DEVELOPMENT OF SUSTAINABLE POND AQUACULTURE PRACTICES FOR *COLOSSOMA MACROPOMUM* AND *PIARACTUS BRACHYPOMUS* IN THE PERUVIAN AMAZON

Ninth Work Plan, New Aquaculture Systems/New Species Research 3 and 6 (9NS3 and 6)
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ABSTRACT

Studies on the sustainable aquaculture production of gamitana (*Colossoma macropomum*) and paco (*Piaractus brachypomus*) in the Peruvian Amazon were conducted at the Instituto de Investigaciones de la Amazonia Peruana (IIAP) Quistococha Aquaculture Station in Iquitos, Peru. Growth performance of paco stocked at 4,000, 6,000, and 8,000 fish ha^{-1} in an experiment was not significantly different among stocking densities. Fish were harvested after six and one-half months for the 4,000, 6,000, and 8,000 fish ha^{-1} study; mean weights of 418.2, 447.5, and 474.9 g, respectively, were attained. Specific growth rates (% d^{-1}) were 1.8, 1.8, and 1.7; feed conversion efficiencies were 72.9, 76.2, and 74.7; and condition factors were 2.7, 2.7, and 2.8 at the low to high densities, respectively. Survival for the paco experiment was > 80%. Paco fingerlings were fed a locally prepared diet (26.7% crude protein, 9.0% crude lipid). Water quality parameters (dissolved oxygen, temperature, total ammonia nitrogen, and pH) remained within acceptable levels for tropical aquaculture. The stocking density study suggests the economic feasibility of rearing paco in the Peruvian Amazon. The cost of production analysis in this and an earlier study indicated that gamitana production is economically more feasible than paco production because of its higher market value (US$3.00 vs. US$2.10 kg^{-1} fresh weight) and equal production costs (US$0.6 to US$0.9 kg^{-1} fresh weight). Production of gamitana and paco at densities of 2,500 fish ha^{-1} and higher will be more profitable than pineapple production, which is the highest market value agriculture cash crop produced in the Loreto region at the present time.

In another experiment, plasma concentrations of sex steroids—testosterone (T), 11-ketotestosterone (11-kT), estradiol-17β (E2) and 17,20β-dihydroxy-4-pregnen-3-one (17,20βP)—were measured by radioimmunoassay following ethyl-ether extraction to monitor and understand the dynamics of gonadal steroidogenesis during maturation of paco and gamitana. In paco, prior to hormonal treatments with luteinizing hormone-releasing hormone analog (LHRHa), the concentrations of 11-kT in males and E2 in females as well as the ones of their precursor T were significantly ($P < 0.01$) higher in fish maintained under normoxic conditions than in fish exposed to hypoxia. After ovulation and spermiation, the concentrations of T and 17,20βP significantly ($P < 0.05$) increased in both sexes in both experiments. However, the levels of plasma sex steroids reached under normoxic conditions were higher than the ones recorded under hypoxia, except the ones of 17,20βP in males. Additionally, the effect of oxygen concentration on human chorionic gonadotropin (hCG) was evaluated during final stages of induced maturation on blood steroid profiles in an attempt to correlate these data with gamete viability. From 8 to 11 November 2000, the second attempt at artificial spawning of paco and the first of gamitana were performed. Six pairs of paco were selected and transferred to indoor concrete tanks. Treatments involved injection of three pairs with LHRHa and three pairs with hCG (Sigma, St. Louis, Missouri) at 500 IU kg^{-1} (females) or 100 IU kg^{-1} (males). Fish were observed during the following 48 h and spawning attempted. Fish were weighed, tags identified, and blood samples taken prior to injection, at the time of ovulation, or 48 h after

injection. In the case of gamitana, four pairs were formed after preliminary selection (robustness or sperm presence). All fish were injected with LHRHa at the same dose as paco. Conditions in ponds and indoor tanks were monitored during spawning procedures. LHRHa proved to be the only sex hormone effective for inducing spawning in both males and females.

INTRODUCTION

The addition of a project in South America to the PD/A CRSP has provided considerable and unique opportunities to expand the CRSP network. In the Eighth Work Plan, a prime site was established at Iquitos, Peru, which is in the heart of the Peruvian Amazon (Loreto Region). The Loreto Region, with a population of 602,000, constitutes 27% of the country's total area. Approximately 46% of the region's population resides in the city of Iquitos. The main resource in the region is the integrated rain forest. The people in the region are primarily engaged in agriculture, cattle-raising, forestry, hunting, fishing, and tourist activities. Other economic activities of major importance to the region include the mining and drilling of nonrenewable resources such as oil, gold, and silica.

In the Peruvian Amazon, there are three important institutions working with aquaculture: Instituto de Investigaciones de la Amazonia Peruana (IIAP), Ministerio de Pesqueria (Peruvian Government), and Universidad Nacional de la Amazonia Peruana (UNAP). In the past ten years they have produced thousands of fry and have refined numerous aquaculture techniques. Gamitana (*Colossoma macropomum*) and paco (*Piaractus brachypomus*) are considered by local aquaculturists as the best fishes for commercialization in the tropical part of Peru. However, considerable potential exists to examine other species, as the Amazon Basin is home to over 2,000 freshwater species of fish.

A memorandum of understanding (MOU) is currently in place linking IIAP, UNAP, and Southern Illinois University at Carbondale (SIUC) (and collaborating US universities with SIUC under this umbrella) within the CRSP network. Between IIAP and UNAP there exist 49 earthen culture ponds ranging in size from 60 m^2 to nearly a hectare. Laboratory facilities also exist to monitor water quality variables of ponds and conduct pertinent research on sustainable aquaculture development of important fish species native to South America. Facilities have been significantly renovated at IIAP during the Ninth Work Plan.

Native species aquaculture has been expanding in the Peruvian Amazon as research has played a major role in the positive evaluation of its potential. Gamitana and paco are native to the Amazon basin and share many characteristics that also make them suitable for aquaculture. Local production of both species is still practiced in an extensive manner, but these species are in high demand and attain a higher price at the market. This motivates local farmers to invest their time in the production of these valued fish. As research develops, more important information becomes available to producers, hence the improvement of native species aquaculture in the region. Although technology is still underdeveloped, external aid has made it possible for the locals to become more aware of and active in aquaculture practices for gamitana, paco, and other native species.

Broodstock are usually collected from their wild habitat, although they are also raised in captivity at research stations. These fish may be immediate descendants of wild broodstock or may be a product of multiple-generation breeding. No standardization exists for stocking densities for fry or fingerlings (Campos, 1993). Likewise, no uniform fish diets are available in the region (Cantelmo et al., 1986; Ferraz de Lima and Castagnolli, 1989). This study determined suitable stocking densities to be as high as 8,000 fish ha^{-1} for optimal and efficient production of gamitana and paco to market size (0.5 to 1.0 kg) using a prepared diet manufactured from locally available ingredients. Replicated pond studies were carried out at IIAP, Iquitos.

METHODS AND MATERIALS

Methods and materials for research objectives are as follows:

Objective 1 (9NS3): Develop a Prepared Feed for Broodstock and Fingerlings

Additional information on nutrition of paco has been obtained via feeding experiments performed by Rebecca Lochmann at the University of Arkansas at Pine Bluff. Literature values for specific nutrients known to affect fish reproduction were calculated from published sources for the broodstock diet. Analytical information on the feedstuffs and diets currently being used in Iquitos, together with published information on the natural diets of paco and broodstock nutrition in other species, was combined to formulate preliminary recommendations for the nutrition and feeding of broodstock (see "Spawning and grow-out of *Colossoma macropomum* and/or *Piaractus brachypomus*," 9NS3A on pp. 85–88 of this report).

Objective 2 (9NS3): Determine Blood Plasma Steroid Concentrations in Relation to Gamete Quality

The plasma concentrations of steroids—testosterone (T), estradiol-17β (E2), 11-ketotestosterone (11-KT), and 17,20β-dihydroxy-4-pregnen-3-one (17,20βP)—were measured by radioimmunoassay, similar to those used previously (Ottobre et al., 1989) following ethyl-ether extraction. The characteristics of these antisera have been reported previously (Dabrowski et al., 1995, for T; Butcher et al., 1974, for E2; Kime and Manning, 1982, for 11-KT; and Fostier and Jalabert, 1986, for 17,20βP).

Objective 3 (9NS3): Compare Hormones to Induce Spawning

In July 1999, paco and gamitana were collected from two separate broodstock ponds located at the IIAP field station in Iquitos, Peru. Twenty-five fish of both species were individually measured, weighed, and tagged. Blood was collected from the caudal vessel of unanesthetized fish using a heparinized syringe. Fish were then released into their respective ponds. Blood was centrifuged at 1,500 rpm for 15 min, and the plasma was stored at –20°C until assayed. During October and November 1999, mature paco (average weight 3,394 ± 575 g and 3,683 ± 606 g in males and females, respectively) were sampled. Spermiating males and robust females were selected and then transferred to an indoor facility. Ovarian maturity was assessed with a microscope using oocytes collected from the ovary with a catheter. Pairs of paco were moved into indoor concrete tanks (0.75 m^3). The male was separated from the female by a net in each tank. Six and four pairs were used in the first and second experiments, respectively. In the first experiment aeration was not provided in the broodfish tanks, and the concentration of oxygen decreased to 2.5 ± 0.3 mg l^{-1}, whereas intensive aeration in the broodstock tanks prior to the stocking resulted in an increased oxygen concentration of 7.5 mg l^{-1}. Both genders were injected with two doses of LHRHa (Conceptal®). The concentration of LHRHa was 0.0042 mg of equivalents of active hormone per ml. Males and females were injected with 1 ml kg^{-1} and 2.6 ml kg^{-1}, respectively. The priming dose (50 and 10% in males and females, respectively) was administered in the morning, whereas the resolving dose (50 and 90% in males and females, respectively) was injected at 2200 h. The presence of a few eggs at the bottom of the tank, as well as the "knocking" sound produced by the male, was used as a sign of female readiness (oviposition). Blood was collected from the caudal vessel of unanesthetized fish prior to the priming injection and after ovulation or spermiation using a heparinized syringe. Blood was centrifuged at 1,500 rpm for 15 min, and the plasma was stored at –20°C until assayed. From 27 to 30 March 2000, gamitana and paco broodstock were caught and transferred to indoor tanks for identification, blood sampling, and possible evaluation of gonad maturity. In total, 12 fish of each species were examined. In addition, we visited two private farmers in the vicinity of Iquitos and sampled gamitana (muscle) fed local diets, including fruits, for possible analysis of phytochemicals.

From 8 to 11 November 2000, the second attempt at artificial spawning of paco and the first of gamitana were performed. The weight of paco and gamitana sampled for blood steroid analysis reached 4,986 ± 511 g and 7,370 ± 538 g, respectively. Six pairs of paco were selected and transferred to indoor concrete tanks. Treatments involved injection of three pairs with LHRHa and three pairs with hCG (Sigma, St. Louis, Missouri), the former at dosages previously described and the latter at 500 IU kg^{-1} (females) or 100 IU kg^{-1} (males). Fish were observed during the following 48 h and spawning attempted. Fish were weighed, tags identified, and blood samples taken prior to injection, at the time of ovulation, or 48 h after injection. In the case of gamitana, four pairs were formed after preliminary selection (robustness or sperm presence). All fish were injected with LHRHa at the same dose as paco. Conditions in ponds and indoor tanks were monitored during spawning procedures for all studies.

Objective 4 (9NS3): Identify Proper Stocking Density for Paco and Gamitana for Pond Culture

Two earlier experiments (Kohler et al., 1999, 2001) tested paco and gamitana at several stocking densities. In this third experiment, nine ponds, ranging in size from 600 to 5,320 m^2, were stocked with paco at three densities: three at 4,000 fish ha^{-1}, three at 6,000 fish ha^{-1}, and three at 8,000 fish ha^{-1}. The mean initial weight was 21.3 g. The study was initiated 2 March 2000 and continued until 15 September 2000. General water quality parameters (dissolved oxygen (DO), temperature, total ammonia nitrogen (TAN), and pH) were measured daily or weekly in the early morning for all studies. Harvest data were analyzed using the Statistical Analysis System (SAS Institute, 1993) with an alpha of 0.05.

RESULTS AND DISCUSSION

The overall goal of the program was to provide food security for the region through the following objectives:

Objective 2 (9NS3): Determine Blood Plasma Steroid Concentrations in Relation to Gamete Quality

The assay characteristics are shown in Tables 1 and 2. Extraction blanks were below sensitivity of assay for examined hormones, and serial dilutions of plasma samples showed parallelism with the standard curve between 25 and 100 ml.

In July 1999, the weight of paco and gamitana sampled for blood steroid analysis reached 3,332 ± 73 g and 5,092 ± 144 g, respectively. At this time it was not possible to identify the sex based on external characteristics of the fish sampled. The average concentrations of plasma sex steroids were low (< 1 ng ml^{-1}) in both species (Table 3). High concentrations (1.2 to 3.9 ng ml^{-1}) of E2 were found in few paco (in 10 of 25 sampled), indicating that those fish were females and had started their gonad recrudescence. The concentrations of 11-kT (1 to 2.1 ng ml^{-1}) were high in 8 gamitana (out of 25 sampled). Those fish were suspected to be males and had started their gonad recrudescence.

Table 1. Radioimmunoassay characteristics of plasma sex steroid hormones—testosterone (T), 11-ketotestosterone (11-kT), estradiol-17β (E2), and 17,20β-dihydroxy-4-pregnen-3-one (17,20βP)—in paco (*Piaractus brachypomus*).

Characteristics	T	E2	11-kT	17,20βP
Within-Assay CV (%) (n = 6)	1.7	2.0	2.5	2.0
Between-Assay CV (%) (n = 3)	9.2	3.9	6.1	5.9
Accuracy (Coefficient of Determination)	0.988	0.995	0.984	0.983
Sensitivity (pg ml^{-1})	2	1	2	1
Recovery of Extraction (%)	85.8	89.7	91.9	98.6

Table 2. Radioimmunoassay characteristics of plasma sex steroid hormones in gamitana (*Colossoma macropomum*). Abbreviations as in Table 1.

Characteristics	T	E2	11-kT	17,20βP
Within-Assay CV (%) (n = 6)	1.9	2.2	2.4	2.1
Between-Assay CV (%) (n = 3)	4.3	3.5	4.5	3.9
Accuracy (Coefficient of Determination)	0.978	0.983	0.948	0.968
Sensitivity (pg ml^{-1})	2	1	2	1
Recovery of Extraction (%)	89.9	89.2	90.5	93.5

Table 3. Plasma sex steroid hormones in a mixed-sex population of paco (*Piaractus brachypomus*) and gamitana (*Colossoma macropomum*) sampled in August 1999. Abbreviations as in Table 1.

Species	Plasma Sex Steroids (pg ml^{-1})			
	T	*E2*	*11-kT*	*17,20βP*
Paco	137 ± 13	106 ± 9	790 ± 108	37 ± 6
Gamitana	180 ± 28	991 ± 230	631 ± 58	15 ± 3

Table 4. Plasma sex steroid hormones of male and female paco (*Piaractus brachypomus*) under hypoxic and normoxic conditions before and after hormonal treatments. Abbreviations as in Table 1. Means within the same column grouped as males and females with different letters are significantly different ($P < 0.01$).

Conditions	Plasma Sex Steroids					
	Male			*Female*		
	T (ng ml^{-1})	11-kT (ng ml^{-1})	17,20βP (pg ml^{-1})	T (ng ml^{-1})	11-kT (ng ml^{-1})	17,20βP (pg ml^{-1})
HYPOXIA (N = 6)						
Before Treatment	0.53 ± 0.10 [a]	5.98 ± 1.61 [a]	30 ± 10 [a]	1.58 ± 0.19 [a]	3.92 ± 0.23 [a]	17 ± 7 [a]
After Treatment	5.82 ± 0.72 [b]	6.29 ± 0.52 [a]	116 ± 25 [b]	11.06 ± 1.80 [c]	3.65 ± 0.53 [a]	736 ± 253 [b]
NORMOXIA (N = 4)						
Before Treatment	6.76 ± 0.98 [b]	37.68 ± 5.48 [b]	22 ± 9 [a]	6.10 ± 1.15 [b]	7.46 ± 0.32 [b]	45 ± 24 [a]
After Treatment	11.11 ± 1.12 [c]	7.46 ± 1.73 [a]	106 ± 18 [b]	24.14 ± 3.49 [d]	4.58 ± 0.75 [a]	2,161 ± 865 [c]

In October and November 1999, the concentrations of plasma sex steroid hormones increased significantly in comparison to those reported in July. Moreover, before the hormonal injections, the concentrations of 11-kT in males and E2 in females, as well as the ones of their precursor (T), were significantly ($P < 0.01$) higher in fish maintained under normoxic conditions than the ones in hypoxia. In contrast, the plasma levels of 17,20βP were similar regardless of the oxygen concentrations (Table 4). The response patterns of plasma sex steroids to the hormonal treatments were similar in both genders. The concentrations of T and 17,20βP significantly ($P < 0.05$) increased in both experiments. However, the levels reached under normoxic conditions were higher than the ones recorded under hypoxia. The exception was the concentration of 17,20βP in males, which did not change significantly. The concentration of 11-kT in males and E2 in females after spermiation or ovulation, respectively, decreased significantly ($P < 0.01$) in fish maintained in normoxic conditions, whereas it remained similar in males in hypoxia (Table 4). In March 2000 the weight of paco and gamitana sampled for blood steroid analysis reached 3,347 ± 113 g and 5,645 ± 250 g, respectively.

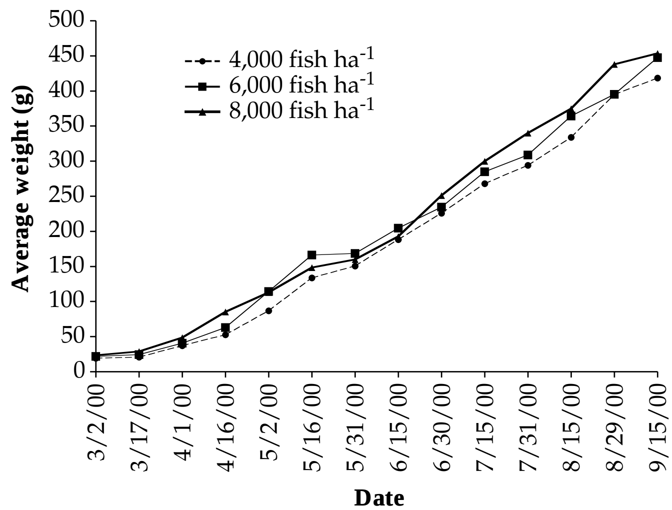

Figure 1. Average weight of *Piaractus brachypomus* stocked at densities of 4,000, 6,000, and 8,000 fish ha^{-1} in Iquitos, Peru, from 2 March through 15 September 2000.

Objective 3 (9NS3): Compare Hormones to Induce Spawning

Spawning induction of paco with LHRHa resulted in ovulation of three females, and a copious amount of sperm was obtained from males. Only one female, however, gave high quality of eggs (over 93% fertilization rate; embryonic-eyed stage). Neither males nor females were observed to mature following hCG injections. Gamitana were not induced to spawn following hormonal injections. Blood samples were collected from all examined fish, and steroid hormones were determined.

We do not recommend further use of hCG for gamitana and paco. Additionally, the effect of oxygen concentration on hCG was evaluated during final stages of induced maturation on blood steroid profiles, attempting to correlate these data with gamete viability.

Objective 4 (9NS3): Identify Proper Stocking Density for Paco and Gamitana for Pond Culture

It was possible to conduct research with both species (*Piaractus* and *Colossoma*) proposed originally in the Ninth Work Plan. No significant differences were present in the first study in grow-out performance of paco when stocked in ponds at densities of 3,000 and 4,000 fish ha^{-1} (Kohler et al., 1999). The mean fish growth rate of 3.0 g d^{-1} in this study is comparable to findings for gamitana (Saint-Paul, 1986; Gunther and Boza Abarca, 1992). Both characids grow slightly better under intensive culture conditions than tilapia (Peralta and Teichert-Coddington, 1989) and similar to *Clarias* (Hogendoorn et al., 1983; Verreth and Den Bieman, 1987). Feed conversion was excellent throughout the first study. The exceptionally high values during the early stages of the study reflect the ability of paco to filter-feed at the fingerling stage. These fish can also consume seeds and some plants found in the water. No differences ($P > 0.05$) existed in this experiment with paco at harvest in weight (418 g at 4,000 fish ha^{-1}, 447.5 g at 6,000 fish ha^{-1}, and 474.9 g at 8,000 fish ha^{-1}; Figure 1); total length (24.8 cm at 4,000 fish ha^{-1}, 26.1 cm at 6,000 fish ha^{-1}, and 25.7 cm at 8,000 fish ha^{-1}); specific growth rate (1.8 at 4,000 fish ha^{-1}, 1.8 at 6,000 fish ha^{-1}, and 1.7 at 8,000 fish ha^{-1}); condition (2.7 at 4,000 fish ha^{-1}, 2.7 at 6,000 fish ha^{-1}, and 2.8 at 8,000 fish ha^{-1}); or feed conversion efficiency (72.9% at 4,000 fish ha^{-1}, 76.2% at 6,000 fish ha^{-1}, and 74.7% at 8,000 fish ha^{-1}; Table 5). Survival exceeded 80%. No significant differences were found among any of the stocking densities at 3,000, 4,000, 6,000, and

Table 5. Performance of paco (*Piaractus brachypomus*) at three densities in pond trials conducted in Iquitos, Peru, from 2 March to 15 September 2000.

Date	4,000 fish ha⁻¹ Weight (g)	TL (cm)	FCE (%)	SGR [a]	K [b]	6,000 fish ha⁻¹ Weight (g)	TL (cm)	FCE (%)	SGR [a]	K [b]	8,000 fish ha⁻¹ Weight (g)	TL (cm)	FCE (%)	SGR [a]	K [b]
02 March	19.0	8.5	--	--	--	21.7	8.5	--	--	--	28.3	9.8	--	--	--
17 March	20.9	9.1	--	--	--	24.3	9.3	--	--	--	33.8	10.6	--	--	--
01 April	37.0	10.9	--	--	--	40.4	11.3	--	--	--	47.5	12.1	--	--	--
16 April	52.7	12.8	--	--	--	62.9	13.5	--	--	--	85.0	14.3	--	--	--
02 May	86.7	14.7	--	--	--	114.0	15.7	--	--	--	133.0	16.3	--	--	--
16 May	133.7	17.0	--	--	--	166.0	17.5	--	--	--	170.3	17.8	--	--	--
31 May	150.7	17.8	--	--	--	168.3	17.7	--	--	--	178.0	18.7	--	--	--
15 June	188.0	19.6	--	--	--	204.3	19.8	--	--	--	192.7	19.4	--	--	--
30 June	225.7	20.2	--	--	--	234.3	20.7	--	--	--	261.7	21.0	--	--	--
15 July	268.0	21.4	--	--	--	284.7	22.0	--	--	--	320.3	23.0	--	--	--
31 July	294.0	22.2	--	--	--	308.7	23.7	--	--	--	350.3	24.7	--	--	--
15 August	333.8	22.9	--	--	--	364.0	24.4	--	--	--	403.0	25.4	--	--	--
29 August	394.7	24.7	--	--	--	395.0	24.9	--	--	--	445.3	25.9	--	--	--
15 September	418.2	24.8	72.9	1.8 [c]	2.7 [c]	447.5	26.1	76.2	1.8 [c]	2.7 [c]	474.9	26.5	74.7	1.7 [c]	2.8 [c]

(TL = Total length)
[a] Specific growth rate: SGR = ln (W_f) – ln (W_0)/T × 100; where W_f and W_0 = final and initial weights (g), respectively, and T = time (d).
[b] K = W/L^3; where W = weight (g), L = total length (cm).
[c] Composite

8,000 fish ha^{-1}. Accordingly, a density of at least 4,000 fish ha^{-1} can be recommended when supplemental feeding is provided. Densities of 2,000 to 3,000 fish ha^{-1} are traditionally used in the region.

Feed conversion for paco was excellent throughout this study. Exceptionally high values indicate its ability to feed on secondary natural sources in the ponds. In contrast to gamitana, they are not equipped with long, fine gillrakers; hence, filter-feeding is not as efficiently performed as in gamitana.

No significant differences were found in grow-out performance of gamitana stocked in ponds at densities of 2,500, 3,250, and 4,000 fish ha^{-1}. The mean fish growth rate of 1.90 g d^{-1} was lower than paco in the previous study. This can be attributed to certain ponds emerging with significant macrophyte infestations, which impeded the feeding process for an undetermined period of time.

Water quality varied among ponds in all density experiments (Table 6). Temperatures ranged from 25.0 to 30.0°C. Minimum DO levels were above 1.0 mg l^{-1} and averaged in excess of 3.0 mg l^{-1}. TAN remained below 1.0 mg l^{-1}. These waters can be classified as soft (hardness = 20 mg l^{-1}; alkalinity = 20 mg l^{-1}; conductivity = 96 ohms cm^{-2}) and slightly acidic.

Table 6. Early morning water quality levels of ponds at the IIAP CRI-Loreto research facility in Iquitos, Peru, for *Piaractus brachypomus,* 2 March through 15 September 2000.

	Temperature (°C)	DO (mg l^{-1})	pH	TAN
Mean	28.0	3.4	7.1	< 1
High	30.0	8.5	9.1	< 1
Low	25.0	1.1	3.4	< 1

Water quality remained well within the tolerances of paco and gamitana throughout all the trials. Of course, it must be recognized that these fish can reduce their metabolic rate during periods of stress. Oxygen declines would need to remain low for days rather than hours to adversely affect them.

All the experiments revealed considerable potential for intensive aquaculture of gamitana and paco in the Peruvian Amazon. No significant differences were found between all the stocking densities.

Objective 5 (9NS3): Determine Cost of Production for Rearing in Ponds at Different Densities

In 2000 and 2001, IIAP produced 30,000 fingerlings of paco and 35,000 fingerlings of boquichico (*Prochilodus nigricans*) in a four- to six-month culture period. This production volume will be doubled in the future since the new hatchery construction has just been finished. Gamitana fingerlings were not produced since the broodstock were stressed from unusual physicochemical parameters in the holding pond.

The results of this study identified that both paco and gamitana are more profitable to produce per hectare at all stocking densities studied since they have a higher market value and equal production costs compared to other traditional agriculture crops (Tables 7 and 8). The production of gamitana and paco (assuming 90% survival) at densities higher than 2,500 fish ha^{-1} will be more profitable than pineapple production, which is the highest market value agriculture cash crop being produced in the Loreto region at the present time (Table 9).

Table 7. Enterprise budget for the production of gamitana at different stocking densities in earthen ponds in Iquitos, Peru.

	Costs per Unit	Stocking Rate (fish ha^{-1})				
		2,500	*3,250*	*4,000*	*6,000*	*8,000*
VARIABLE COSTS (US$)						
Fingerlings	0.13 each	325.0	422.5	520.0	780.0	1,040.0
Feed (kg fish)	0.31 kg^{-1}	775.0	1,007.5	1,240.0	1,860.0	2,480.0
Liming (500 kg ha^{-1})	214.3 ha^{-1}	214.3	214.3	214.3	214.3	214.3
Labor/Liming	25.0 ha^{-1}	25.0	25.0	25.0	25.0	25.0
Fertilizer (Chicken Manure)	125.0 ha^{-1}	125.0	125.0	125.0	125.0	125.0
Labor/Fertilizing	25.0 ha^{-1}	25.0	25.0	25.0	25.0	25.0
Maintenance	90.0 ha^{-1}	90.0	90.0	90.0	90.0	90.0
Total Variable ha^{-1}		1,579.3	1,909.3	2,239.3	3,119.3	3,999.3
FIXED COSTS (US$)						
Pond Construction Interest	313.0	313.0	313.0	313.0	313.0	313.0
Taxes	86.0	86.0	86.0	86.0	86.0	86.0
Pond Depreciation	120.0	120.0	120.0	120.0	120.0	120.0
Total Fixed ha^{-1}	519.0	519.0	519.0	519.0	519.0	519.0
TOTAL HA^{-1} (FIXED + VARIABLE)		2,098.3	2,428.3	2,758.3	3,638.3	4,518.3
SURVIVAL	90%	2,250	2,925	3,600	5,400	7,200
COST KG^{-1} HA^{-1} (COSTS/SURVIVAL, US$)		0.9	0.8	0.8	0.7	0.6
PRICE KG^{-1} (US$)		3.0	3.0	3.0	3.0	3.0
PROFIT POTENTIAL KG^{-1} (US$)		2.1	2.2	2.2	2.3	2.4
TOTAL PROFIT HA^{-1} (PROFIT × SURVIVAL, US$)		4,651.7	6,346.7	8,041.7	12,561.7	17,081.7

Table 8. Enterprise budget for the production of paco at different stocking densities in earthen ponds in Iquitos, Peru.

	Costs per Unit	Stocking Rate (fish ha^{-1})				
		2,500	*3,250*	*4,000*	*6,000*	*8,000*
VARIABLE COSTS (US$)						
Fingerlings	0.13 each	325.0	422.5	520.0	780.0	1,040.0
Feed (kg fish)	0.31 kg^{-1}	775.0	1,007.5	1,240.0	1,860.0	2,480.0
Liming (500 kg ha^{-1})	214.3 ha^{-1}	214.3	214.3	214.3	214.3	214.3
Labor/Liming	25.0 ha^{-1}	25.0	25.0	25.0	25.0	25.0
Fertilizer (Chicken Manure)	125.0 ha^{-1}	125.0	125.0	125.0	125.0	125.0
Labor/Fertilizing	25.0 ha^{-1}	25.0	25.0	25.0	25.0	25.0
Maintenance	90.0 ha^{-1}	90.0	90.0	90.0	90.0	90.0
Total Variable ha^{-1}		1,579.3	1,909.3	2,239.3	3,119.3	3,999.3
FIXED COSTS (US$)						
Pond Construction Interest	313.0	313.0	313.0	313.0	313.0	313.0
Taxes	86.0	86.0	86.0	86.0	86.0	86.0
Pond Depreciation	120.0	120.0	120.0	120.0	120.0	120.0
Total Fixed ha^{-1}	519.0	519.0	519.0	519.0	519.0	519.0
TOTAL HA^{-1} (FIXED + VARIABLE)		2,098.3	2,428.3	2,758.3	3,638.3	4,518.3
SURVIVAL	90%	2,250	2,925	3,600	5,400	7,200
COST KG^{-1} HA^{-1} (COSTS/SURVIVAL, US$)		0.9	0.8	0.8	0.7	0.6
PRICE KG^{-1} (US$)		2.1	2.1	2.1	2.1	2.1
PROFIT POTENTIAL KG^{-1} (US$)		1.2	1.3	1.3	1.4	1.5
TOTAL PROFIT HA^{-1} (PROFIT × SURVIVAL, US$)		2,626.7	3,714.2	4,801.7	7,701.7	10,601.7

Assumptions: 90% survival
Fixed costs are per year; assume a two-month "rest" before production begins again.
US$313 interest is for year 1 only; it drops to US$260, US$199, US$129, and US$48 for years 2 through 5, respectively.
US$3 kg^{-1} wholesale market price for gamitana and US$2.10 kg^{-1} for paco.

Fish that were fed for an additional five months (ten months total) reached about a kilogram in size (from 27.5 g). The prepared diet used in the study cost US$1.02 to produce 1.0 kg of whole fish, and fingerlings generally sell for about US$0.13 each. Food-size paco sell in the Iquitos market for US$2.10 kg^{-1} and gamitana for over US$3.00 kg^{-1}. Some success has been achieved in encouraging local consumers to purchase small farm-raised fish (250 g) over the large (> 5 kg) wild-caught ones, particularly during the dry-season months when these two species are scarce. Consumers are slowly changing their ways to a point where some are beginning to identify smaller fish as synonymous with better taste. Additionally, the family food preparer is discovering the advantage of serving a whole fish per plate to their family as opposed to serving only a portion of a large one. It is important to mention that the majority of the producers located along the Iquitos–Nauta road have identified the high economic value of their aquaculture crop to the point that they might utilize part of their traditional agriculture crops as supplemental or exclusive diets for gamitana or paco.

Objective 1 (9NS6): Conduct Outreach Activities to Regionalize CRSP Outcomes

<u>The Chemistry Lab Will Be Upgraded, Equipped, and Supplied with Reagents to Become Functional for the Performance of All CRSP Water Quality Analyses</u>

A new hatchery was recently finished. This hatchery will facilitate the production of fingerlings not only of paco and gamitana but also of *Pseudoplatystoma* and *Arapaima* for the experiments and studies of the Tenth Work Plan. Most of the equipment and reagents present at IIAP Quistococha Aquaculture Station were updated, including the following additions: microscope, stereoscope, spectrophotometer, oxygen and pH meters, minimum/maximum thermometers, weather equipment, and reagents to determine various water quality parameters.

<u>A South American Network of Aquaculturists Will Be Initiated</u>

An Amazon Aquaculture website was created at <ws1.coopfish.siu.edu/amazonia/index.html> to initiate a network specializing in Amazonian species for the purpose of bringing together Amazon aquaculture researchers from around the world for information exchange in their efforts to improve the culture and marketing of existing species and of expanding the species list even further. Several contacts have been established in Honduras as well as in our host country, Peru. All of these contacts were made in person.

<u>Reinforce Extension Activities for Local Farmers</u>

The extension activities conducted in the Eighth and Ninth Work Plans are still being conducted jointly with the Italian NGO Terra Nuova and Programa de la Seguridad Alimentaria (PROSEAL), serving the 260 local farmers along the road system between the cities of Iquitos and Nauta. Farmers will be provided guidance by Terra Nuova until the end of December 2001. PROSEAL will continue together with the CRSP through the Tenth Work Plan to administer this service to the local farmers. They now provide services to 71% of fish farmers, who account for almost 62% of total fish ponds in the region (Table 10). PROSEAL has been a direct beneficiary of the CRSP program in Peru. Results from research conducted at our host country facilities provided much of the information that PROSEAL extended to farmers. Thanks to leadership provided by our host country principal investigator (PI), Fernando Alcántara, as well as other IIAP and UNAP members, valuable information developed from our project has been transferred to the local area fish farmers. Efforts began in the Ninth Work Plan to create an extension working committee, which will allow us to formally integrate our extension activities for the Tenth Work Plan into the existing host country program. The committee will ensure proper cooperation among all participating entities and help avoid redundancy in the proposed work region. Alcántara, with PD/A CRSP support, will continue to serve as the lead aquaculture extensionist. The PROSEAL project is scheduled to terminate in December 2001. Accordingly, the continuity of this important effort will be reliant on PD/A CRSP support thereafter.

<u>Technicians Will Be Provided with Training for Laboratory and Pond Practices Following CRSP Protocols</u>

All IIAP aquaculture technicians have been trained for laboratory and pond practices through the workshops that have been offered to the fish producers by PROSEAL and sponsored by the PD/A CRSP and Terra Nuova.

<u>A Workshop Will Be Planned</u>

Alcántara (IIAP, host country PI) and Palmira Padilla (co-investigator) presented several weekend workshops for the regional farmers involved in local extension projects and for high school students. Padilla continues to offer general aquaculture courses to high school students in Iquitos. The purpose is to introduce the local population to this discipline and arouse interest in this form of food production. In addition to these workshops, several international presentations were given in numerous symposia and conferences.

Objective 2 (9NS6): Complete Spanish-Language Production Manual for Small-Scale Pond Aquaculture in the Peruvian Amazon

The production manual "Reproducción Inducida de Gamitana y Paco" was printed and distributed. It is currently being used as an extension manual by IIAP collaborators. The manual fully acknowledges the PD/A CRSP, as well as IIAP and SIUC. The manual includes the following sections: broodstock preparation, broodstock selection, hormonal treatment, ovulation and spawning, fecundity, incubation, larvae culture, and grow-out. Alcántara is planning to prepare a new edition to cover the new aspects that have been generated this year and that will be in subsequent years.

Table 9. Estimated production of other local agriculture crops in one hectare of land in the Loreto region, Peru.

Crop	Production Volume	Production Cost (US$)	Market Value (US$)	Total Value (US$)	Profit (US$)
Yucca	8,000 kg	160.0	2.00 $(50\ kg)^{-1}$	320.0	160.0
Palmito	8,000 stalks	280.0	0.07 $stalk^{-1}$	560.0	280.0
Aguaje	6,000 kg	342.6	5.71 $(50\ kg)^{-1}$	685.2	342.6
Plantain	400 bunches	228.0	1.14 $bunch^{-1}$	456.0	228.0
Pineapple	16,000 tons	1,232.0	0.14 kg^{-1}	2,240.0	1,008.0

Objective 3 (9NS6): Expand List of Locally Available Ingredients for Practical Diets Suitable for *Colossoma* and *Piaractus* Broodstock to Include Grow-out Diets

We have expanded the list of practical ingredients developed by Lochmann for broodstock diets to include grow-out diets. Alternative local grow-out sources have been identified. Numerous wild fruits and plant products for small-scale sustainable aquaculture production of gamitana and paco are currently being used by the local farmers as fish feed in and around Iquitos (Table 11).

The fruits and plants surveyed have the following seasonal availability: pijuayo (*Bactris gasipaes*), winter; guayaba (*Psidium guajaba*), winter; lady finger banana (*Musa paradisiaca*), all year round; papaya (*Carica papaya*), all year round; airambo (*Phytolaca rivinoides*), winter; mullaca (*Physalis angulata*) and camu camu (*Myrciaria dubia*), December to April (during flooding season); cetico (*Cecropia* sp.), winter; míspero (*Achras sapota*), winter; renaco (*Ficus* sp.), winter; yucca (*Manihot esculenta*), all year round, although during the dry season (from June through September) it is more abundant; mishquipanga (*Renealmia alpina*), winter; picho huayo (*Siparuna guianensis*), winter; cocona (*Solanum sessiliflorum*), all year round; cashew (*Anacardium occidentalis*), winter; caimito (*Chrysophyllum cainito*), all year round; anona (*Annona muricata*), winter.

ANTICIPATED BENEFITS

We were able to identify suitable stocking densities for paco and gamitana for profitable pond culture in the Peruvian Amazon. Most farmers generally use organic fertilizers and periodically provide fruits, nuts, and kitchen scraps. The experiment utilized an economic prepared diet (26.7% protein and 9% lipids) for grow-out. Considering the excellent growth rates that occurred (3.4 g to 1 kg in ten months), it appears that

Table 10. Local organizations and their extension responsibilities along the Iquitos–Nauta road as of January 2001 (Alcántara, pers. comm.).

Organization	Surface Area (ha)	Percentage of Total	Fish Farmers	Percentage of Total	Ponds	Percentage of Total
PROSEAL	44.00	35.40	260	70.65	308	61.97
CURMI (NGO)	8.99	7.23	41	11.14	42	8.45
CARITAS (NGO)	10.95	8.81	10	2.72	10	2.01
FONDEPES (GO)	1.80	1.44	6	1.63	6	1.20
Independent Farmers	52.32	42.09	49	13.32	84	16.90
Government Farms	6.25	5.03	2	0.54	47	9.45
Total	124.31	100.00	368	100.00	497	100.00

Table 11. Proximate analysis values (when known) of some fruits and other local plant products utilized to feed fish around Iquitos (food value per 100 g, modified from Morton, 1987).

Common Name	Scientific Name	Calories	Proteins (g)	Carbohydrates (g)	Lipids (g)	Fiber (g)	Ash (g)
Pijuayo	*Bactris gasipaes*	196	2.6	41.7	4.4	1.0	ND
Guayaba	*Psidium guajaba*	36–50	0.9–1.0	9.5–10.0	0.1–0.5	2.8–5.5	0.4–0.7
Lady Finger Banana	*Musa paradisiaca*	110.7–156.3	0.8–1.6	25.5–36.8	0.1–0.8	0.3–0.4	0.6–1.4
Papaya	*Carica papaya*	23.1–25.8	0.1–0.3	6.2–6.8	0.1–1.0	0.5–1.3	0.3–0.7
Airambo	*Phytolaca rivinoides*	ND	ND	ND	ND	ND	ND
Mullaca	*Physalis angulata*	ND	0.05	ND	0.16	4.9	1.0
Cetico	*Cecropia* sp.	ND	ND	ND	ND	ND	ND
Míspero	*Achras sapota*	ND	ND	ND	ND	ND	ND
Renaco	*Ficus* sp.	80	1.2–1.3	17.1–20.3	0.1–0.3	1.2–2.2	0.48–0.85
Yucca	*Manihot esculenta*	135	1.0	32.4	0.2	1.0	0.9
Mishquipanga	*Renealmia alpina*	ND	ND	ND	ND	ND	ND
Picho Huayo	*Siparuna guianensis*	ND	ND	ND	ND	ND	ND
Cocona	*Solanum sessiliflorum*	ND	0.6	5.7	ND	0.4	ND
Cashew	*Anacardium occidentalis*	ND	0.1–0.2	9.1–9.8	0.1–0.5	0.4–1.0	0.2–0.3
Caimito	*Chrysophyllum cainito*	67.2	72.0–2.33	14.7	ND	0.6–3.3	0.4–0.7
Anona	*Annona muricata*	53.1–61.3	1.0	14.6	1.0	0.8	0.60
OTHERS							
Rice Meal Powder	*Oryza sativa*	ND	6.2	36.0	5.2	28.9	15.7
Wheat Bran	*Triticum aestrivum*	ND	15.2	53.8	3.9	10.0	6.1

ND = No data available

this diet meets or exceeds nutritional needs of gamitana and paco. Results of the present study are being shared with local farmers via extension work, and future results will be shared similarly. We have also gained perspective as to when these fish reach their reproductive peak during their annual cycle in order to better program spawning efforts. We also determined some parameters that can be controlled to obtain improved gamete quality from the broodstock. Most importantly, the information gleaned from the Ninth Work Plan is being made available to local farmers through an extension program now fully in place.

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