilapia was carried out every 30 days for 90 days. Total weight was determined on a digital scale (Adam AQT600, ±0.1 g). The total length of the prawn (from the postorbital notch to the posterior end of the telson) and tilapia was measured with a ruler (±0.1 cm). Zootechnical parameters were determined with the following formulas:

Percentual gain (%) = $[(X_2 - X_1)/X_1] * 100$

Absolute growth rate = $(X_2 - X_1)/t_2 - t_1$

Specific growth rate (%/day) = $[\ln X_2 - \ln X_1)/t_2 - t_1] * 100$

Survival (%) = $(N_i * 100)/N_o$

Yield = $(X_2 * D_2)/1000$

where X_1 and X_2 are the length, wet weight, start and end; t_1 and t_2 are the duration in days; ln X_1 and ln X_2 are the natural logarithm of length or initial and final weight; N_o and N_i are the initial and final number of stocked organisms, respectively; and D_2 is final density.

Water quality. Accumulated solid waste in aquariums was removed weekly. Water quality was monitored every 15 days, and dissolved oxygen and water temperature were determined with digital oximeter (Hatch LDO, ±0.01 mg/L, ±0.01°C), and total hardness, total ammonia and nitrites were determined with the Nutrafin colorimetric test (±0.1 mg/L).

Statistical analysis. The data were analyzed with the Shapiro-Wilk test ($p<0.05$), and all data met the normal distribution assumption. To determine if there were differences between the treatment means, one-way analysis of variance (ANOVA) was performed, and Tukey's multiple comparison test was used to determine which were significantly different ($p<0.05$). Statistical processing was performed with SPSS version 23 software for Windows.

Ethical aspects. In the procedure of the experiment with live animals, the current Peruvian Law was taken into account (Law 27265, Law for the Protection of Domestic Animals and Wild Animals Held in Captivity).

RESULTS

Prawn farming. The average final length (6.46±0.17 cm, F=0.126, p=0.884) and average final weight (9.37±0.69 g, F=0.172; p=0.846) of the prawn in all treatments were significantly similar; likewise, the differences occurred with the specific growth rate, absolute growth rate and percentage gain. However, the greatest percentage gains in length were obtained in coculture with tilapia at 100 and 200 fish/m^3 (10.29±4.02% and 10.45±3.00%, respectively), and percentage gains in weight were obtained with 200 and 300 fish/m^3 (25.41±3.02% and 23.29±9.41%, respectively). Similar trends were obtained with the specific growth rate and absolute growth rate in length and weight (Table 1). Prawn survival was similar (92.59±8.79%, F=0.333, p=0.729) between treatments, but greater survival (94.44±9.62%) was obtained in those cocultured at 100 and 200 fish/m^3, and the lowest survival (88.89±9.62%) was obtained with 300 fish/m^3 (Table 1).

Prawn deaths were caused by incomplete ecdysis because the exuvia was trapped in the pereopods or in the chelipeds. However, some prawn whose exuvia was trapped in the major cheliped survived because they carried out an autotomy of said cheliped. In addition, it was observed that prawn frequently extended their arms through the holes of the culture container with which they trying to catch tilapia, but there were no deaths of tilapia that were due to this behavior of the prawn. Prawn yield was similar (0.291±0.031 kg/m^2, F=2.918, p=0.130) between treatments, but higher yields were obtained in cocultures with tilapia at 100 and 200 fish/m^3 (0.302±0.038 and 0.308±0.017 kg/m^2, respectively), and the lowest yield (0.263±0.015 kg/m^2) was obtained in those with 300 fish/m^3 (Table 1).

Table 1. Zootechnical parameters (means ± standard deviation) of *C. caementarius* in coculture with *O. niloticus* at different densities, for 90 days.

Parameters	Tilapia density (fish/m^3)		
	100	**200**	**300**
Initial length (cm)	5.88 ±0.10^a	5.86 ±0.16^a	5.83 ±0.14^a
Final length (cm)	6.49 ±0.30^a	6.47 ±0.11^a	6.41 ±0.09^a
SGR (% length/day)	0.108 ±0.041^a	0.110 ±0.030^a	0.105 ±0.043^a
AGR (cm/day)	0.007 ±0.003^a	0.007 ±0.002^a	0.006 ±0.003^a
PG (%)	10.29 ±4.02^a	10.45 ±3.00^a	10.01 ±4.18^a
Initial weight (g)	7.87 ±0.16^a	7.62 ±0.25^a	7.46 ±0.25^a
Final weight (g)	9.37 ±1.17^a	9.56 ±0.51^a	9.19 ±0.44^a
SGR (% weight/day)	0.189 ±0.145^a	0.251 ±0.027^a	0.230 ±0.086^a
AGR (g/day)	0.016 ±0.014^a	0.021 ±0.003^a	0.019 ±0.007^a
PG (%)	19.24 ±15.82^a	25.41 ±3.02^a	23.29 ±9.41^a
Yield (kg/m^2)	0.302 ±0.038^a	0.308 ±0.017^a	0.263 ±0.015^a
Survival (%)	94.44 ±9.62^a	94.44 ±9.62^a	88.89 ±9.62^a

SGR: Specific growth rate. AGR: Absolute growth rate. PG: Percentual gain. Data with different superscript letters in the same row indicates significant difference (p<0.05).

Tilapia culture. Growth in weight and length of tilapia varied inversely proportionate to density (Table 2). In tilapia grown at 100 fish/m^3, the growth parameters in length were significantly greater (F=12.207, p=0.008) than that of those grown at 200 and 300 fish/m^3;similar results were observed for the final weight (12.90±1.13 g) and absolute growth rate in weight (0.114±0.013 g/day). In contrast, the specific growth rate (1.759±0.133%/day) and percentage gain (389.48±56.52%) in the weight of those grown at 100 fish/m^3 were similar to those of tilapia grown at 200 fish/m^3 (1.538±0.109%/day and 300.53±40.12%/day) but differed from those of tilapia grown at 300 fish/m^3 (Table 2).

Table 2. Zootechnical parameters (means ± standard deviation) of *O. niloticus* at different densities in coculture with *C. caementarius*, for 90 days.

Parameters	Tilapia density (fish/m³)		
	100	**200**	**300**
Initial length (cm)	5.64 ±0.04ᵃ	5.65 ± 0.02ᵃ	5.65 ±0.05ᵃ
Final length (cm)	9.25 ±0.37ᵃ	8.56 ±0.21ᵇ	8.20 ±1.17ᵇ
SGR (% length/day)	0.550 ±0.038ᵃ	0.461 ±0.029ᵇ	0.413 ±0.017ᵇ
AGR (cm/day)	0.040 ±0.004ᵃ	0.032 ±0.003ᵇ	0.028 ±0.001ᵇ
PG (%)	64.21 ±5.66ᵃ	51.47 ±3.98ᵇ	45.04 ±2.14ᵇ
Initial weight (g)	2.64 ±0.09ᵃ	2.58 ±0.11ᵃ	2.59 ±0.05ᵃ
Final weight (g)	12.90 ±1.13ᵃ	10.32 ±0.64ᵇ	8.90 ±0.42ᵇ
SGR (% weight/day)	1.759 ±0.133ᵃ	1.538 ±0.109ᵃᵇ	1.369 ±0.042ᵇ
AGR (g/day)	0.114 ±0.013ᵃ	0.086 ±0.081ᵇ	0.070 ±0.004ᵇ
PG (%)	389.48 ±56.52ᵃ	300.53 ±40.12ᵃᵇ	243.01 ±13.00ᵇ
Yield (kg/m²)	1.193 ±0.280ᵇ	1.736 ±0.494ᵃᵇ	2.213 ±0.302ᵃ
Survival (%)	91.67 ±14.63ᵃ	83.33 ±19.09ᵃ	83.33 ±14.43ᵃ

SGR: Specific growth rate. AGR: Absolute growth rate. PG: Percentual gain. Data with different superscript letters in the same row indicates significant difference (p<0.05).

Tilapia survival was similar (86.11±14.58%, F=0.267, p=0.775) between treatments, but the highest survival (91.67±14.63%) was obtained in 100 fish/m³, and the lowest survival was obtained at 200 and 300 fish/m³ (83.33±19.09% and 83.33±14.43%, respectively). The highest yield of tilapia (2.213±0.302 kg/m³) was obtained at 300 fish/m³, which was significantly higher (F=5.661, p=0.042) than that obtained with 100 fish/m³ (1.193±0.280 kg/m³) (Table 2). In the last month, tilapia grown at high density presented small lacerations around the mouth.

Water quality. Aquarium water temperature was maintained at 23.36±0.12°C on average. Oxygen in the water decreased as the density of tilapia increased, with oxygen decreasing (p<0.05) from 6.22±0.03 mg/L obtained at 100 fish/m³ to 5.75±0.19 mg/L obtained at 300 fish/m³. Total ammonia was similar (p>0.05) between treatments (≤0.02±0.00 mg/L). Nitrites increased (p<0.05) with the density of tilapia, from 0.11±0.01 mg/L obtained at 100 fish/m³ to 0.18±0.02 mg/L at 300 fish/m³. On the other hand, the total hardness of the water differed (p<0.05) between treatments, being greater a density of 200 fish/m³ (109.33±1.15 mg/L) and less at a density of 300 fish/m³ (104.00±0.00 mg/L).

Table 3. Physical and chemical parameters (means ± standard deviation) of the coculture water *C. caementarius* with *O. niloticus* at different densities, during 90 days.

Parameters	Tilapia density (fish/m³)		
	100	**200**	**300**
Temperature (°C)	23.33 ±0.11ᵃ	23.42 ±0.08ᵃ	23.34 ±0.21ᵃ
Dissolved oxygen (mg/L)	6.22 ±0.03ᵃ	6.06 ±0.28ᵃᵇ	5.75 ±0.19ᵇ
Total ammonium (mg/L)	0.00 ±0.00ᵃ	0.02 ±0.00ᵃ	0.02 ±0.00ᵃ
Nitrites (mg/L)	0.11 ±0.01 ᵃ	0.18 ±0.03 ᵇ	0.18 ±0.02ᵇ
Total hardness (mg $CaCO_3$/L)	107.33 ±1.15ᵃ	109.33 ±1.15 ᵇ	104.00 ±0.00ᶜ

Data with different superscript letters in the same row indicates significant difference (p<0.05).

DISCUSSION

The temperature of the water (23.36°C) was within the range was registered for the natural environment of the prawn (13), but it was not appropriate for tilapia since the greatest growth and use of food in tilapia is achieved between 27 and 32°C (21), which must have contributed to growth retardation. The decrease in the oxygen concentration of the water (6.22 to 5.75 mg/L) as the density of tilapia increased was significant but was within that reported for the species (20) as well as in other similar cocultures with tilapia and prawn (22,23). Total ammonium (≤0.02 mg/L) was similar between treatments, and the nitrites (≤0.18 mg/L) that increased significantly with density were not harmful, as they were within the range reported for the natural environment of the species (20,21,24). These results indicate that the cultivation system used maintained the levels of nitrogenous products of water in an acceptable range for the species, despite the increase in biomass mainly for high-density tilapia, which caused the deterioration of water quality (9).

The average final length (6.46±0.17 cm) and average final weight (9.37 g), as well as the length and weight growth parameters of the prawn, were similar between treatments (Table 1). However, the greatest percentage gains in length were obtained in the coculture with tilapia at 100 and 200 fish/m^3 (10.29% and 10.45%, respectively). A similar trend was obtained with the specific growth rate and the absolute growth rate in terms of length. These results are in agreement with those obtained in the same prawn species grown in individual containers but from studies that evaluated other stimuli (25,26).

The highest percentage gains in prawn weight were obtained in the cocultures with tilapia at 200 and 300 fish/m^3 (25.41% and 23.29%, respectively) but were lower than those previously obtained in the same species of prawn (15,25,27). These results were because some male prawn were unable to complete the ecdysis process and they autotomized their cheliped to survive, thereby losing weight. The loss of a cheliped in male prawn reduces the weight between 12 and 22%; the loss of both chelipeds, between 30 and 40% (15,28). In *Pagurus middendorffii*, there is suppression of somatic growth due to regeneration of the greater cheliped (29).

The survival of the male *C. caementarius* prawn was high (94.44 and 88.89%), and there was no difference between treatments. In *C. quadricarinatus* grown in individual containers, survival was between 73 and 98% (16), between 64 and 67% in *Scylla paramamosain* (30) and up to 86% in *H. gammarus* (31). In the investigation, the decrease in the survival of prawn cultured in individual containers was not due to the presence of tilapia or to density in the coculture system but to incomplete ecdysis syndrome that caused death because the exuvia was trapped in the pereopods. This syndrome occurs in *C. caementarius* due to nutritional deficiencies (25,26) and is not due to the size of the individual containers used (15). In previous studies with the species grown in the same containers, survival rates >61% were obtained, where the deaths were due to incomplete ecdysis (14,25). Survival >90% was obtained in *C. quadricarinatus* within individual containers, although the causes were not reported (16). However, it is not known whether molting death syndrome occurs in the natural environment. In the present investigation, the efficiency of the individual culture system to maintain high prawn survival by avoiding intraspecific interaction is corroborated, and this study demonstrated for the first time that the system reduces interaction with tilapia. This system will allow cocultivation with other fish species and even with other freshwater crustaceans.

Death due to incomplete ecdysis, as well as the loss of chelipeds during ecdysis, not only affected the survival and growth but also the productive yield of *C. caementarius* (0.263 to 0.308 kg/m^2); however, this yield was within what has been previously reported in the same species grown in the same containers (0.241 and 1.049 kg/m^2) (15,26). It is convenient to continue with the investigations to determine how to avoid prawn in culture losing chelipeds since *C. caementarius* is marketed whole and since the loss of chelipeds significantly reduces the weight of the prawn (28) and, therefore, the productive yield, as has been demonstrated in research.

The growth of *O. niloticus* was inversely affected by an increase in density during the culture period, where the growth parameters were higher when they were grown at 100 fish/m^3, except for the specific growth rate and percentage gain in weight, which were similar up to 200 fish/m^3. These results are in agreement with those reported in tilapia, where the greatest growth in weight was obtained with 100 fish/m^3 (8) and densities greater than 150 fish/m^3 cause competition for food and space that affect growth (9). In contrast, the significantly decreased growth in tilapia cultured at a density of 300 fish/m^3 could be a consequence of intraspecific interactions since it is known that at high density, there are changes in the metabolism of tilapia due to an increase in energy to counteract stress (9). Furthermore, although the nonformulated food for the species had 30% crude protein and 8.1% total lipids, it is probable that some other nutrients were lacking or deficient and did not contribute to nutrition. In the same species of tilapia fed a diet with 30% protein, increased protein and amino acid retention occurs, which improves growth (32). Likewise, fatty acids, such as linoleic acid, eicosapentaenoic acid and docosahexaenoic acid, are beneficial for growth and health (33).

In the prawn /tilapia coculture, it is necessary to use a specific diet for each species since the tilapia in this study consumed only food formulated for prawn, but in a low proportion. The level of feeding used (5%) for tilapia fry, which was thought to increase with the food that comes out of the prawn culture containers, was not sufficient in quantity or quality. In tilapia, 10% of the biomass is used as a daily ration (34). This food deficiency for tilapia was more evident in the last month of culture, when small lacerations were observed in the fish's mouth that would indicate aggressiveness due to competition for food. This behavior must have caused some infection that caused fish death and decreased survival (83%) at a high density although survival was similar (91%) to that at low density. Tilapia is a territorialist, and the increase in density affects growth due to competition for food (35). It is convenient to continue with the investigations that allow improving the management of the coculture of prawn/fish in relation to nutrition and with the environmental conditions required by the species to achieve the full use of the body of water without affecting the environment.

The productive yield of tilapia was significantly higher with the increase in density, even though the growth was lower. These results could be a consequence of the initial size of the fish since we used fry of 2.61 g with which it was possible to increase the yield from 1.193 to 2.213 kg/m^2. Cultivation with small tilapia fry (0.80 g) in polyculture with *M. rosenbergii* yields between 0.162 and 0.254 kg/m^2 (36). In contrast, when large juveniles (29.54 g) cultivated in cages are used, yields of 13.9 to 28.56 kg/m^3 are achieved, which increases with density (37).

In the investigation, it was once again shown that males of *C. caementarius* support a reduced physical space such as the individual containers used in this and other investigations (15,25,26,27). However, the aggressive interaction of prawn with tilapia was evident in that the prawn attempted to capture the fish when they removed their chelipeds through the holes in the culture vessel, but there were no tilapia deaths. These results corroborate the aggressive nature of male prawn (15). In addition, the aggressive behavior of the prawn shows that, in traditional polyculture, both species would be affected by increased cannibalism and by physical interaction, as occurs in other species. In the polyculture of *O. niloticus* with *P. acanthophorus*, there is competition for space, food and even predation by tilapia during molting of the crustacean (38). Likewise, in polyculture of *M. rosenbergii* with *O. niloticus*, competition for food and space affects production (5). It would be beneficial to investigate the behavior of the species in coculture, but at the level of seminatural ponds, as well as the technical and economic viability, as has been established for other combinations of aquatic organisms in coculture in ponds (39) which are aimed at establishing commercial production.

In conclusion, the growth and survival of the prawn *C. caementarius* was affected by molt death syndrome but not by the presence of tilapia density in the coculture system however, there were no significant differences between treatments. Conversely, greater growth of tilapia *O. niloticus* was obtained with 100 fish/m^3, and survival was similar between treatments; however higher yield was achieved at 300 fish/m^3. The use of specific feed for both species is necessary to achieve greater growth. In addition, an economic study is required to determine the viability of commercial prawn/tilapia coculture in seminatural ponds.

Conflict of interest

The authors have no conflict of interest.

REFERENCES

1. Fitzsimmons KM, Shahkar E. Tilapia-Shrimp polyculture. In: Perschbacher PW, Stickney RR (Eds). Tilapia in intensive co-culture. Wiley Blackwell: EU; 2017. https://www.doi.org/10.1002/9781118970652.ch10

2. New MB, Valenti WC. Tilapia-*Macrobrachium* polyculture. In: Perschbacher PW, Stickney RR. (Eds) Tilapia in intensive co-culture. Wiley Blackwell: EU; 2017. https://www.doi.org/10.1002/9781118970652.ch11

3. Schmalenbach I, Buchholz F, Franke HD, Saborowski R. Improvement of rearing conditions for juvenile lobster (*Homarus gammarus*) by co-culturing with juvenile isopods (*Idotea emarginata*). Aquac. 2009; 289(3-4):297-303. https://www.doi.org/10.1016/j.aquaculture.2009.01.017

4. Rohmana D, Surawidjaja EH, Sukenda S, Ekasari J. Water quality and production performance of catfish-prawn co-culture with organic carbon source addition. Aquacult Int. 2015; 23:267-276. https://www.doi.org/10.1007/s10499-014-9814-2

5. Tidwell JH, Coyle SD, Bright LA. Polyculture of Nile tilapia, *Oreochromis niloticus*, either confined in cages or unconfined in freshwater prawn, *Macrobrachium rosenbergii*, ponds. J World Aquac Soc. 2010; 41(4):616-625. https://www.doi.org/10.1111/j.1749-7345.2010.00402.x

6. Tesfahun A, Temesgen M. Food and feeding habits of Nile tilapia *Oreochromis niloticus* (L.) in Ethiopian water bodies: A review. Int J Fish Aquat Stud. 2018; 6(1):43-47. http://www.fisheriesjournal.com/archives/2018/vol6issue1/PartA/5-6-54-506.pdf

7. Nunoo FKE, Asase A. Comparative growth performance of *Oreochromis niloticus* (Linnaeus, 1758) in cages at different stocking densities. Int J Fish Aquat Stud. 2017; 5(4):279-283. http://www.fisheriesjournal.com/archives/2017/vol5issue4/PartD/5-4-4-982.pdf

8. Araujo G, Rodrigues J, Da Silva J, Farias W. Cultivo da tilápia do Nilo *Oreochromis niloticus* em tanques-rede circulares em diferentes densidades de estocagem. Biosci J. 2010; 26(3):428-434. http://www.seer.ufu.br/index.php/biosciencejournal/article/view/7080

9. Abdel-Tawwab M. Effects of dietary protein levels and rearing density on growth performance and stress response of Nile tilapia, *Oreochromis niloticus* (L.). Int Aquat Res. 2012; 4(3):1-12. https://www.doi.org/10.1186/2008-6970-4-3

10. Yakubu A, Obi A, Okonji V, Ajiboye O, Adams T, Olaji E, et al. Growth performance of Nile tilapia (*Oreochromis niloticus*) as affected by stocking density and feed types in water flow through system. World J Fish Marine Sci. 2012; 4(3):320-324. http://www.doi.org/10.5829/idosi.wjfms.2012.04.03.6230

11. Shubha M, Reddy S. Effect of stocking density on growth, maturity, fecundity, reproductive behaviour and fry production in the mouth brooding cichlid *Oreochromis mossambicus* (Peters). Afr J Biotechnol. 2011; 10(48):9922-9930. http://dx.doi.org/10.5897/AJB11.697

12. Moscoso V. Catálogo de crustáceos decápodos y estomatópodos del Perú. Bol Inst Mar Perú. 2012; 27(1-2):8-207. http://biblioimarpe.imarpe.gob.pe/handle/123456789/2190

13. Wasiw J, Yépez V. Evaluación poblacional del camarón *Cryphiops caementarius* en ríos de la costa sur del Perú. Rev Inv Vet Perú. 2015; 26(2):166-181. http://dx.doi.org/10.15381/rivep.v26i2.11103

14. Ministerio de la Producción. Anuario estadístico pesquero y acuícola 2017. La actividad productiva del sector en números, Perú. 2018. http://ogeiee.produce.gob.pe/images/Anuario/Pesca_2017.pdf

15. Reyes W. Effect of culture container on the survival and growth of male *Cryphiops caementarius* in individualized systems. Revista Bio Ciencias. 2016; 3(4):311-325. https://www.doi.org/10.15741/revbio.03.04.06

16. Manor R, Segev R, Pimenta M, Aflalo ED, Sagi A. Intensification of redclaw crayfish *Cherax quadricarinatus* culture II. Growout in a separate cell system. Aquacult Eng. 2002; 26(4):263-276. https://www.doi.org/10.1016/S0144-8609(02)00035-3

17. Drengstig A, Bergheim A. Commercial land-based farming of European lobster (*Homarus gammarus* L.) in recirculating aquaculture system (RAS) using a single cage approach. Aquacult Eng. 2013; 53:14–18. https://www.doi.org/10.1016/j.aquaeng.2012.11.007

18. Méndez M. Claves de identificación y distribución de los langostinos y camarones (Crustacea: Decapoda) del mar y ríos de la costa del Perú. Bol Inst Mar Perú. 1981; 5:1-169. http://biblioimarpe.imarpe.gob.pe/handle/123456789/1028

19. Reyes W, Terrones S, Baltodano I. Effects chelipeds regeneration in molting and growth of male *Cryphiops caementarius* Molina 1782 (Decapod, Palaemonidae). Revista Bio Ciencias. 2017; 4(4): 1-18. http://dx.doi.org/10.15741/revbio.04.04.05

20. Cornejo J, Pérez L, Reyes W. Effect of *Saccharomyces cerevisiae* yeast in the diet of male shrimp *Cryphiops caementarius* (Crustacea, Palaemonidae) on total and differential hemocytes count. Revista Bio Ciencias. 2015; 3(3):173-186. http://dx.doi.org/10.15741/revbio.03.03.04

21. Pandit NP, Nakamura M. Effect of high temperature on survival, growth and feed conversion ratio of Nile tilapia, *Oreochromis niloticus*. Our Nature. 2012; 8(1):3219-224. https://doi.org/10.3126/on.v8i1.4331

22. López-Gómez C, Ponce-Palafox T, Castillo-Vargasmachuca S, Puga-López D, Castillo-Campo LF, García-Ulloa M. Evaluation of two mix-cultures of white shrimp (*Litopenaeus vannamei*) with red tilapia hybrid and spotted rose snapper (*Lutjanus guttatus*) in intensive indoor brackish water tanks. Lat Am J Aquat Res. 2017; 45(5):922-929. http://www.doi.org/10.3856/vol45-issue5-fulltext-7

23. Juárez-Rosales J, Ponce-Palafox T, Román-Gutiérrez AD, Otazo-Sánchez OM, Pulido-Flores G, Castillo-Vargasmachuca SG. Effects of White shrimp (*Litopenaeus vannamei*) and tilapia nilotica (*Oreochromis niloticus* var, Spring) in monoculture and co-culture systems on water quality variables and production in brackish low-salinity water earthen ponds during rainy and dry seasons. Span J Agric Res. 2019; 17(3): e0605. https://www.doi.org/10.5424/sjar/2019173-14938

24. Wasiw J, Yépez V. Evolución de la condición poblacional del camarón *Cryphiops caementarius* en el río Cañete (2000-2015). Rev Inv Vet Perú. 2017; 28(1):13-32. http://dx.doi.org/10.15381/rivep.v28i1.12942

25. Acosta A, Quiñones D, Reyes W. Efecto de dietas con lecitina de soya en el crecimiento, muda y supervivencia de machos del camarón de río *Cryphiops caementarius* (Crustacea: Palaemonidae). Sci Agropecu. 2018; 9(1):143-151. http://www.doi.org/10.17268/sci.agropecu.2018.01.15

26. Terrones S, Reyes W. Efecto de dietas con ensilado biológico de residuos de molusco en el crecimiento del camarón *Cryphiops caementarius* y tilapia *Oreochromis niloticus* en cocultivo intensivo. Sci Agropecu. 2018; 9(2):167-176. http://www.doi.org/10.17268/sci.agropecu.2018.02.01

27. Ramírez M, Cántaro R, Reyes W. Growth and survival of males of *Cryphiops caementarius* (Palaemonidae) with diets supplemented with common salt. Lat Am J Aquat Res. 2018; 46(2):469-474. http://www.doi.org/10.3856/vol46-issue2-fulltext-22

28. Reyes W. El síndrome de la ecdisis incompleta en machos adultos de *Cryphiops caementarius* (Crustacea: Palaemonidae) y sus consecuencias en cultivo intensivo. Rev Inv Vet Perú. 2018; 29(1):68-374. http://dx.doi.org/10.15381/rivep.v29i1.14200

29. Yasuda CI, Matsuo K, Wada S. Rapid regeneration of the major cheliped in relation to its function in male-male contests in the hermit crab *Pagurus middendorffii*. Plankton Benthos Res. 2014; 9(2):122-131. https://www.doi.org/10.3800/pbr.9.122

30. Islam ML, Siddiky MNSM, Yahya K. Growth, survival and intactness of green mud crab (*Scylla paramamosain*) broodstock under different captive grow out protocols. SAARC J Agri. 2018; 16(1):169-180. http://dx.doi.org/10.3329/sja.v16i1.37432

31. Daniels CL, Wills B, Ruiz-Perez M, Miles E, Wilson RW, Boothroyd D. Development of sea-based container culture for rearing European lobster (*Homarus gammarus*) around South West England. Aquac. 2015; 448:186-195. http://dx.doi.org/10.1016/j.aquaculture.2015.05.026

32. Teodósico R, Engrola S, Colen R, Masagounder K, Aragão C. Optimizing diets to decrease environmental impact of Nile tilapia (*Oreochromis niloticus*) production. Aquacult Nutr. 2019; 26(2): 422-431. http://www.doi.org/10.1111/anu.13004

33. Liu Y, Wen JJ, Ning LJ, Jiao JG, Qiao F, Chen LQ, et al. Comparison of effects of dietary-specific fatty acids on growth and lipid metabolism in Nile tilapia. Aquacult Nutr. 2019; 25(4):862-872. https://doi.org/10.1111/anu.12906

34. Bessa AP, Borges CMS, Silva F, Henry-Silva GG. Polyculture of Nile tilapia and shrimp at different stocking densities. R Bras Zootec. 2012; 41(7):1561-1569. http://dx.doi.org/10.1590/S1516-35982012000700002

35. Costa ÂAP, Roubach R, Dallago BSL, Bueno GW, McManus C, Bernal FEM. Influence of stocking density on growth performance and welfare of juvenile tilapia (*Oreochromis niloticus*) in cages. Arq Bras Med Vet Zootec. 2017; 69(1):243-251. http://dx.doi.org/10.1590/1678-4162-8939

36. Tidwell JH, Coyle SD, Bright LA. Polyculture of Nile tilapia, *Oreochromis niloticus*, either confined in cages or unconfined in freshwater prawn, *Macrobrachium rosenbergii*, ponds. J World Aquac Soc. 2010; 41(4):616-625. https://www.doi.org/10.1111/j.1749-7345.2010.00402.x

37. Osofero S, Otubusin S, Daramola J. Effect of stocking density on tilapia (*Oreochromis niloticus* Linnaeus 1757) growth and survival in bamboo-net cages trial. Afr J Biotechnol. 2009; 8(7):1322-1325. https://www.ajol.info/index.php/ajb/article/view/60113/48369

38. Hernández-Vergara MP, Cruz-Ordóñez SB, Pérez-Rostro CI, Pérez-Legaspi A. Polyculture of crayfish (*Procambarus acanthophorus*) and Nile tilapia (*Oreochromis niloticus*) as a strategy for sustainable water use. Hidrobiológica. 2018; 28(1):11-15. https://www.doi.org/10.24275/uam/izt/dcbs/hidro/2018v28n1/HernandezV

39. Mondal A, Bhattacharya S, Mitra A, Sundaray JK, Mohanty RK. Performance evaluation of mud crab *Scylla olivacea* (Herbst, 1896) coculture with different fish species in confined brackishwater ponds. Aquac. 2020; 522:735125. https://doi.org/10.1016/j.aquaculture.2020.735125