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Research Article

Effect of Nile tilapia (*Oreochromis niloticus*) on the growth performance of Pacific white shrimp (*Litopenaeus vannamei*) in a sequential polyculture system

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ABSTRACT. The present study was carried out at the Environmental Research Laboratory (ERL), University of Arizona, to assess the effect of the addition of Nile tilapia (*Oreochromis niloticus*), at different densities, on the growth performance of Pacific white shrimp (*Litopenaeus vannamei*). The growth rate and feed conversion of shrimp, both in polyculture and monoculture, were evaluated. Shrimp-tilapia proportions were 20:8 individuals in Treatment One (T1), 20:4 individuals in Treatment Two (T2) and 20:2 individuals in Treatment Three (T3), while in Treatment Four (T4) shrimp were stocked as a control group with a ratio of 20:0. The experiment lasted for four weeks at 10 ppt water salinity. The shrimp and fish were fed once a day with 8% and 3% of their body weight, respectively, using a 35% protein feed. At the end of the experiment, the average individual weight and best feed conversion ratio were obtained in shrimp polyculture treatment with highest tilapia density 6.08 ± 0.18 g and 1.26 ± 0.01 respectively, while the lowest scores were found in the monoculture treatment with 5.14 ± 0.59 g and 1.35 ± 0.01, respectively ($P < 0.05$). The present study demonstrate that integrated farming of shrimp and tilapia, with a polyculture sequential tanks system is technically feasible and increases the production of shrimp, which is higher than in monoculture, without any adverse interaction between fish and shrimp.

Keywords: aquaculture, polyculture, sequential system, shrimp, tilapia.

Efecto de la tilapia del Nilo (*Oreochromis niloticus*) sobre el crecimiento del camarón blanco del Pacífico (*Litopenaeus vannamei*), en un sistema de policultivo secuencial

RESUMEN. El presente estudio se llevó a cabo en el Laboratorio de Investigación del Medio Ambiente (ERL). de la Universidad de Arizona, para evaluar el efecto de la adición de la tilapia del Nilo (*Oreochromis niloticus*) a diferentes densidades, en el desempeño del crecimiento del camarón blanco del Pacífico (*Litopenaeus vannamei*). La tasa de crecimiento y conversión alimenticia del camarón, tanto en policultivo y monocultivo, fueron evaluados. Las proporciones de camarón y la tilapia fueron de 20:8 individuos en el tratamiento uno (T1), 20:4 en el tratamiento dos (T2) y de 20:2 en el tratamiento tres (T3), mientras que en el tratamiento cuatro (T4), únicamente fueron sembrados camarones, participando como grupo control con una relación de 20:0. El experimento se realizó durante cuatro semanas y agua a 10 ppm de salinidad. Los camarones y peces fueron alimentados una vez al día con el 8% y 3% de su peso corporal, de manera respectiva, empleando alimento con el 35% de proteína. Al final del experimento, el peso individual promedio y la mejor conversión alimenticia de los camarones fueron obtenidos en el policultivo con mayor densidad de tilapia 6.08 ± 0,18 g y 1,26 ± 0,01, mientras que, los resultados más bajos se encontraron en el tratamiento de monocultivo con 5,14 ± 0.59 g y 1,35 ± 0,01, respectivamente ($P < 0,05$). El presente estudio demuestra que el cultivo integral de camarón y tilapia, con un sistema de tanques secuenciales, es técnicamente viable e incrementa la producción de camarón, la cual es más alta que en el monocultivo, sin ninguna interacción adversa entre los peces y camarones.

Palabras clave: acuacultura, policultivo, sistema secuencial, camarón, tilapia.

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INTRODUCTION

Aquaculture continues to be the fastest-growing animal-food-producing sector and to outpace population growth, with per capita supply from aquaculture increasing from 0.7 kg in 1970 to 7.8 kg in 2008, an average annual growth rate of 6.6 percent (FAO, 2010). The aquaculture production in 2008 was 52.5 million ton, with a value of US$ 98.4 billion (FAO, 2010). However, the shrimp aquaculture industry faces several problems, including contamination caused by farm effluent (Martínez-Porchas *et al*., 2010). Therefore, it is important to develop some strategies to improve the productivity of shrimp farms and minimize these problems.

According to Ponce-Marbán *et al*. (2006) many research areas address how to increase profitability in aquaculture companies. One recognized strategy is polyculture, which can considerably improve farm production yields by optimizing use of available resources (Bardach *et al.*, 1972; Landau, 1992). Polyculture consists of adding one or more subordinate species to the culture system of a main species (Lanza-Espino *et al*., 1991). Polyculture is also referred to as multi-trophic aquaculture, co-culture or simply integrated aquaculture (Bunting, 2008). There are at least three general types of polyculture: direct polyculture, cage-cum-pond polyculture and sequential polyculture (Yi & Fitzsimmons, 2004). In the sequential system, water is moved from one growing unit to another.

Tilapia represents a strong candidate for polyculture with shrimp because of its high resistance to adverse conditions, commercial demand and feeding habits (Martinez-Porchas *et al*., 2010). According to Yuan *et al*. (2010), tilapia-shrimp polyculture with appropriate feeding strategy is technically feasible, economically attractive and environmentally friendly. Polyculture can also provide benefits associated with advanced ecological stability and function (McKinnon *et al*., 2002; Gooley & Gavine, 2003).

Tilapia and shrimp stocked together can reduce the impact that shrimp in monoculture systems produce in the environment. When they grow, tilapias become effective filter feeders of phytoplankton and predators of zooplankton. In intensive farms, most nutrition is derived from pelleted feeds; although fish will continue to spend time feeding on algal and bacterial films from all surfaces (Yi *et al*., 2002). On the basis of these findings, this experiment was conducted under a sequential water system to determine the effect of the presence of Nile tilapia (*O. niloticus*) at different densities on the production, growth and FCR of shrimp (*L. vannamei*) in a polyculture system.

MATERIALS AND METHODS

The present study was conducted to determine the growth performance of shrimp when stocked with tilapia and when grown as a single species. The trial was conducted in 12 fiberglass tanks (capacity of 50 L).

The experiment was performed using four treatments and three replicate tanks per treatment. Fish and shrimp were weighed and randomly distributed in the system containing saline water at 10 ppt. Salinity and water temperature were measured once a day, whereas dissolved oxygen (DO) and pH were monitored once a week. Water samples were taken each week for analyses of total ammonia (NH_3), nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N).

The juvenile Pacific white shrimp (*L. vannamei*) were obtained from Shrimp Improvement Systems, Inc. Miami, FL, whereas, the tilapia (*O. niloticus*) was an improved line obtained from existing stocks at the ERL facilities with original stocks from Auburn University (Auburn, AL).

Fish and shrimp were fed with commercial pellets at 3 and 8% body weight, respectively, using 35% protein food pellets. The data were evaluated using a one way analysis of variance (ANOVA). Determination of statistical differences was set at a confidence level of 5%.

Experimental design

To test the effects of tilapia (*O. niloticus*) on shrimp (*L. vannamei*), the performance of organisms was evaluated in polyculture and monoculture systems. In the sequential system, tilapia were stocked at different densities ranging from two to eight individuals per tank, whereas, shrimp were stocked at five individuals per compartment (four compartments/tank). For this evaluation, four treatments were set at four shrimp/ tilapia stocking ratios. Shrimp were stocked with tilapia in three of the treatments at ratios of 20:8

individuals in Treatment One (T1), 20:4 individuals in Treatment Two (T2) and 20:2 individuals in Tretament Three (T3). In Treatment Four (T4) shrimp were stocked with a ratio of 20:0 as a control group. All were stocked in a recirculating system.

Feed and feeding regime

In this study, sinking and floating feeds were used. Shrimp and fish were fed once a day. The shrimp were fed a daily ration of 8% of their total biomass, while for fish 3% of their body weight was used. Commercial extruded feeds (floating pellets with 1-2 mm ACE feeds from Star Milling (Perris, CA) with 35% crude protein was used to feed Nile tilapia. For feeding shrimp, 35% protein sinking feeds from Rangen Company (Buhl, ID) was used (Table 1).

Water quality measurements

All the water quality parameters such as temperature, pH, salinity, dissolved oxygen (DO), ammonia (NH_3), nitrite (NO_3-N) and nitrate (NO_2-N) were measured and recorded during the experiment. Dissolved oxygen concentrations were measured on site once a week with a YSI model 550A oxygen meter, while the water temperature and pH were determined daily with a Combo pH/Conduct/TDS/and temperature. Salinity level was measured once a day with an S/Mill-E Handheld Seawater Salinity Refractometer. A Hach model DR/890 portable colorimeter was used to determine total ammonia-N, nitrite and nitrate.

Statistical analysis

The differences among the growth performance of both groups (tilapia and shrimp) in this study, were evaluated using a one-way ANOVA. These differences were considered significant at an alpha level of 0.05.

RESULTS

Values in Table 2, show that shrimp polyculture at high tilapia density reached a mean final weight of 6.08 ± 0.18 g at the end of the experiment, which was higher than shrimp polycultures at mid and low density (5.83 ± 0.12, 5.77 ± 0.10) and shrimp monoculture (5.14 ± 0.59 g), respectively. Significant differences were found ($F_{3,\ 12}$ = 106.6, P < 0.0001). From the beginning the shrimp in treatment with the highest tilapia density started to gain more weight than shrimp in the other treatments. In fact, at the end of the 4th week, the shrimp of this treatment achieved a total increase of 103.8 g being the best treatment of this trial. The total weight of shrimp for the second and third Polyculture treatments were 99.1, 98.2 and 85.6 g while the fourth monoculture treatment had the lowest weed biomass.

Shrimp growth performance

The growth performance of shrimp and tilapia is summarized in Tables 2 and 3 respectively. At harvest (week 4) the highest specific growth rate for shrimp was 6.01% g day^{-1} in T1 (polyculture) and the lowest was 5.28% g day^{-1} in T4 (monoculture). Survival of Nile tilapia and shrimp were 100% for all treatments.

The high density tilapia treatment not only had the highest shrimp biomass at harvest but also the lowest FCR in those shrimp, which was significantly better than those in the control ($F_{3,\ 12}$ = 132, P < 0.0001), but not significantly different from the medium and low tilapia densities (P > 0.05).

Figure 1, shows that shrimp in the highest tilapia density, had the highest individual mean weight while the lowest was obtained in the monoculture treatment. The highest weights and growth rate of shrimp were achieved in the polyculture tanks with tilapia stocked at eight fish per tank with a final mean weight of 6.08 ± 0.18 g, whereas, the lowest weight was reached in shrimp monoculture with a final mean weight of 5.14 ± 0.59 g.

Tilapia growth performance

The highest mean final weight of fish 39.6 ± 3 g was reached at the highest tilapia density in shrimp polyculture treatment, while the lowest 35.1 ± 3 g was reached at the lowest tilapia density. The specific growth rate showed a similar pattern as did individual weight, with results of 2.60, 2.55 and 2.32 % g day^{-1} for T1, T2 and T3, in that order. The increased weight and feed offered to tilapia was recorded in order to determine the FCR at the final of the evaluated period The FCR for the three groups were 1.0 ± 0.02, 1.09 ± 0.01 and 1.17 ± 0.02, respectively. There were no significant differences ($F_{2,\ 11}$ = 1.15, P = 0.35) among treatments (Table 3). In addition, no mortality was found in any treatment.

Water quality parameters were compared by examining the overall average values at the final of the experimental period and they were not significantly affected by density or size of shrimp-tilapia stocked. The pH showed values between 7.1 and 7.6, whereas, the mean temperature was 28.5 ± 0.33ºC during the four weeks of the experiment. The concentration of total ammonia was found to range from 0.10 to 0.14 mg L^{-1}, nitrite (NO_2) from 0.001 to 0.02 mg L^{-1} and nitrate (NO_3) from 0.001 to 0.002 mg L^{-1}. In general, all the water parameters were maintained at adequate

Table 1. Distribution and percentage of shrimp and fish feed.

Tabla 1. Distribución y porcentajes de alimentación de camarones y peces.

Treatments	Number of shrimp/tilapia		Feeding rate (%)	
(T)	Shrimp	Tilapia	Shrimp	Tilapia
1	20	8	8	3
2	20	4	8	3
3	20	2	8	3
4	20	-	8	-

Table 2. Mean ± SD of growth performance of Pacific white shrimp (*L. vannamei*) cultured for four weeks in tilapia-shrimp polyculture and shrimp monoculture.

Tabla 2. Valores promedio ± DE del crecimiento de camarón blanco del Pacifico (*L. vannamei*) cultivado durante cuatro semanas en policultivo de tilapia y camarón y en monocultivo.

Shrimp	Treatments/ fish densities			
Parameters	T_1 high (8)	T_2 mid (4)	T_3 low (2)	T_4 (no fish)
Stock	20	20	20	20
Mean initial weight (g)	0.89 ± 0.20	0.87 ± 0.21	0.86 ± 0.22	0.86 ± 0.09
Harvest	20	20	20	20
Mean final weight (g)	6.08 ± 0.18^a	5.83 ± 0.12^a	5.77 ± 0.10^a	5.14 ± 0.59^b
Total final weight (g)	121.6	116.6	115.4	102.8
[1] Specific growth rate GR (g day^{-1})	6.01	5.71	5.78	5.28
[2] FCR	1.26 ± 0.01^a	1.26 ± 0.01^a	1.25 ± 0.01^a	1.35 ± 0.01^b

Numbers with the same superscripts in the row are not significantly different.
[1]SGR (g) = (ln Final wet weight – In initial wet weight)/ days of culture X100.
[2]FCR = Feed intake (g)/Body weight gain (g).

Table 3. Mean ± SD of growth performance of Nile tilapia (*O. niloticus*) cultured for four weeks in the tilapia-shrimp polyculture.

Tabla 3. Promedio ± DE del crecimiento de tilapia nilotica (*O. niloticus*) cultivada por cuatro semanas en policultivo de tilapia y camarón.

Fish	Treatments and densities		
Initial	T1 (high) 8	T2 (mid) 4	T3 (low) 2
Initial mean weight (g)	17.8 ± 3	18.2 ± 5	18.3 ± 3
Harvest	8	4	2
Mean final weight (g)	39.6 ± 3	37.2 ± 6	35.1 ± 3
[1]Specific growth rate GR (%g day^{-1})	2.60	2.55	2.32
FCR[2]	1.0 ± 0.02^a	1.09 ± 0.01^a	1.17 ± 0.02^b

[1]SGR (g) = (ln Final wet weight – In initial wet weight)/ days of culture X100.
[2]FCR = Feed intake (g)/Body weight gain (g).

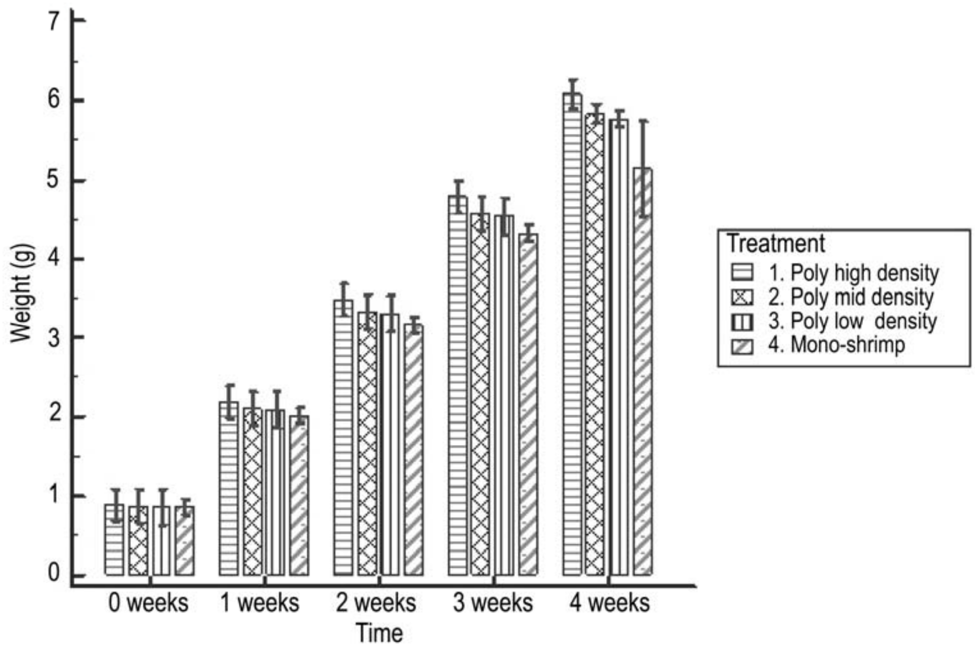

Figure 1. Mean ± SD Final weight of shrimp (*L. vannamei*) by treatment during the experimental period (four weeks).

Figura 1. Valores promedio ± DE Peso final de los camarones (*L. vannamei*) por tratamiento durante el periodo experimental (cuatro semanas).

Table 4. Mean ± SD of water quality parameters of the treatments.

Tabla 4. Valores promedio ± DE de los parámetros de calidad del agua.

Parameters/ Days	7	14	21	28
DO (mg L^{-1})	7.6 ± 0.16	7.2 ± 0.23	7.4 ± 0.15	7.1 ± 0.27
Temperature (^{o}C)	28.6 ± 0.2	28.9 ± 0.1	28.1 ± 0.1	28.5 ± 0.2
Salinity (ppt)	10	10	10	10
pH	7.2 ± 0.2	7.5 ± 0.1	7.9 ± 0.1	7.9 ± 0.2
TAN (mg L^{-1})	0.13 ± 0.011	0.14 ± 0.01	0.102 ± 0.001	0.13 ± 0.002
NH_3-N (mg L^{-1})	0.001 ± 0.001	0.001 ± 0.002	0.004 ± 0.001	0.002 ± 0.001
NO_2-N (mg L^{-1})	0.02 ± 0.001	0.03 ± 0.003	0.02 ± 0.001	0.01 ± 0.001
NO_3-N (mg L^{-1})	0.135 ± 0.008	0.145 ± 0.005	0.168 ± 0.007	0.183 ± 0.003

levels for growing tilapia and white shrimp. The results reached in both cultures are shown in Table 4.

DISCUSSION

The ammonia and nitrite levels in this study remained within safe limits hence, no mortality was recorded and no sign of stress was observed.

The results of this study, in which both floating and sinking feeds were used, suggest that the culture of these two species in polyculture tanks is technically feasible and can result in better growth of shrimp when the tilapia-shrimp density is optimized.

Our results, show us the advantage of using the shrimp - tilapia polyculture system, although there are other studies with better results like the study conducted by Saelee (2002), in which the polyculture of shrimp and Nile tilapia in low salinity water showed that FCR of shrimp from polyculture was almost equal to 2 and was higher than that in the monoculture (about 1.6).

The present research indicated that the shrimp polyculture with tilapia in a sequential tanks system is technically feasible and improves the total production of shrimp with significant differences at ($F_{3,\ 12}$ = 106.6, $P < 0.0001$) between polyculture and monoculture treatments.

According to Cruz *et al.* (2008), shrimp benefit from tilapia biomanipulation in two ways. First, shrimp are feeding on organic waste and second, due to bioperturbation of sediments. Different studies suggest that the positive effect of Nile tilapia on shrimp performance could be due to the addition of undigested food particles excreted by Nile tilapia that served directed as food for shrimp (Gonzales-Corre, 1988).

In this study, the better growth of shrimp appears to be a result of shrimp that were able to utilize waste materials of Nile tilapia which were fed a pelleted feed. With uneaten feed, some feed particles always reach the bottom where it becomes available to shrimp. More importantly, the tilapia fecal matter contributes to the detrital rain that supports the shrimp (Yi *et al.*, 2002).

Another possibility to explain the increased growth of shrimp in polyculture is based on the nutritional values contained in the food. As conservative estimates, typical tilapia assimilation efficiency is 70% for protein and 51% for total energy (Bowen, 1982). Therefore 30% of the protein and 49% of the energy would be available to the shrimp from tilapia feces. Finally, this study shows that the concepts of polyculture can be utilized in the design of shrimp-tilapia farms under intensive or semi-intensive recirculation systems.

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