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ANIMAL SCIENCE

Polyculture of bullfrog tadpoles and Nile tilapia fry

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Abstract: Two experiments were carried out to test better stocking proportion according to animal size for tilapia (*Oreochromis niloticus*) and tadpole (*Lithobates catesbeianus*). The experiments were laid out in a completely randomized design with five treatments (in Experiment I) and four treatments (in Experiment II). In Experiment I, the treatments consisted of a tilapia monoculture; a 75% tilapia + 25% tadpole polyculture; a 50% tilapia + 50% tadpole; a 25% tilapia + 75% tadpole; and a tadpole monoculture. In Experiment II, the treatments were represented by a tilapia monoculture; a 12.5% tilapia + 87.5% tadpole polyculture; a 25% tilapia + 75% tadpole; and a tadpole monoculture. In the first trial, mortality rate differed significantly, with the polyculture treatments having almost 100% mortality of tadpoles. In the second experiment, after adjustments in the initial size of the species, there were significant differences between treatments, with the 12.5% tilapia + 87.5% tadpole polyculture and the tadpole monoculture providing the best results. Regardless of the chosen density, for a polyculture of Nile tilapia and bullfrog tadpoles, ideal conditions would be stocking tilapia fry weighing 50% of the weight initial tadpoles and the proportion of one tilapia for seven tadpoles.

Key words: aquaculture, fish farming, frog farming, production.

INTRODUCTION

Nile tilapia (*Oreochromis niloticus*) is a species widely used in fish farming due to its rapid growth (Little et al. 2008). In addition to being resistant to variations in water temperature and quality and to pathogens, it adapts well to diets with different types of ingredients. The species can also be used in polycultures, as it tolerates high densities (El-Saidy & Gaber 2005, Bomfim et al. 2008).

Bullfrog (*Lithobates catesbeianus*) is the main frog species farmed across the world owing to its easy domestication and excellent weight gain in a short time (Pereira et al. 2014). This amphibian of the order Anura has a complex life cycle, with two very distinct phases: in the initial phase, the animal is aquatic and, in the second phase, it becomes terrestrial (Wilbur 1980). During the tadpole phase, maintaining water quality in terms of ammonia and pH parameters is essential for better animal growth (Borges et al. 2014).

An alternative to improve water quality in an aquaculture system is the polyculture of different species. This system is defined as the simultaneous cultivation of two or more species of aquatic organisms in the same environment, where species with different eating habits and different trophic niches are normally farmed. Polyculture aims to increase production through a more efficient use of the available ecological resources (Silva et al. 2006).

A production strategy that combines two or more complementary species can increase productivity by an adjustment in the food chain structure which is rearranged to make a better use of natural food, reducing the demand for artificial food (Lutz 2003).

A proper combination of ecologically different species at adequate densities will make the system more efficient because grazing pressure is distributed among different feeding niches and levels, and wastes from one species can be utilized by another (Milstein 1997).

Although tilapia are widely used in polyculture, especially with shrimp and other fish species (Candido et al. 2006, Simão et al. 2013, Brito et al. 2017) due to its omnivorous eating habit, to date, there are no literature data on their cultivation with bullfrog tadpoles, another omnivorous, filter-feeder, and scraper aquatic organism (Pryor 2014). Bullfrog tadpoles for being scrapers, filters and moving separately will explore environments that are not explored by Nile tilapia.

However, one polyculture study was developed with post-metamorphosis bullfrogs and tilapia in hapas in which good results were reported for both species, with the frogs using the surface environment and the tilapia being submerged in the hapa (Sousa et al. 2010, Castro et al. 2014).

A problem with the polyculture system in aquaculture may be aggressive behavior by one species towards the other and or predation (Marques et al. 2016).

This study proposes to evaluate the production performance of two species of aquatic organisms from different aquaculture activities (fish farming and frog farming), using different polyculture proportion and initial body size of species.

MATERIALS AND METHODS

Experimental site and period

The research project was approved by the ethics committee of the institution (approval no. 23083.001788/2018-31).

The experiment was carried out in the municipality of Mangaratiba – RJ (latitude 22°54′06” and longitude 43°33′42”), Brazil, during the months of April and June 2018.

Animal acclimation, experimental design, and treatments

In Experiment I, 400 Nile tilapia juveniles with an average weight of 3.01±0.34 g and 400 bullfrog tadpoles with an average weight of 0.3±0.1 g were used. The animals were acclimatized for 30 days in 300-L tanks with an average temperature of 25±1.2 °C and constant aeration provided by an air blower.

Experiment II involved 200 Nile tilapia with an average weight of 0.90±0.09 g and 420 bullfrog tadpoles with an average weight of 1.82±0.06 g. Both species were acclimatized for 10 days in 300-L tanks with an average temperature of 25±0.9 °C and constant aeration provided by an air blower.

The experiments were laid out in a completely randomized design with four replicates per treatment.

In Experiment I, five proportions tilapia/tadpoles were tested with tilapia juveniles weighing 5.39±0.35 g and tadpoles weighing 2.42±0.11 g. The treatments were represented by a tilapia monoculture; a 75% tilapia + 25% tadpole polyculture; a 50% tilapia + 50% tadpole polyculture; a 25% tilapia + 75% tadpole polyculture; and a tadpole monoculture (% = animals number).

In Experiment II, four proportions tilapia/tadpoles were evaluated using tilapia juveniles weighing 0.89±0.09 g and tadpoles weighing

1.82±0.06 g. The treatments consisted of a tilapia monoculture; a 25% tilapia + 75% tadpole polyculture; a 12.5% tilapia + 87.5% tadpole polyculture; and a tadpole monoculture (% =animals number).

Experimental site and animal management

Five recirculation systems were used in Experiment I and four in Experiment II, with four tanks in each system interconnected in a linear layout.

The water in the tanks was drained from the bottom and directed to a mechanical filter. After filtration, the water went to the biological filter and returned to the system via pumping, using a submersible pump (SB2000, Sarlobetter). Each tank was supplied individually.

Combined, the mechanical and the biological filter contained approximately 80 L of water, and each tank had the same usable volume, totaling 400 L of water within each system (line). The water renewal rate of each tank was 200% daily.

The rearing system was set up inside a closed room with controlled lighting (12 h light/12 h dark) so that the temperature in the tanks remained as homogeneous as possible throughout the experiment. Twenty water tanks with a capacity of 100 L each and a usable volume of 80% were used for the experiments. The tanks were arranged in lines (five lines for Experiment I and four lines for Experiment II), which were interconnected by the same drain pipe. The drain water left the tanks and was conducted to the tank (80 L of water) with the filters through a mechanical filter (composed of a sponge filter) to remove suspended particles from the water (animal remains and feces). After passing through the mechanical filter, the water was directed to the biofilters (PVC scrap, 2 cm). Once filtered, the water returned to the tanks through taps.

During the experiments, the water was partially exchanged at different intervals. In Experiment I, 40% of the total water volume of the lines was exchanged every 10 days. The same was applied for Experiment II, only at a 15-day interval.

Experiment I

The animals were distributed into 20 tanks with constant aeration. Nile tilapia juveniles were stocked at the density of one fish per 2 L in the 100% tilapia treatment. Tadpoles were housed at the density of one animal per 2 L of water in the 100% tadpole treatment. In the polyculture system, the densities were maintained according to the proportions tilapia/tadpoles of each treatment.

Fish and tadpoles received a commercial extruded feed three times daily, until food satiety (NUTRIPISCIS TR), with the following characteristics: 120 g/kg moisture, 320 g/kg crude protein (CP), 60 g/kg crude fiber, 100 g/Kg ether extract and 120 g/kg mineral matter (information provided by the manufacturer); 118.95 g/Kg moisture, 333.10 g/Kg crude protein (CP), 98.0 g/Kg ether extract and 114 g/kg mineral matter (information centesimal composition analyzed). The feed was ground to a particle size of 0.8 mm (Seixas et al., 1998) and distributed evenly over the water. Daily feed intake was estimated daily by weighing the feed before the first and after the last supply. The experiment lasted 30 days.

Experiment II

The animals were distributed into 16 tanks. Nile tilapia fry were stored at the density of one fish for 2 L of water in the 100% tilapia treatment. Tadpoles were housed at the density of one animal for 2 L of water in the 100% tadpole treatment. In the polyculture system, the densities were maintained according to the proportions tilapia/tadpoles of each treatment.

Fish and tadpoles received commercial extruded feed, until food satiety, three times daily, (NUTRIPISCIS TR), as in the previous experiment. The experiment lasted 30 days.

Water quality

Dissolved oxygen (mg L^{-1}), pH, and temperature (°C) were measured twice daily using a multiparameter instrument (AK88, Akso), before feeding. Ammonia tests (colorimetry; Labcon Test Amonia) were performed every two days and nitrite tests (colorimetry; Labcon Test Nitrito) were carried out once weekly.

Production performance

The animals were weighed and measured to be subsequently euthanized with an overdose of benzocaine (500 mg L^{-1}). Once the weight and length data were obtained, the following variables were calculated: final average weight (g); standard and total lengths (mm); weight gain (WG, in g; considering the following formula: WG = Final average weight – Initial average weight); estimated biomass (g); survival; specific growth rate (% day^{-1}; SGR = (ln (final live weight) − ln (initial live weight))x100/experimental days); and feed conversion (g g^{-1} live weight).

In both experiments, the number of dead tilapia and tadpoles was counted daily to estimate survival and the number of animals per tank. Prior to stocking, an initial biometric assessment was performed in both experiments to determine initial weight and length data. A second biometric measurement was carried out at 15 days and a final biometric assessment took place at the end of the experiment, at 30 days.

Centesimal composition analysis

Approximately 30 g of slaughtered bullfrog tadpoles and Nile tilapia were sampled for centesimal analysis, in all experimental units (in the monoculture units, only the farmed species was sampled).

The CP content of the samples was determined by the Kjeldahl method (6.25 multiplication factor). Ether extract was determined by extraction with petroleum ether in a Soxhlet extractor for 12 h. The ash content was determined by oven-drying at 550 °C and the dry matter content was obtained by oven-drying at 105 °C for 18 h. The employed methodologies were described by Silva & Queiroz (2002).

Statistical analysis

Results were subjected to the Shapiro-Wilks and Barlett tests to check for data normality and homoscedasticity, respectively. Subsequently, analysis of variance (ANOVA) was carried out and in case of differences between the means, these were compared by Tukey's test at the 5% significance level. All statistical procedures were performed using SAS software (Statistical Analysis System, version 9.0).

RESULTS

Water quality and production performance

Experiment I

The mean temperature, dissolved oxygen, pH, and total ammonia values throughout the experimental period in the tanks were adequate for the studied aquatic species (Nile tilapia and bullfrog tadpole) (Table I). Results found according to recent literature.

The biomass, average weight, mortality, and feed intake results of the polyculture of Nile tilapia fry and bullfrog tadpoles revealed that using Nile tilapia with an initial weight higher than that of bullfrog tadpoles, results for polyculture were lower than those for

Table I. Water quality of polyculture (P) between bullfrog tadpoles (BT) and Nile tilapia (T), tilapia monoculture (TM) and a bullfrog tadpole monoculture (BTM) experiment 1.

Tratament	Temperature (C°)	NH_3 (mg.L^{-1})	pH	Oxygen dissolved (mg.L^{-1})
BTM	24.48±0.55	1.56±0.28	7.18±0.28	7.12±0.26
P50T/50BT	24.71±0.71	1.71±0.49	7.28±0.35	6.81±0.23
P25T/75BT	24.90±0.72	1.75±0.20	7.22±0.26	6.65±0.13
P75T/25BT	24.98±0.98	1.98±0.17	7.28±0.33	6.37±0.25
TM	25.00±0.86	1.90±0.85	7.25±0.30	6.34±0.52
P-value	0.4563	0.2453	0.8145	0.0922

Average ± Standard deviation. Value-P<0.05, averages differ by the variance analysis.

monoculture. This is confirmed, for instance, by mortality rate, which reached 100% of the tadpoles in some treatments (Table II).

Experiment II

During the entire experimental period, the mean temperature, dissolved oxygen, pH, and total ammonia values in the tanks were adequate for both aquatic species (Table III).

The average weight and specific growth rate of Nile tilapia polycultured with bullfrog tadpoles did not differ (P>0.05) between the treatments. However, the average weight of bullfrog tadpoles in polyculture with Nile tilapia differed (P<0.05) only at 15 days of experiment, with higher values obtained by the animals in polyculture (Table IV).

The total biomass of the treatments differed (P<0.05) initially, at 15 days, and at 30 days, mainly because the tadpoles started the experiment with a higher weight than the Nile tilapia, which was established to prevent and reduce competition and predation (Table V). The results throughout the biometric measurements revealed biomass growth in the polyculture between bullfrog tadpoles and Nile tilapia and in their respective monocultures.

Feed intake differed between treatments (P<0.05), with the lowest values obtained by the tadpoles in monoculture and the tadpoles polycultured with 12.5% Nile tilapia and the highest by the tilapia in monoculture (Table VI).

In terms of biomass gain, there were no differences (P>0.05) between the treatments in mono- or polyculture (Table VI).

The feed conversion ratios of the bullfrog tadpoles in monoculture and polycultured with 12.5% Nile tilapia were 1.36 g/g and 1.39 g/g, respectively (P<0.05), which were superior to the 1.59 g/g achieved in the polyculture of bullfrog tadpoles with 25% Nile tilapia and the 1.78 g/g obtained by the Nile tilapia in monoculture (Table VI).

Centesimal composition analysis revealed differences (P<0.05) in moisture and ash contents between the tadpoles in monoculture and the tadpoles reared in polyculture systems with Nile tilapia (Table VII). In addition to moisture and ash, differences were also detected for the ether extract content of Nile tilapia when the monoculture systems were compared with the polyculture treatment P25.0T/75.0BT (Table VII), indicating the influence of the nutritional quality of the diet in relation to mono or polyculture systems.

Table II. **Biomass (g), average weight (g), mortality (%) e feed intake (%) of the polyculture (P) breeding of Nile tilapias fingerlings (T) and bullfrog tadpoles (BT), tilapia monoculture (TM) and a bullfrog tadpole monoculture (BTM) in the experiment 1.**

Treatment	**Biomass (g)**		
	Initial	**15 days**	**30 days**
BTM	94.42±1.70 e	129.72±4.67 e	97.71±5.69 e
P50T/50BT	158.85±4.34 c	201.15±10.81 c	222.11±7.27 c
P25T/75BT	127.55±1.73 d	160.82±14.35 d	122.18±3.95 d
P75T/25BT	185.28±2.05 b	271.80±5.21 b	521.98±8.75 b
TM	214.31±4.13 a	352.85±8.63 a	605.57±6.05 a
P-Value	<0.0001	<0.0001	<0.0001
Treatment	Bullfrog tadpoles average weight (g)		
	Initial	15 days	30 days
BTM	2.36±0.04	3.23±0.08	3.34±0.04
P50T/50BT	2.50±0.55	2.86±0.68	0.00±0.00
P25T/75BT	2.46±0.08	3.15±0.23	3.82±0.30
P75T/25BT	2.37±0.64	20.9±1.32	0.00±0.00
P-Value	0.3890	-	-
Treatment	Tilapias average weight		
	Initial	15 days	30 days
P50T/50BT	5.44±0.23	8.48±0.29	12.99±0.63 b
P25T/75BT	5.38±0.16	8.70±1.01	14.47±0.99 a
P75T/25BT	5.38±0.08	8.73±0.40	11.77±0.51 b
TM	5.35±0.10	9.15±0.53	11.38±0.14 b
P-Value	0.9818	0.8961	0.0226
Treatment	Mortality (%)		
	Tadpoles	Tilapias	30 days
BTM	11.25±3.30	-	11.25±3.30
P50T/50BT	100.00±0.00	0.00±0.00	50.00±0.00
P25T/75BT	96.66±3.33	5.00±5.00	73.75±3.14
P75T/25BT	100.00±0.00	1.66±0.96	26.25±0.72
TM	-	1.25±1.25	1.25±1.25
P-Value	-	-	-
Treatment	Feed intake (g)		
	0-15 days	16-30 days	Final
BTM	46.42±0.89 e	19.38±0.78 d	65.81±1.27 e
P50T/50BT	92.51±1.57 d	70.95±2.51 b	163.46±2.91 c
P25T/75BT	88.16±2.17 c	61.38±0.72 c	149.55±2.57 d
P75T/25BT	124.87±1.93 b	84.45±1.58 a	209.32±2.57 b
TM	169.27±5.71 a	81.63±1.61 a	250.91±2.67 a
P-Value	<0.0001	<0.0001	<0.0001

Average ± Standard deviation. Value-P<0.05, averages differ by the variance analysis. Different letters in the same column differ to P<0.05 by the Tukey test.

Table III. Water quality of polyculture (P) between bullfrog tadpoles (BT) and Nile tilapia (T), tilapia monoculture (TM) and a bullfrog tadpole monoculture (BTM) experiment 2.

Treatment	Temperature (C°)	NH_3 (mg.L^{-1})	pH	Oxygen dissolved (mg.L^{-1})
P12.5T/87.5BT	25.98±1.16	0.07±0.02	7.71±0.16	5.47±1.03
BTM	25.19±1.06	0.07±0.06	7.28±0.22	5.35±0.78
P25.0T/75.0BT	24.36±1.12	0.05±0.05	7.14±0.27	5.16±0.66
TM	24.35±1.13	0.09±0.01	7.07±0.26	5.21±0.58
P-value	0.1192	0.2100	0.7643	0.8891

Average ± Standard deviation. Value-P<0.05, averages differ by the variance analysis.

Table IV. Average weight (g) and specific growth rate (%/day) of bullfrog tadpoles (BT) and Nile tilapias (T) during the experimental period in the polyculture (P), tilapia monoculture (TM) and a bullfrog tadpole monoculture (BTM) breeding in the experiment 2.

Treatment	Nile tilapias average weight (g)			Nile tilapia SGR (%/day)
	Initial	15 days	30 days	
P12.5T/87.5BT	0.87 ± 0.08	2.02 ± 0.36	3.12 ± 0.54	4.17 ± 0.18
P25.0T/75.0BT	0.85 ± 0.07	2.28 ± 0.15	3.04 ± 0.26	4.23 ± 0.09
TM	0.97 ± 0.06	1.83 ± 0.09	2.77 ± 0.04	3.52 ± 0.09
P-value	0.5354	0.4286	0.7593	0.1543
Treatment	Bullfrog tadpoles average weight (g)			Tadpoles SGR (%/day)
	G Initial	15 days	30 days	
P12.5T/87.5BT	1.80 ± 0.12	2.86 ± 0.19 a	3.46 ± 0.09	2.16 ± 0.03
P25.0T/75.0BT	1.85 ± 0.13	2.85 ± 0.17 a	3.43 ± 0.11	1.87 ± 0.05
BTM	1.71 ± 0.11	2.26 ± 0.15 b	3.22 ± 0.23	2.08 ± 0.12
Valor-P	0.3425	0.0482	0.5448	0.4325

Average ± Standard deviation. Value-P<0.05, averages differ by the variance analysis. Different letters in the same column differ to P<0.05 by the Tukey test.

Table V. Total biomass of Nile tilapias (T) fingerlings and bullfrog tadpoles (BT) in polyculture, tilapia monoculture (TM) and a bullfrog tadpole monoculture (BTM) breeding in the experiment 2.

Treatment	Total Biomass (g)		
	Initial	15 days	30 days
P12.5T/87.5BT	66.34 ± 1.23 b	108.45 ± 1.77 b	127.55 ± 3.02 a
BTM	72.08 ± 0.78 a	117.48 ± 1.02 a	131.31 ± 0.71 a
P25.0T/75.0BT	56.18 ± 1.23 c	89.87 ± 2.33 c	115.82 ± 3.3 b
TM	35.27 ± 1.93 d	64.66 ± 2.63 d	93.27 ± 1.79 c
P-value	0.0001	0.0001	0.0001

Average ± Standard deviation. Value-P<0.05, averages differ by the variance analysis. Different letters in the same column differ to P<0.05 by the Tukey test.

Table VI. Feed intake (g), weight gain (g) and feed conversion in polycuture breeding of fingerlings Nile tilapias (T) and bullfrog tadpoles (BT), tilapia monoculture (TM) and a bullfrog tadpole monoculture (BTM) in the experiment 2.

Treatment	Feed intake (g)	Weight gain (g)	Feed conversion (g/g)
P12.5T/87.5BT	84.90±4.27 a	61.21 ± 1.86	1.39 ± 0.07 a
BTM	80.90±1.81 a	59.22 ± 0.90	1.36 ± 0.03 a
P25.0T/75.0BT	94.28±2.71 b	59.64 ± 3.17	1.59 ± 0.11 b
TM	103.56±3.53c	58.00 ± 0.33	1.78 ± 0.55 c
P-Value	0.0001	0.6989	0.0083

Average ± Standard deviation. Value-P<0.05, averages differ by the variance analysis. Different letters in the same column differ to P<0.05 by the Tukey test.

Table VII. Centesimal composition; moisture (g/kg), crude protein (g/kg), ether extract (g/kg) and ash (g/kg) of bullfrog tadpoles (BT) and Nile tilapia (T) in polyculture, tilapia monoculture (TM) and a bullfrog tadpole monoculture (BTM) experiment 2.

Treatment	Moisture (g/kg)	Crude Protein (g/kg)	Ether extract (g/kg)	Ash (g/kg)
Bullfrog tadpoles (BT)				
P12.5T/87.5BT	867.8±12.4 b	56.6±10.5	33.3±10.5	12.3±0.5 b
BTM	868.9±04.5 b	55.8±03.6	35.1±02.3	30.2±1.4 a
P25.0T/75.0BT	883.5±10.7 a	49.3±02.5	29.9±02.4	27.3±1.2 a
P-value	0.0173	0.9874	0.9010	0.0042
Nile tilapias (T)				
P12.5T/87.5BT	766.4±06.7 b	112.2±7.4	84.8±6.1 a	26.6±0.7 c
TM	750.5±10.6 b	124.0±4.7	71.3±2.3 a	38.2±1.5 b
P25.0T/75.0BT	782.1±02.9 a	115.7±5.8	51.0±1.9 b	41.2±2.5 a
P-value	0.0004	0.0618	0.0001	0.0001

Average ± Standard deviation. Value-P<0.05, averages differ by the variance analysis. Different letters in the same column differ to P<0.05 by the Tukey test.
Values are expressed on the basis of dry matter.

DISCUSSION

The water quality (water temperature, oxygen, pH, and ammonia) values were within the range considered optimal for farming tadpole (Lima et al. 2003, Bambozzi et al. 2004, Hayashi et al. 2004, Seixas Filho et al. 2012) and tilapia (Sanchez & Matsumoto 2011) in recirculation systems. However, ammonia in the first experiment showed a high value but within the limit for the species.

Future studies should observe adjustments for polyculture between fish and tadpoles in terms of water quality, as this is the first research on the subject.

In Experiment I, the results for bullfrog tadpoles in polyculture with Nile tilapia were unsatisfactory in terms of biomass, average weight (tadpoles and fish), feed intake and, especially, mortality. One possibility for high mortality in tadpoles can be predation and behavior of dominance in environment by fry of Nile tilapia.

A negative effect has also been reported with the introduction of Nile tilapia in the cultivation of marine shrimp (*Litopenaeus vannamei*), which resulted in decreased shrimp growth and low feed conversion ratios (Simão et al. 2013). This result is explained by behavioral traits of Nile tilapia such as predation, which interferes with polyculture.

Polyculture can favor one species over the another, as demonstrated in the cultivation of *Mugil platanus* with marine shrimp, which revealed a positive result for the growth of the fish but a negative outcome for the crustacean (Costa et al. 2013).

In Experiment II, in which stocking densities of bullfrog and Nile tilapia tadpoles were again evaluated, an inverse relationship was observed between the body size of the tadpoles and the tilapia, as seen by the initial weights for stocking.

The mortality in experiment II was zero for both species, and there was no predation and others problems. It is thus inferred that, for this polyculture, the initial weight of tilapia should be around 1 g and tadpoles around 2 g. In another experiment, the polyculture between fish and crustaceans was more efficient with the combination of 2 tilapia (7.61 g for initial weight) with 2.5 or 5 shrimp (0.36 g for initial weight) per square meter and feeding adjusted according to need of the fish (Simão et al. 2013). The satisfactory result was due to the observation of biological aspects of the species.

The feed conversion ratios in the polycultures with 25% tilapia + 75% tadpoles and 12.5% tilapia + 87.5% tadpoles in the second experiment were 1.59 g/g and 1.39 g/g, whereas the tadpole and tilapia monocultures showed 1.36 and 1.78 g/g, respectively. In the literature, bullfrog tadpoles exhibited an average feed conversion ratio of 1.50 g/g (Lima et al. 2003, Seixas Filho et al. 2013), that is, the results obtained with the tadpoles in the current study are within the normal range for the species, for this parameter.

Tilapia farmed in hapas showed feed conversion ratios ranging from 1.67 to 1.96 g/g when fed with feed dispensers (Oliveira et al. 2016) and from 1.03 to 1.17 g/g in conventional systems with live feed (Calvalcante et al. 2017). Therefore, the 1.78 g/g found in this study for the tilapia indicates that, when compared with the literature descriptions, the polyculture system favored the tadpoles, without, however, impairing fish growth.

It is important to remember that the diet contained 32% CP, which may have induced the tilapia fry in monoculture to increase their feed intake in an attempt to meet their need for protein nutrients of 39% CP (Takishita et al. 2009). For tadpoles, possibly the diet met their nutritional needs.

The density of tadpoles and tilapia in polyculture influenced their body composition in terms of moisture and ash for both, and ether extract (fat) for the tilapia. Similar results have been described for bullfrog tadpoles fed a diet with 270 g/kg digestible protein, which showed a centesimal composition of 851.5 g/kg moisture, 87.9 g/kg protein, 44.3 g/kg fat, and 15.7 g/kg ash (Pinto et al., 2015). In another study, the same species receiving commercial feed with 550 g/kg CP showed a centesimal composition of 881.5 g/kg moisture, 70.0 g/kg protein, 36.0 g/kg fat, and 12.4 g/kg ash (Mansano et al. 2013). In an experiment using a commercial feed containing 360.00 g/kg CP, bullfrog tadpoles had a body composition consisting of 863.8 g/kg moisture, 7.37 g/kg CP, 44.6 g/kg fat, and 17.9 ash (Mansano et al. 2014).

In some aspects, the body composition of the Nile tilapia raised in polyculture with bullfrog tadpoles in the present study differed from those of Thai and GIFT tilapia measuring 5 to 10 cm (Santos et al. 2012), whose composition analysis revealed the respective values: 767.4 and 805.3 g/kg moisture, 47.6 and 30.9 g/kg ether extract, 101.5 and 101.9 g/kg CP, and 29.91 and 29.90 g/kg ash. These differences are probably because the tilapia in this study received feed with a lower CP content (32%) than that recommended for the species at this stage (36 to 40%).

Polyculture for Nile tilapia and tadpoles did not prove to be an efficient system based on the results of the first experiment, but with the results and adjustments proposed in relation to the initial size of the species in the next experiment, it proved to be efficient and can be recommended in aquaculture.

The polyculture of bullfrog tadpoles and Nile tilapia is possible and efficient when the tadpoles are initially larger than the tilapia and the proportion of one tilapia for seven tadpoles is adopted.

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