Nutrition of *Colossoma macropomum* and *Piaractus brachypomus*

Tenth Work Plan, Feeds and Fertilizers Research 1 (10FFR1)
Final Report

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Abstract

Research studies provided considerable information related to the nutrition, feeding, and general culture of targeted Amazonian fish species. Three diets were formulated with crude protein (CP) levels at 22, 27, and 32% using the same ingredients as diets in the Ninth Work Plan to feed *Piaractus brachypomus*. Nine ponds (3 treatments with 3 replicates) were stocked at a rate of 8,000 25-g fingerlings ha^{-1}. Pond liming, fertilizing, conditioning, feed ration adjustment, and water quality monitoring were accomplished as in previous work plans. *Piaractus brachypomus* grew similarly with all three diets over a six-month trial, though condition factor was highest among fish fed the 32% CP diet. Based on these results, the standard 28% CP diet currently being employed by the Instituto de Investigaciones de la Amazonia Peruana appears to be a suitable diet for grow-out, but diets lower in CP levels (perhaps 25%) should be considered to further reduce costs. We designed two diets that our Peruvian PhD student will test in the Eleventh Work Plan for acceptability and digestibility. From June to March 2003, a study was conducted as part of the same Peruvian student's dissertation to assess the role of *P. brachypomus* and *Colossoma macropomum* in seed dispersal throughout the flooded forest. Three *C. macropomum* and three *P. brachypomus* for each of three weight-groups (1, 3, and ≥ 5kg) were placed in randomly assigned cages (6 m^3) floating in ponds. Fish were starved for two days to ensure they had released their gastric contents before being fed fruits and seeds (one of each at a time) until satiation. After verifying fish seed consumption, fish were placed into individual tile-lined raceways to collect seeds—both whole and broken—in the feces. Digested and undigested seeds from the same tree (control) were sowed into sterilized humus to determine their viability and germination rate. Seeds of some of the different fruits ingested by the fish germinated at rates as good or better than did controls.

Introduction

In South America, eight countries have USAID-presence status (Bolivia, Brazil, Colombia, Ecuador, Guyana, Paraguay, Peru, and Venezuela). Excluding Paraguay, these countries are linked by major river systems, particularly the drainages comprising the Amazon and Orinoco Rivers, which contain the largest diversity of freshwater fishes in the world. Accordingly, South America offers a special opportunity to develop appropriate technologies to cultivate alternative aquaculture species native to this continent.

In the Peruvian Amazon, three important institutions are working on 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 millions of fry and have refined numerous aquaculture techniques. *Colossoma* and *Piaractus* are considered by local aquaculturists as the best fishes for commercialization in the tropical part of Peru. However, considerable potential exist to examine other species, as the Amazon Basin is home to over 2,000 freshwater species of fish.

Table 1. Nutritional composition of some fruits and other local plant products utilized to feed fish in the Peruvian Amazon (food value per 100 g, modified from Morton, 1987).

Common Name	Scientific Name	Calories (kcal kg^{-1})	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	*Phytolacca 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
Guanabana	*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 aestivum*	ND	15.2	53.8	3.9	10.0	6.1

ND = No data available

A Memorandum of Understanding is currently in place linking IIAP, UNAP, and Southern Illinois University at Carbondale (SIUC) (and collaborating US universities with SIUC under this umbrella) into the CRSP network. IIAP and UNAP facilities include 49 earthen culture ponds ranging in size from 60 m^2 to nearly a hectare. Laboratory facilities 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 upgraded or renovated at IIAP during the Ninth and Tenth Work Plans. Outcomes of the Tenth Work Plan have greatly facilitated the establishment of Peru as a full-fledged host country site for PD/A CRSP activities and research.

For the Tenth Work Plan, four projects were funded: 1) Amazon Aquaculture Outreach, 2) Nutrition of *Colossoma macropomum* and *Piaractus brachypomus*, 3) Broodstock Diets and Spawning of *Colossoma macropomum* and/or *Piaractus brachypomus*, and 4) Studies on Reproduction and Larval Rearing of Amazonian Fish. These projects are extensions of research and outreach activities developed during the Ninth Work Plan. Outreach and networking activities were undertaken to facilitate regionalizing the benefits of the CRSP. Previous hatchery problems at IIAP have largely been rectified and efforts concentrated on larval rearing, broodstock nutrition, and development of grow-out diets (both prepared feeds and plant products for grow-out) for *C. macropomum* and/or *P. brachypomus*. Additionally, efforts were expanded to include two South American catfishes, *Pseudoplatystoma fasciatum* and *P. tigrinum*, both of which are attracting attention in South America as potential species for aquaculture in the Amazon Basin. The Peru Project is also supporting activities in the Tenth Work Plans of collaborating institutions and projects, such as those investigating soil-water interactions and socioeconomics.

METHODS AND MATERIALS

Objective 1. Compare Aquaculture Performance of *Colossoma* and/or *Piaractus* Fed Formulated Diets at Varying Protein Levels

Diets were formulated with protein levels at 22, 27, and 32% using the same ingredients as diets in the Ninth Work Plan (fishmeal, soybean, wheat, rice, cornmeal, vitamin C, vitamin/mineral premix, and fish oil). Nine ponds at the IIAP aquaculture stations (3 treatments with 3 replicates) approximately 0.125 ha in size were stocked at a rate of 8,000 25-g fingerlings per hectare. Prior to stocking, ponds were filled with runoff water and limed (0.1 kg/m^{-2}). Ponds were fertilized at stocking with chicken manure (0.1 kg m^{-2}) and green grass (0.15 kg/m^{-2}). Fish were fed twice daily at 1000h and 1400h. Growth was monitored over a six-month period. Water quality parameters [pH, dissolved oxygen (DO), nitrite, nitrate, ammonia, CO_2, and chlorides] were monitored weekly, and temperature and transparency (Secchi disk, cloud-free days at noon) were measured daily.

Fish were sampled biweekly and weighed to adjust food rations. At harvest, survival (%), specific growth rate (SGR), standing crop at harvest, condition factor (K), and feed conversion efficiency (FCE) were calculated. Data values were analyzed by one-way analysis of variance (ANOVA). Appropriate transformations were made where necessary. The appropriate post hoc tests were employed when significant differences among treatment means were found. The accepted level of significance was 0.05.

Objective 2. Assess the Feasibility of Utilizing Native Amazonian Plant Products for Small-Scale Sustainable

Aquaculture Production of *Colossoma* and *Piaractus*

Numerous wild fruits and plant products are reportedly utilized as fish feed in the Iquitos region (Table 1). To assess the feasibility of utilizing these plant products for small-scale sustainable aquaculture production of *Colossoma* and *Piaractus*, samples of various fruits and plant products were collected. Protein, amino acid, lipid, and fatty acid content of leaves, trunk, roots, flowers, and fruits, as appropriate, were analyzed using standard techniques (Kjeldahl, Folch, spectrophotometry, and chromatography). In addition, data on the seasonal availability of the plants/plant products was collected. Several seasonally based feeding protocols were developed based on the nutritional content and seasonal availability of the ingredients.

Objective 3. Assess and Compare the Plant Seed Dispersal Potential of *Colossoma* and *Piaractus*

Three individuals of *C. macropomum* for each weight-group (1, 3, and ≥ 5 kg) were placed in randomly assigned cages (6 m^3) in ponds. Fish were starved for two days to release their gastric contents. Fish were then fed fruits and seeds (one of each of the eight species at a time) until satiation. After verifying fish seed consumption, fish were placed into individual tile-bottom tanks, and feces were collected. Seeds were collected from feces by separating whole from broken seeds. Viability and germination rates were determined for whole digested seeds and undigested seeds from the same tree (control) previously sowed into sterilized humus (120°C for 24 h) and held under similar conditions (light intensity, photoperiod, temperature, and moisture).

RESULTS

Objective 1. Compare Aquaculture Performance of *Colossoma* and/or *Piaractus* Fed Formulated Diets at Varying Protein Levels

Excluding K, all data (Table 2) followed a normal distribution; thus, we used one-way ANOVA to analyze the effects of pro-

Table 2. Performance in earthen ponds by Piaractus brachypomus stocked at 8,000 25-g fish ha^{-1} fed three levels of protein over a 6-month trial. Note: Values in columns with the same letter are not significantly different.

Protein (%)	Length (cm)	Weight (g)	Biomass (kg)	FCE	SGR	K × 100
22	26.1 [a]	374.33 [a]	293.7 [a]	70 [a]	1.8 [a]	2.2 [a]
27	25.7 [a]	358.25 [a]	299.6 [a]	70 [a]	1.8 [a]	2.3 [a]
32	25.8 [a]	363.33 [a]	369.1 [a]	67 [a]	1.8 [a]	4.6 [b]

Table 3. Updated nutritional analysis data of agriculture products fed directly to the frugivorous fish in the Peruvian Amazon.

Common Name	Scientific Name	Calories ($kcal\ kg^{-1}$)	Proteins (g)	Carbohydrates (g)	Lipids (g)	Fiber (g)	Ash (g)	Seasonality
Guanabana [c]	*Annona muricata*	53.1–61.3	1.0	14.6	1.0	0.8	0.6	ND
Pijuayo [c]	*Bactris gasipaes*	196.0	2.6	41.7	4.4	1.0	0.7–0.9 [a]	Feb–May/Sept–Nov
Guava [c]	*Psidium guajaba*	36–50	0.9–1.0	9.5–10.0	0.1–0.5	2.8–5.5	0.4–0.7	Feb–Mar/Sept–Oct
Plantain [c]	*Musa paradisiaca*	11.1–156.3	0.8–1.6	25.5–36.8	0.1–0.8	0.3–0.4	0.3–0.7	Year-Round
Papaya [c]	*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	Feb–June/Aug–Nov
Yucca [c]	*Manihot esculenta*	135.0	1.0	32.4	0.2	1.0	0.9	Year-Round
Caimito [c]	*Chrysophyllum cainito*	67.2	72.0–2.33	14.7	1.1 [a]	0.6–3.3	0.4–0.7	Jan–Apr/Sept–Nov
Cocona [c]	*Solanum sessiliflorum*	ND	0.6	5.7	0.7 [a]	0.4	0.7 [a]	Year-Round
Cashew [c]	*Anacardium occidentalis*	ND	0.1–0.2	9.1–9.8	0.1–0.5	0.4–1.0	0.2–0.3	Sept–Dec
Anona [a]	*Rollinia mucosa*	53.0	1.1	12.9	0.4	0.6	0.6	Aug–Nov
Huito [a]	*Genipa americana*	ND	1.2–1.3	14.0–25.7	0.1–0.2	1.6–11.8	0.6–0.8	May–July
Camu-Camu [a]	*Myrciaria dubia*	17.0	0.5	4.7	ND	0.6	0.2	Nov–Mar
Aguaje [a]	*Mauritia flexuosa*	283.0	3.0	18.1	21.1	10.4	0.9	Year-Round
Cacao [a]	*Theobroma cacao*	71.0	2.8	16.5	0.3	1.1	1.2	Sept–Dec
Uvilla [a]	*Pourouma cecropiifolia*	64.0	0.3	16.7	0.6	0.9	0.3	Mar–Apr/Sept–Nov
Macambo [a]	*Theobroma bicolor*	44.0	2.1	8.3	0.8	0.7	0.8	Year-Round
Ubos [a]	*Spondias mombin*	70.0	0.8	2.1	2.1	13.8	1.8	Year-Round
Tumbo [a]	*Passiflora quadrangularis*	98.0	4.0	22.0	0.7	12.0	0.8	Year-Round
Guaba [a]	*Inga edulis*	53.0	1.0	13.6	0.1	0.8	0.4	Apr–May/Sept–Nov
Punga [b]	*Pseudobombax munguba*	5.27	21.3	ND	31.9	15.9	5.2	June–July
Shiringa [b]	*Hevea brasiliensis*	6.25	19.2	ND	44.2	9.3	2.9	June–Aug
Huiririna [d]	*Astrocaryum jauari*	597.2	6.0	42.5	25.6	17.4	1.6	Feb–May/Sept–Nov
Wild Rice [b]	*Oryza* sp.	4.31	8.1	ND	2.0	0.0	1.7	ND

aData from Flores-Paitan, 1996.
b Data from Roubach and Saint-Paul, 1994.
c Data from Araujo-Lima and Goulding, 1997.
d Data from Moreira Da Silva et al., 1999.

Table 4. Nutritional composition of the two experimental diets formulated using two abundant plants from the Peruvian Amazon.

Ingredient	Positive Control	Negative Control	Pijuayo	Yucca
Fish Meal	0.1	0.1	0.1	0.1
Soybean Meal	0.2	0.2	0.2	0.2
Rice Meal	0.2	0.2	0.2	0.2
Pijuayo	0	0	0.28	0
Yucca	0	0	0	0.28
Wheat Middlings	0.28	0	0	0
Corn	0.2	0.2	0.2	0.2
NaCl (%)	0.01	0.01	0.01	0.01
Vitamins and Minerals (%)	0.015	0.015	0.015	0.015
Protein (g) (as Fed)	0.23706	0.1945	0.20178	0.1973
Lipid	0.05962	0.0487	0.06102	0.048756
Fiber	0.0693	0.0413	0.0441	0.0441
Ash	0.08538	0.0683	0.07054	0.07082
Energy (kcal kg^{-1})	22.6432	17.788	18.3368	18.166
Crude Protein as Dry Matter (%)	CE	CE	CE	CE
Total	**1.005**	**0.725**	**1.005**	**1.005**

CE: crude estimates

Table 5. Seed germination rates (%) from fruits fed to paco (Piaractus brachypomus) and gamitana (Colossoma macropomum) at three different weight groups (∝ = 0.05).

Fruits Offered	Presentation	Seed Size (mm)	Paco				Gamitana			
			1 kg	*3 kg*	*> 5 kg*	P *Value*	*1 kg*	*3 kg*	*> 5 kg*	P *Value*
Guava	Whole	2.5	34.8	32.6	SB	0.6980	49.4	54.2	50.7	0.6503
Sardina-Caspi	Whole	7.0	SB	32.0	50.0	0.0822	-	-	-	-
Punga	Seed	8.0	-	-	-	-	81.7	75.3	82.7	0.2672
Camu-Camu	Whole	10.0	SB	75.0	75.0	0.9543	90.3	77.3	94.3	0.4369
Coto-Huayo	Whole	14.0	36.3	56.2	SB	0.2762	-	-	-	-
Shiringa	Whole	15.0	SB	SB	SB	-	SB	SB	SB	-
Nejilla	Whole	15.0	-	-	-	-	SB	SB	SB	-
Pijuayo	Seed	20.0	-	-	-	-	SB	SB	SB	-

SB: All seeds broken and no whole seeds found to sow.

tein levels (22, 27, and 32%) on length, weight, biomass, SGR, and FCE and the non-parametric Wilcoxon/Kruskal-Wallis test for the condition-factor (Table 2). No differences among fish groups fed the three protein levels were found in length ($P = 0.9875$), weight ($P = 0.9641$), biomass ($P = 0.2921$), SGR ($P = 0.9963$), and FCE ($P = 0.9406$); however, K was significantly ($P = 0.0452$) different.

Objective 2. Assess the Feasibility of Utilizing Native Amazonian Plant Products for Small-Scale Sustainable Aquaculture Production of *Colossoma* and *Piaractus*

Nutritional data for various native Amazonian plant products being fed to *Piaractus* and *Colossoma* by producers along the Iquitos-Nauta Road were determined as well as their seasonal availability (Table 3). Two diets (Table 4) were designed based on the availability of the local fruits during the rainy and dry seasons.

Objective 3. Assess and Compare the Plant Seed Dispersal Potential of *Colossoma* and *Piaractus*

From June 2002 to March 2003, a study was conducted at IIAP facilities as part of a dissertation by a Peruvian national (Fred K. Chu) to assess the viability of seeds passed through the digestive system of *Colossoma* and *Piaractus* (Table 5). Guava (small-size seeds), and camu-camu and punga seeds (medium-size seeds) germinated after passing through the *Colossoma* digestive system while ñejilla and shiringa seeds (large-size seeds) were broken during ingestion and did not germinate. Also, size of *Colossoma* did not significantly influence seed germination rate (guava $P = 0.6503$, camu-camu $P = 0.4369$, and punga $P = 0.2672$). In the case of *Piaractus*, guava (small-size seeds), camu-camu and sardina-caspi (medium-size seeds), and coto-huayo (large-size seeds) germinated while shiringa (large-size seeds) were broken during ingestion by all fish size groups and did not germinate. Pijuayo seeds were not ingested. Similarly to *Colossoma*, *Piaractus* weight did not have a significant effect on seed germination rate (guava $P = 0.6980$, sardina-caspi $P = 0.822$, camu-camu $P = 0.9543$, and coto-huayo $P = 0.2762$).

Discussion

Considering no significant differences were found in all performance parameters excluding K, the protein level (28%) that is currently being used at IIAP appears to be an appropriate level; however, it may be possible to lower the protein level to 25%, which would provide further cost savings.

There is a good potential to use some of the locally available fruits as substitutes for some of the high-cost ingredients. We designed two diets that will be tested for acceptability and digestibility in Eleventh Work Plan by our Peruvian student as part of his dissertation.

Our results are consistent with the widely held notion that both *Piaractus* and *Colossoma* are active seed dispersing agents and likely play an important role in disseminating seeds of many tree species throughout the flooded forest. Small, hard, and spherical plants seeds (e.g., guava, camu-camu, and punga) are more likely to pass through the fish's digestive tract intact than the larger seeds such as coto-huayo. Additional work on this topic will be conducted by our Peruvian PhD student as part of his dissertation in Work Plan Eleven.

Conclusions

2. Nutrition of *Colossoma macropomum* and/or *Piaractus brachypomus* (10FFR1).

Piaractus brachypomus grew similarly in all three diets (22, 27, and 32% crude protein), though K was highest among fish fed the highest protein level. Based on these results, the standard 28% crude protein diet currently being employed by IIAP appears to be a suitable diet for grow-out, but diets lower in crude protein levels (perhaps 25%) should be considered to further reduce costs. Some of the abundantly available agriculture products are good candidates to be used as substitutes for some of the high-cost ingredients for the manufacturing of native fish feeds and will be investigated in the Eleventh Work Plan. Our studies indicate that the frugivorous fish (*P. brachypomus* and *C. macropomum*) are active seed dispersing agents and likely play an important role in disseminating seeds of many tree species through the flooded forest.

Anticipated Benefits

Aquaculture is an alternative form of agriculture offering significant benefits to rural residents and farmers throughout the Peruvian Amazon. Aquaculture requires considerably less land than that needed for cattle ranching, and ponds can be used year after year whereas rainforest lands converted to traditional agricultural practices are rarely productive for more than a couple of seasons. Such lands, once abandoned, usually can no longer support normal jungle growth. Aquaculture will benefit both rural and urban poor through the addition of a steady supply of high quality protein in the marketplace.

The Tenth Work Plan investigated key aspects of nutritional requirements, reproduction biology, and ecological significance of several Amazonian freshwater fish species, in particular *C. macropomum* and *P. brachypomus*, in order to improve or develop sustainable aquaculture technology. *Colossoma* and *Piaractus* have been suggested to play a crucial ecological role in disseminating seeds from the flooded forest (Goulding, 1980; Araujo-Lima and Goulding, 1997). Accordingly, the aquaculture of *Colossoma* and *Piaractus* may be ecologically as well as economically and nutritionally beneficial to the inhabitants of the Peruvian Amazon. Enhanced spawning performance as a result of improved nutrition of the broodstock of two important food fishes in the Peruvian Amazon, *Colossoma macropomum* and *Piaractus brachypomus*, is an anticipated outcome of the research. Development of the technology of intensive growth of these species and stocking four-to-six week-old juveniles will dramatically increase their survival and efficiency of production. The first beneficiaries of this research will be the local producers of *Colossoma* and *Piaractus* species in the Peruvian Amazon. Aquaculture of these species should relieve some of the fishing pressure on these over-harvested native species.

This study contributed toward capacity strengthening by providing training for IIAP staff on various aspects of fish nutrition and reproduction. Results of the training include:

The steps in:

1) Two diets formulated for successful grow-out of *Colossoma* and *Piaractus*, and
2) Twenty-three Amazonian plant products determined to be of nutritive value that are actually used by fish farmers in Peru for Colossoma and Piaractus.

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