Stock densities, growth and survival for pacu (*Piaractus mesopotamicus*)

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Stocks of the indigenous freshwater pacu (*Piaractus mesopotamicus*) and other omnivorous species have been adversely affected by environmental changes in the La Plata river basin in Argentina; in particular, dam construction and pollution from industrial, agriculture and organic matter. These species have almost disappeared from Uruguay River, while they have been reported as scanty to medium and low in the Paraná river (Quiros 1990).

According to Machado-Allison (1980), pacu must be considered as an omnivorous species because they eat mainly fruits, seeds, vegetables and invertebrates; mainly crustaceans, molluscs and insects.

Two factors have contributed to an interest in culturing pacu: a remarkable decrease in wild stocks and its high demands in the local markets and restaurants in the country (Figure1). Its culture is also being considered as an option for those interested in agriculture diversification. Yields of over 400 tons annually (2004) can be obtained in semi-intensive systems. Cultured pacu have been sold whole, frozen, as boneless fillets, as burgers, as well as alive for stocking recreational fishing ponds. Pacu is offered in several expensive and exclusive restaurants in Buenos Aires.

The aim of this study at Centro Nacional de Desarrollo Acuícola (CENADAC) was to carry out experimental culture research concerning pacu production at different densities with the goal of producing large individuals in the shortest culture period. Two diets (35 percent crude protein), successfully used in previous experiences were employed. Experimental feeds were formulated with locally available ingredients according to nutritional requirements set in Brazil by Cantelmo and Souza (1988) and Cantelmo (1993).

Fish growth differs according to culture density. Aggressiveness seems to increase at lower densities and decrease at higher ones in some species, while others show greater levels of aggression and even cannibalism when density increases (Stickney 1994). There also appears to be a clear relationship among culture density, oxygen requirements and metabolic waste production. Piper *et al.* (1986) reported that density reduction yielded better quality even though there was no apparent environmental stress caused by crowding. Hepher (1993) pointed out that as the biomass in a pond increases, there is a greater requirement for DO, as well as an increase in metabolic wastes, mainly ammonia nitrogen, excreted by the fish, which restrains growth on account the toxicity.

Fig. 1. Pacu sampled at commercial size.

Study Methods

Experimental pacu monoculture studies were carried out at the CENADAC in the northeastern region of Argentina (27º32´S, 58º30´W; Figure 2). Studies were carried out in 35 excavated earthen ponds (300 and 500 m^2, each). The culture period ran for 16 months from late December 1999 to late April 2001, in a semi-intensive system, with water only being supplied in case of leakage or to make up for evaporative losses. Before stocking, the ponds were fertilized with poultry manure (400 kg/ha) and inorganic manure (urea and triple superphosphate at 1.5 to 5.0 kg/ha (Boyd 1998). Previous lime treatment was not necessary because of the favorable soil characteristics. Adult herbivorous carp (500-1,000 g initial weight) were stocked at a density of 150/m^2 to control weed growth, with excellent results. The water supply came from a deep well at pH 7.9, alkalinity of 9.1 mg/L, total hardness of 8.6 mg/L and DO of 2.85 ppm at the wellhead.

The study began with densities of 1.0 (A), 0.5 (B) and 0.3 (C) pacu/m^2. Experimental feed was based on two isocaloric and isonitrogenous diets, with a total of 35 percent crude protein, six percent lipid and 40 percent carbohydrate. The energy level was 3.36 kcal/kg. The diet contained 12 percent ash and nine percent moisture. Periodic samples to determine feed composition were analyzed in the laboratory. Ingredients included fishmeal, soybean,

Fig. 2. Pacu ponds (CECADAC)

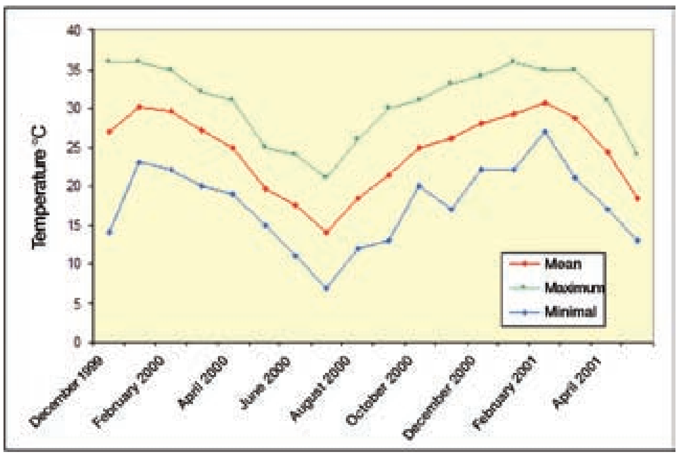

Fig. 3. Mean water temperature registered during the culture cycle.

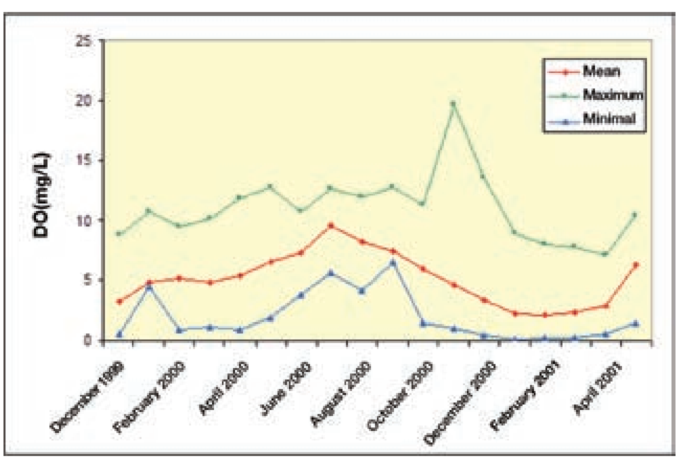

Fig. 4. Mean dissolved oxygen levels registered during culture cycle

corn and wheat meal, rice bran and soybean oil. Except for fishmeal, all ingredients were available in the current pacu production region.

Fish were fed daily, six days per week. From December 1999 to March 2000, food was given three times a day. Between April and May it was supplied twice a day and in winter, early June to late August, once a week in the afternoon. Twice daily feedings began again early in September. From November until the final culture stage, only one feeding was administered at 1600. Food ration rate varied according to body weight, 10 percent during the initial stage, decreased to four percent in March 2000 and to two percent in October 2000. Rations were offered at a maximum of 45 kg/ha/day and it was not offered if water temperature remained below 20ºC during the winter season. The Fish were not fed if the dissolved oxygen level was ≤2 mg/L and water temperature was above 35ºC.

Fish were supplied by a local commercial fish farm. Their initial average weight was 0.25 g. Water variables recorded twice daily during the early morning and late in the afternoon prior to feeding were temperature, dissolved oxygen and pH.

Ten percent of the fish population, were sampled on a monthly basis to determine fish growth, fish health and to calculate required feeding rate. All the fish were weighed at the end of experiment. Survival and overall production were determined, as well as feed conversion ratio (FCR) and specific growth rate (SGR). Statistical data analyses were performed and treatment groups compared by ANOVA and Duncan test, according to Hintze (1998).

Study Results

Water quality results

Mean water temperature during the culture cycle ranged from 14 to 31ºC, with an optimum for growth appearing to be 26-28ºC (Figure 3). The lowest temperature was 7ºC and had little effect on fish mortality. Dissolved oxygen levels (Figure 4) were always >3 ppm, except for the second summer when extreme values (< 1 ppm) were recorded very early in the morning because of high temperatures and high biomass. In one case, 80 percent mortality was recorded because of a sudden DO depletion during the night. Water pH values exhibited slight daily and seasonal variations and ranged from 6.6 to 8.0.

Growth response

Growth response is shown in Figure 5 for each pond density employed and the outcome for each treatment is detailed in Table 1. The D density was the result of high mortality in six ponds s.

Density A (1.0 fish/m^2). Results from 10 out of 12, 300 and 500 m^2 were assessed. Final average weight was 560.3 g (ranging from 443.3 to 627.7 g). Average FCR was 1.45 (ranging from 1.30 to 1.66)

Density B (0.5 fish/m^2). Results from 11 out of 12, 300 and 500 m^2 ponds were employed in the analysis. Final average weight was 753.7 g (ranging from 597.3 to 950.3 g). The average FCR was placed in 1.56 (ranging from 1.40 to 1.78).

Density C (0.3 fish/m^2): Results from eight out of 12, 300 and 500 m^2 ponds were considered. Final average weight was 953.0 g (ranging from 807.9 to 1,195.2 g). Final FCR was 1.75 (ranging from 2.03 to 1.45).

Density D (less than 0.3 fish/m^2): Results from six, 300 and 500 m^2 ponds were evaluated. Ponds were stocked at 1.0, 0.5 and 0.3/m^2. High mortality rates were during the first sampling. Larval mortality was probably a result of bird predation.

Average mortality at final harvest across in the D group was 0.21 fish/m^2 (ranging from 0.3 to 0.12 fish/m^2). In those 6 ponds there was a food oversupply that could be clearly seen in the FCR values. Final average weight was 1.37 g (ranging from 1.14g to 1.72 g). Average FCR was 2.70 (ranging from 2.02 to 4.10).

In February 2001, average weight for the four densities were significantly different. Density A was 447.7 g, density B was 565.0 g, density C was 692.6 g and density D was 1,917.5 g.

Differences among weights became clearer as time went by. This made us think that the fish in density A ponds were nearly reaching their maximum carrying capacity. According to Bernardino *et al.* (1998) that would be in the range of 500-600 g/m^2. At final harvest, the density A ponds showed 607.0 g/m^2 carrying capacity while B density units were 417.0 g/m^2. Both showed daily weight gains of less than 3.0 g while the carrying capacity of densities C and D ponds was around 300 g/day, with growth of 4.5-5.1 g/day (Table 1).

Our data differed from those of Jacobo *et al.* (1992) and Roux and Bechara (1998) because in the present study lower densities showed higher weight gains. Results from the present study were similar to those of Silva *et al*. (1997), working with pacu in Ceará, Brazil, without a clear winter season. Fish were grown at two densities for more than a year on a low protein ration (22 percent). Differences among the studies mentioned are shown in Table 2.

Survival

Survival was high in densities A, B and C, ranging between 97.5 and 99.7 percent. Survival in the six density D ponds at final harvest was 43.8 percent. There were no significant mortalities from diseases or parasites.

Table 1. Growth of Pacu variables at culture for A, B, C and D densities.

Density	A (1 ind/m^2)	B (0.5 ind/m^2)	C (0.3 ind/m^2)	D (<0.3 ind/m^2)
Initial mean weight (g)	0.25	0.25	0.25	0.25
Final mean weight (g)	560.2	753.7	953.0	1374.2
Days of culture	495	495	495	495
Number of ponds	10	11	8	6
Mean growth (g)	559.8	753.5	952.8	1374.0
Daily mean growth (g/day)	1.13	1.52	1.92	2.77
Specific growth rate[1]	1.56	1.62	1.66	1.74
Initial feeding rate (%)	10	10	10	10
Final feeding rate (%)[2]	< 2	< 2	< 2	< 2
Mean FCR[3]	1.45	1.56	1.75	2.70
Survival rate (%)	97.5	99.7	99.1	43.8
Mean Production (kg/ha)	6071	4170	3027	2890

[1]*Specific growthrRate = (ln fW – ln iW) x 100 / t = %percent/day*
[2]*Means determined at crop for each density. Range 0.75-1.5 percent.*
[3]*Feed conversion ratio (FCR) = Feed offered/mean weight gain*

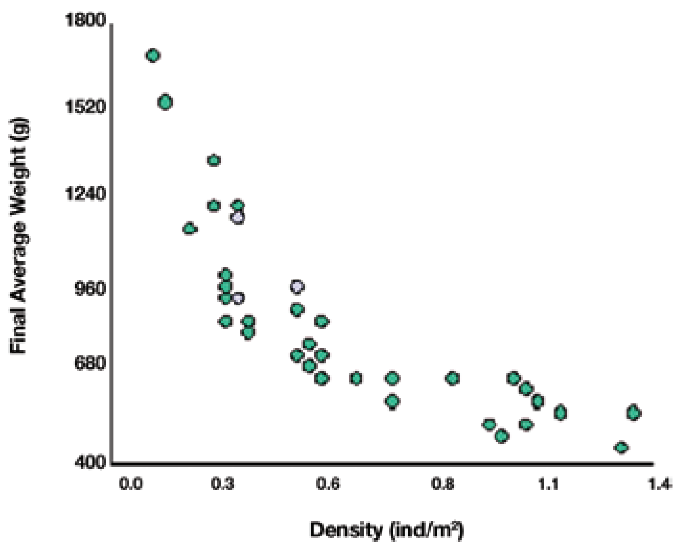

Fig. 5. Pacu final weight at different stock density.

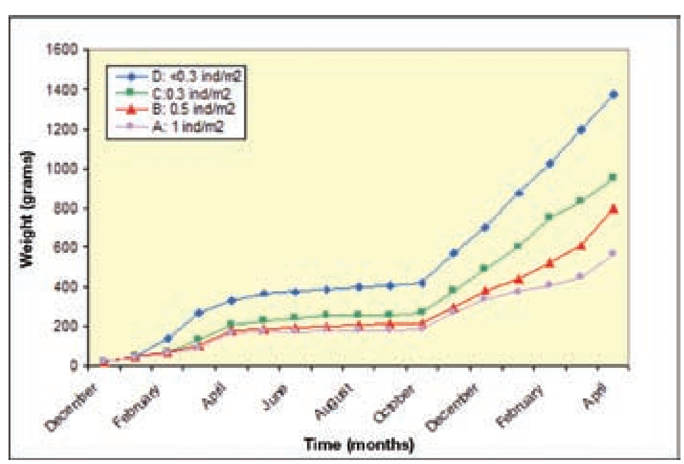

Fig. 6. Growth for Pacu at different culture densities (A,B,C and D).

Table 2. Experimental results compared with other authors results on *Piaractus mesopotamicus* culture

Authors	Jacobo,W 1992		Silva *et al*. 1997		Roux and Bechara, 1998				This work			
Density (ind/m^2)	0.98	0.64	1.0	0..5	1.0	0.8	1.0	0.8	1.0	05	0.3	0.21
Initial weight (g)	3.0	3.0	27.0	33.0	1.0	1.0	1.0	1.0	0.25	0.25	0.25	0.25
Final weight (g)	1,085	846.0	656.0	978.0	880.0	740.0	670.0	649.0	560.2	753.7	953.0	1.374.2
Days of culture	431	431	375	375	350	350	350	350	495	495	4.95	495
Number of ponds	1	1	3	3	1	1	1	1	10	11	8	6
FCR[1]	1.8	2.79	4.94	4.4	1.9	2.5	2.3	2.5	1.46	1.56	1.75	2.70
SGR[2]	1.36	1.30	0.86	0.91	0.84	0.82	0.78	0.78	1.56	1.62	1.66	1.74
Production (kg/ha)	10.182	5.032	5,717	4.5828	8.900	5.920	6.700	5.129	6.071	4.170	3.027	2.890

[1]FCR = Feed conversion ratio
[2]SGR = Specific growth rate

Discussion

Because *Colossoma* and *Piaractus* species have intramuscular Y bones (Peralta and Teichert-Coddington 1989), fish farmers should produce fish bigger than 1.2 kg in order to sell them in local markets. The results showed that growth is density dependent in semi-intensive culture without either water exchange or supplemental aeration. If larger commercial sizes are desired, it is advisable not to exceed a maximum carrying capacity of 500-600 g/m^2.

In conclusion, the stocking density to be used in growout culture should be <0.3 fish/m^2. The density of 0.2 fish/m^2 proved to be the most suitable one for producing fish that can be marketed in regional or foreign markets and if climatic conditions in the Argentinean subtropical region are taken into account. The technology will allow farmers to get specimens larger than 1.2 kg with a two-summer culture.

Notes

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