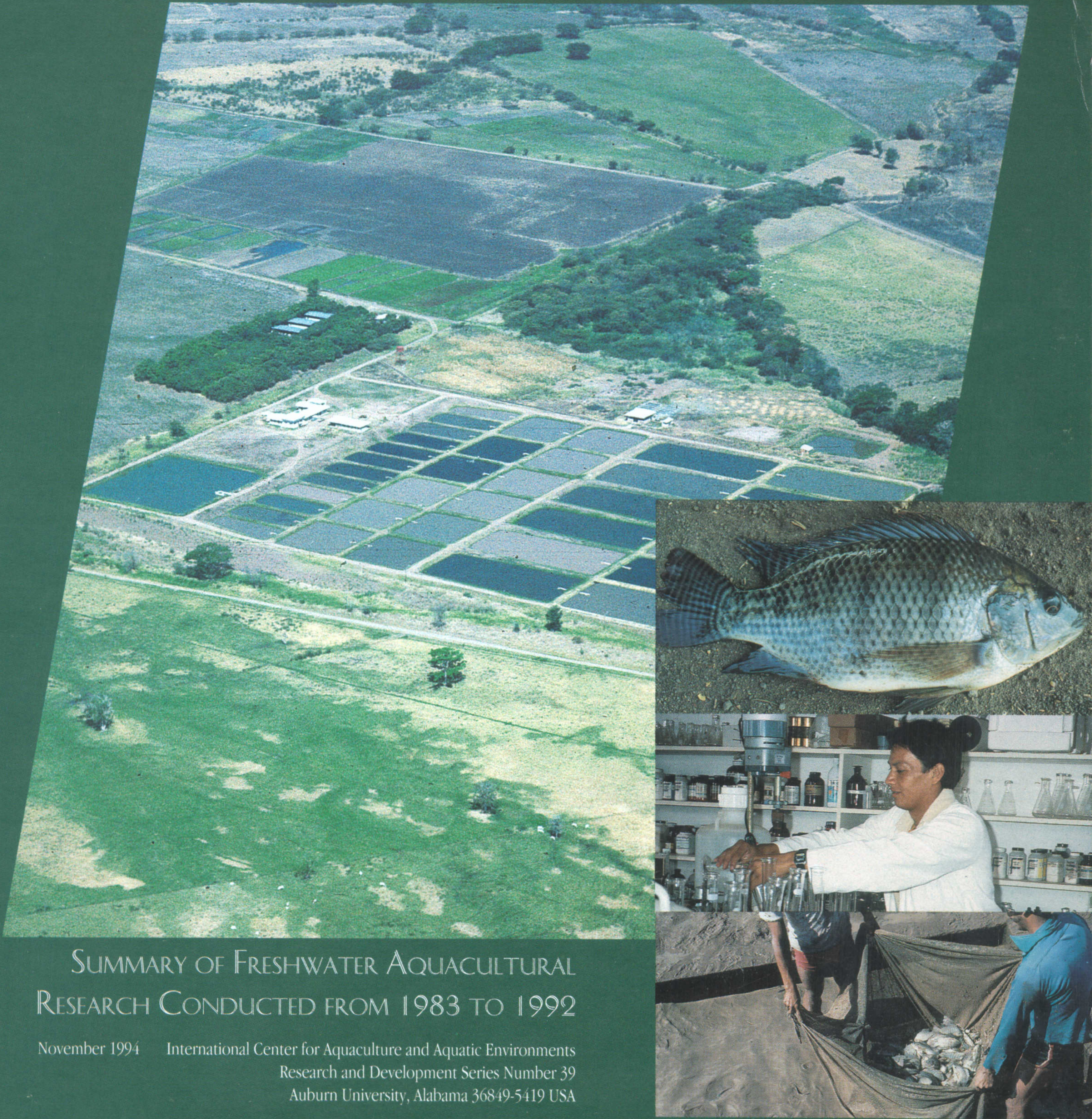
DEVELOPMENT OF SEMI-INTENSIVE AQUACULTURE TECHNOLOGIES IN HONDURAS



SUMMARY OF FRESHWATER AQUACULTURAL RESEARCH CONDUCTED FROM 1983 TO 1992

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CONTENTS

EXECUTIVE SUMMARY

Aquacultural research has been conducted collaboratively in Honduras since 1983 by the International Center for Aquaculture and Aquatic Environments, Auburn University and the Dirección General de Pesca y Acuicultura, Secretaría de Recursos Naturales. This research was carried out at the El Carao National Fish Culture Research Center, Comayagua, Honduras, under the auspices of the USAID-financed Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP). The goal of PD/A CRSP is to increase tilapia yields by optimizing resource use in systems based predominantly on natural pond productivity.

Ponds were stocked with male Nile tilapia (*Oreochromis niloticus*). Pond nutrient inputs were organic and chemical fertilizers, and supplemental feed either alone or in some combination. Fish stocking rate was 10,000/ha during the initial five years of work. During this same period, experiments were repeated during the rainy and dry seasons on the assumption that seasonal differences would significantly affect pond productivity. However, temperature proved to be the factor that affected fish growth most, and the cooler period of the year overlapped the rainy and dry seasons. Thereafter, a warm and cool experimental season was used rather than a rainy and dry season. Differences in fish yield between warm and cool seasons can exceed 25 percent.

Stocking more than 10,000 fish/ha in organically-fertilized ponds resulted in smaller fish and no greater fish yields. Increasing stocking rate to 20,000/ha resulted in greater yield when organic fertilizer (chicken litter) was supplemented with nitrogen as urea. In research on the combination of organic fertilization and supplemental feeds, feed use was more efficient when combined in low amounts (1.5 percent biomass/d) with fertilizer, or when used beginning the third or fourth month of grow-out. Higher economic gains with feed over sole use of chicken litter were never realized at stocking rates less than 20,000 fish/ha. Economic returns from organic fertilizer plus feed were no greater than returns from organic fertilizer plus nitrogen as urea. Tilapia yields of 3,500 kg/ha in 150 days were obtained in fertilized ponds without feeds. Yields increased to 5,300 kg/ha in 150 days when supplemental feeds were used, but high feed cost reduced net returns to less than those for fertilizers alone.

Assuming a market value independent of fish size, manure plus urea was the most profitable management system. Sixteen pond management strategies resulted in positive economic returns. All treatments with positive economic returns used stocking rates of at least 20,000 tilapia/ha. Production of large tilapia (> 400 g) necessitates the use of formulated feeds, but a higher market value for large tilapia is required in order for profitabilty of this management system to exceed that of systems based on organic fertilization plus urea. Large tilapia generally are produced for export markets, and require more intensive production practices. Tilapia harvested from semi-intensively managed ponds can supply domestic markets in Central America. Combined use of organic and chemical fertilizers as nutrient inputs for tilapia ponds requires less capital expenditure than commercial feeds, and therefore are appropriate for small- to medium-scale commercial producers who supply domestic markets.

DEVELOPMENT OF SEMI-INTENSIVE AQUACULTURE TECHNOLOGIES IN HONDURAS

SUMMARY OF FRESHWATER AQUACULTURAL RESEARCH CONDUCTED FROM 1983 TO 1992

BARTHOLOMEW W. GREEN, DAVID R. TEICHERT-CODDINGTON[1], AND TERRILL R. HANSON[2]

INTRODUCTION

Three consecutive aquacultural projects have been implemented during the period 1983 to 1993; research results and economic analyses of production systems are summarized in this report.

BACKGROUND

Since 1983, aquacultural research has been conducted in Honduras as a collaborative effort between the International Center for Aquaculture and Aquatic Environments (ICAAE), Auburn University, Alabama, USA, and the General Directorate of Fisheries and Aquaculture, Ministry of Natural Resources (MNR), Republic of Honduras. Research has concentrated on development of freshwater fingerling and foodfish production systems, and on semi-intensive marine shrimp production systems.

Early in 1983, implementation of the centrally-funded Agency for International Development Title XII Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP) was initiated in Honduras, Indonesia, Panama, Philippines, Rwanda and Thailand. PD/A CRSP research was designed to quantify biological, chemical, and physical processes of management systems for pond fish culture. The PD/A CRSP was implemented at the El Carao National Fish Culture Research Center, General Directorate of Fisheries and Aquaculture, Ministry of Natural Resources, Comayagua, Honduras. Budget reductions in 1987 resulted in termination of Honduras, Indonesia, and Philippines PD/A CRSP activities in August 1987. Panama was selected as the Latin American site for the PD/A CRSP world wide effort.

USAID/Honduras, in response to a request from MNR, contracted ICAAE to provide aquacultural technical assistance for 15 months following the termination of the PD/A CRSP. The purpose of this project was to continue applied research on tilapia fingerling and food fish production systems appropriate for Honduras, and to provide aquacultural technical assistance to the USAID/Honduras Natural Resources Management Project.

Political difficulties forced the cessation of the Panama PD/A CRSP in December 1987. The PD/A CRSP was re-established at the El Carao station in Spring 1988 largely through the efforts of the ICAAE. Experiments were initiated in August 1988.

RESEARCH STATION FACILITIES

Freshwater aquacultural research was conducted at the El Carao National Fish Culture Research Center, Comayagua. The station, located about 8 km from the city of Comayagua, is the largest of a series of aquacultural experiment stations operated by the General Directorate of Fisheries and Aquaculture (Dirección General de Pesca y Acuicultura), Ministry of Natural Resources (Secretaría de Recursos Naturales) (Figures 1-2). The El Carao Station is used principally for the production of tilapia, grass carp, silver carp, tambaquí, and guapote tigre fingerlings for fish farmers. Other activities undertaken by the station's technical staff are extension and some research.

Facilities at the station include offices, a chemical - biological limnology laboratory, a modest technical library, and equipment/supply storage areas (Figure 3). Of the 36 ponds, 12 are 0.5-ha, 12 are 0.1-ha, and 12 are 0.2-ha. Each pond is equipped with a concrete harvest sump. Water (total alkalinity of 43 mg/L $CaCO_3$, total hardness of 31 mg/L $CaCO_3$) is supplied by gravity to ponds from a 0.4-ha reservoir, which is supplied with water from irrigation canals originating at the Selguapa River. Pond inlets were equipped with saran screen filters. A wet-lab area, comprised of ten 20-m^2, four 3-m diameter, and eight 2-m^2 concrete tanks, is supplied with well water. Detailed site description was given by Egna et al. (1987).

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Figure 1. Map of Central America showing location of Honduras and the cities of Tegucigalpa and Comayagua. Figure 2. INSET: map of Comayagua Valley, Honduras, showing the location of the El Carao National Fish Culture Research Center which is located at 14°26'N latitude and 87°41'W longitude, and at an elevation of 583 m above sea level. Not to scale.

RESEARCH ACTIVITIES

FINGERLING PRODUCTION

Monosex hybrid tilapia culture has been practiced in Honduras since at least 1980. Fingerling production practices at the El Carao station when project implementation was initiated were based on partial harvests of fingerling reproduction ponds at 4- to 6-wk intervals. Harvested fingerlings were stocked into nursery ponds for further growth prior to distribution to fish farmers. Reproduction ponds were stocked with female *Oreochromis niloticus* and male *O. urolepis hornorum*. As demand for tilapia fingerlings by fish farmers increased, it was necessary to intensify production practices in order to meet demand. Demand for tilapia fingerlings continued to increase through the 1980s, but production of hybrid fingerlings lagged and delays in fingerling deliveries resulted.

PD/A CRSP research required the use of male *O. niloticus*. Therefore, fingerling production capability for this species was established at El Carao in 1983. Hormonal sex reversal to produce monosex populations was implemented in early 1988 to augment fingerling supplies.

Trials to produce sex reversed *O. niloticus* fingerlings were conducted with fry produced in earthen ponds. Prior to pond inundation 1.27-cm square mesh knotted nylon netting was draped over the harvest sump and was held in place by rocks. A cylindrical drain screen approximately one meter long and covered with aluminum window screen was placed in the drain pipe opening to reduce fry loss from suction during draining. Pond water was lowered until level with the top edge of the harvest sump, at which time brood fish were removed from the sump by lifting the nylon netting. Brood fish were transferred to concrete holding tanks for restocking the following cycle. Fry were harvested from the sump with dipnets equipped with 1.6-mm ace nylon netting.

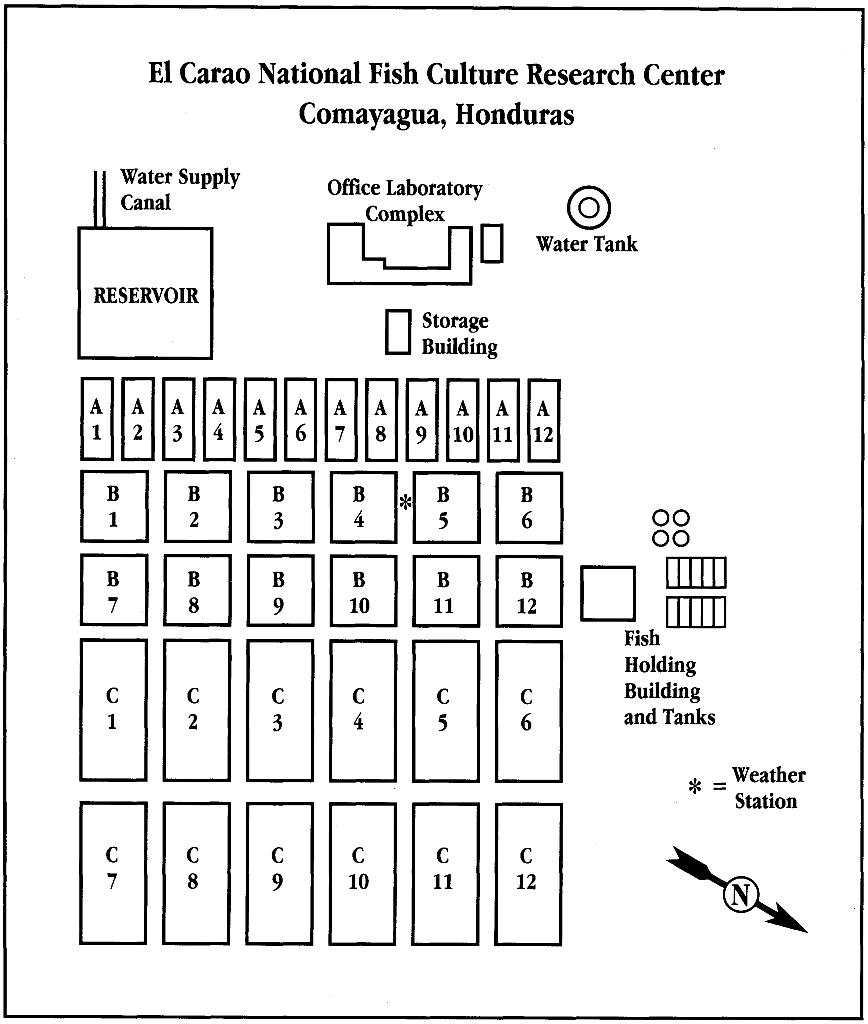


Figure 3. Schematic layout of ponds and support buildings at El Carao National Fish Culture Research Center. Not to scale.

STUDY A1. EFFECT OF HARVEST FREQUENCY ON HYBRID TILAPIA FINGERLING PRODUCTION

The objective of this study was to determine if more frequent partial harvests of reproduction ponds would increase hybrid tilapia fingerling production.

Two consecutive studies were conducted in which female *Oreochromis niloticus* and male *O. urolepis hornorum* were stocked into triplicate 0.05-ha earthen ponds at a rate of 5,000 fish/ha; four females were stocked per one male. Mean weight of brood fish was approximately 400 g.

Ponds were fertilized weekly with chicken litter (140 kg/ha) during the first study or with fresh dairy cow manure (244 kg/ha) during the second study. Fish were fed corn gluten (3 percent of fish biomass) Monday through Friday during both studies.

During the first study (15 January to 10 May 1985), fingerlings were harvested from brood ponds beginning on day 34 and subsequently at 25-day intervals, making three passes with a seine of 6.35-mm square mesh. Ponds were drained and harvested 114 days after stocking. In the second study (17 May to 20 August 1985), partial harvests of fingerlings were initiated 25 days after stocking and repeated at seven-day intervals. After 95 days, ponds were drained and harvested. At each partial harvest, mean fingerling weight was determined by weighing two random samples of 1,000 fingerlings per pond. Total numbers of fingerlings harvested were calculated from total weight of fingerlings divided by mean fingerling weight. Mean water temperatures in ponds were 24.8 °C and 27.6 °C during the first and second studies, respectively.

The total number of fingerlings harvested increased as the harvest frequency increased (Table 1; Figure 4). The number of fingerlings obtained per pond at each subsequent partial harvest decreased with 25-day interval partial harvests (Figure 5).

Cannibalism of newly hatched fry by larger fingerlings significantly reduces tilapia fingerling production in ponds. When partial harvests were conducted at 25-day intervals, the observed decline in mean fingerling production at each subsequent harvest probably resulted from cannibalism. More frequent harvests (seven-day intervals) yielded greater cumulative numbers, likely in response to reduced cannibalism.

TABLE 1. SUMMARY OF TILAPIA FINGERLING PRODUCTION (MEAN ± SE) IN 0.05-HA EARTHEN PONDS STOCKED WITH 5,000 BROOD FISH/HA AND SUBJECTED TO MONTHLY OR WEEKLY PARTIAL HARVESTS

Harvest frequency	Cumulative total production	Daily production	Individual weight	Duration
Days	*No./0.05 ha*	*No./m² /day*	*g/fingerling*	*days*
25	49,000 ± 9,037	0.86	1.5 ± 0.2	114
7	104,100 ± 17,644	2.19	0.9 ± 0.1	95

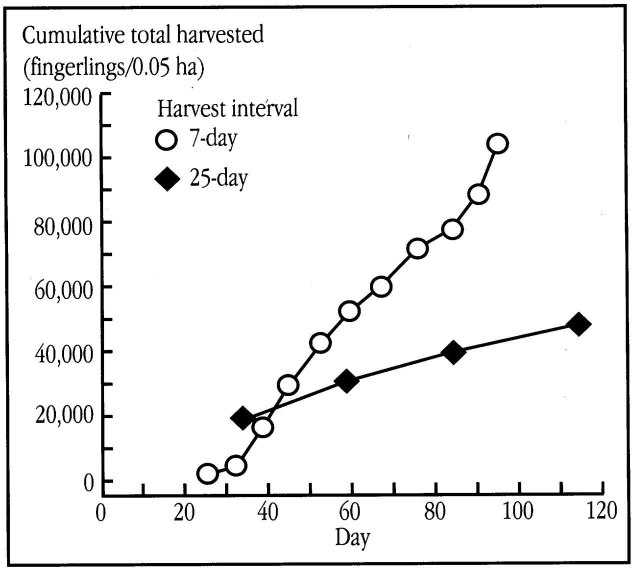


Figure 4. Mean cumulative number of tilapia fingerlings harvested from 0.5-ha earthen reproduction ponds subjected to weekly or monthly partially harvests.

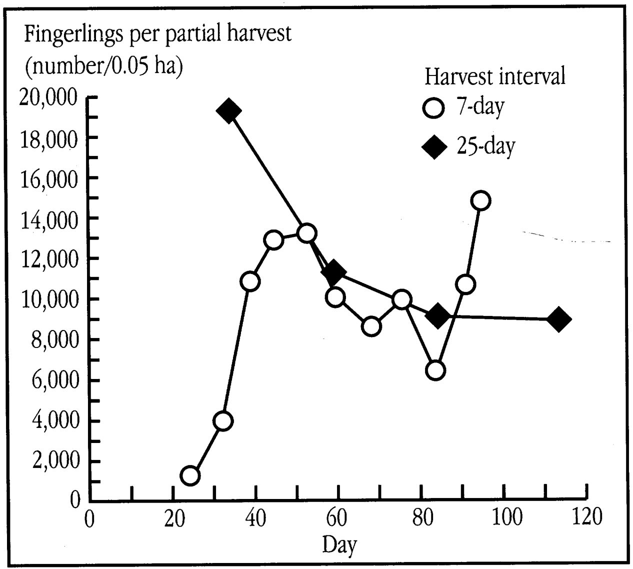


Figure 5. Mean number of tilapia fingerlings harvested from 0.05-ha earthen ponds at weekly or monthly partial harvests.

STUDY A2. EFFECT OF WATER TEMPERATURE ON PRODUCTION OF *OREOCHROMIS NILOTICUS* FRY FOR SEX REVERSAL

Recently hatched tilapia fry 9 to 11 mm in total length (TL) are preferred for hormonal sex reversal (masculinization) because they are presumed to be sexually undifferentiated. Oral administration of androgen to these fish for three to four weeks results in populations of fish comprised of 97 to 100 percent males. Observations made during preliminary fry production trials indicated that the duration of the reproduction pond cycle necessary to produce 9 to 11 mm TL fry varied with water temperature. The objective of this research was to quantify the effect of water temperature, in terms of degree-days, on *Oreochromis niloticus* fry production for sex reversal in earthen ponds.

Two 0.05-ha earthen ponds were used for each trial. Thirty-three trials were conducted between 25 September 1988 and 15 March 1990. *Oreochromis niloticus* brood fish were randomly allocated to, and concurrently stocked in, each pond. Mean number of females and males stocked per pond was 220 and 101, respectively. Average (± SD) individual weights were 233 ± 53 g and 319 ± 39 g, respectively. Mean weight of fish by sex was determined prior to each trial and remained relatively constant across all trials. Broodfish were fed a 23 percent protein pelleted ration at 3 percent of fish biomass per day, five days per week.

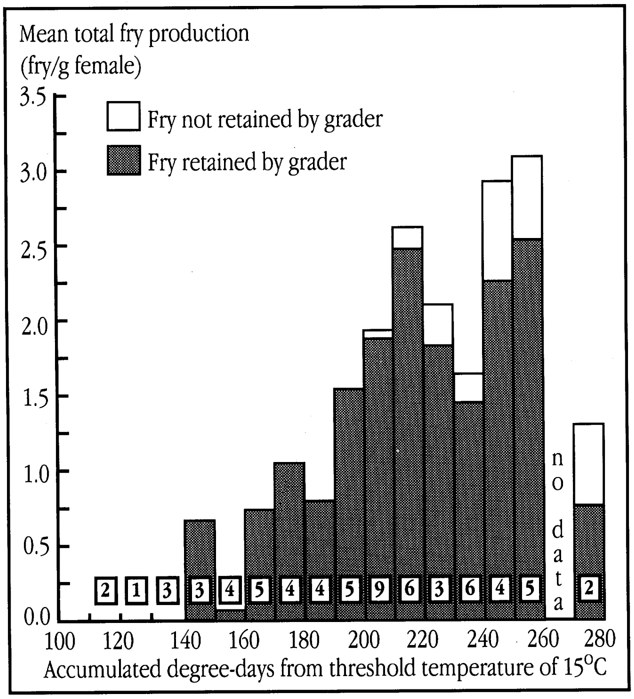


Figure 6. Mean total production of Nile tilapia fry from 0.05-ha earthen ponds in relation to accumulated degree-days and shown by 10-degree-day intervals. Number of observations per 10-degree-day interval is given in the box.

In each trial, one pond usually was drained 17 days after stocking (range 16 to 18 days), and the other 20 days after stocking (range 19 to 21 days). Fry harvest was suspended when fewer than several hundred fry were captured after two to three consecutive passes with the dipnet. Quantification of the few fry remaining in the harvest sump, trapped in puddles on the pond bottom, or impaled on the drain screen was not attempted.

Harvested fry were graded through 0.32-cm mesh vexar which retained fry larger than 13 mm TL. Total

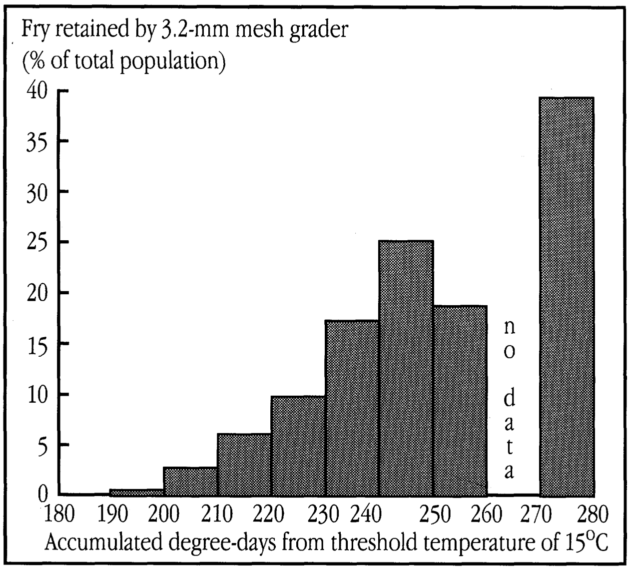


Figure 7. Mean percent of total *O. niloticus* fry population retained by 3.2-mm vexar mesh grader in relation to accumulated 10-degree-day intervals. Average total fry yield (non-retained plus retained fry) was 86,000 fry/0.05 ha per harvest.

number of fry per pond not retained by the grader was determined by visual comparison to a counted sample of 2,000 fry. A random sample averaging 434 fry/pond was individually measured (TL) to the nearest millimeter.

Pond depth averaged 90 cm. A maximum-minimum thermometer was installed at 50-cm depth in each pond. Water temperatures were recorded between 0700 and 0800 hours six days per week. Data for missing values was estimated by averaging water temperature from the preceding and following days. Average daily temperature was estimated from maximum and minimum daily temperatures. Calculation of degree-days was based on the difference between the mean daily temperature and a threshold temperature of 15 °C; the threshold temperature was subtracted from the average temperature each day, and the results summed over the trial period.

Daily water temperatures across all trials ranged from 16.5 to 30.8 °C. Cumulative degree-days per trial ranged from 119.6 to 276.0 with a mean of 198.2. No fry were harvested at less than 140 degree-days, but eggs were observed at the lowest number of degree-days noted. Mean total fry harvest per gram of female (y) increased significantly as cumulative degree-days (x) increased above 140 ($y = 0.021x - 2.605$, $r^2 = 0.535$, $p = 0.0001$). Figure 6 shows mean total fry production per 10-degree-day intervals. Mean total fry yield per harvest was 86,000 fry per 0.05 ha. Cumulative fry production during the 33 trials was 4,897,000 fry, 89 percent of which were of the preferred size for hormonal sex reversal.

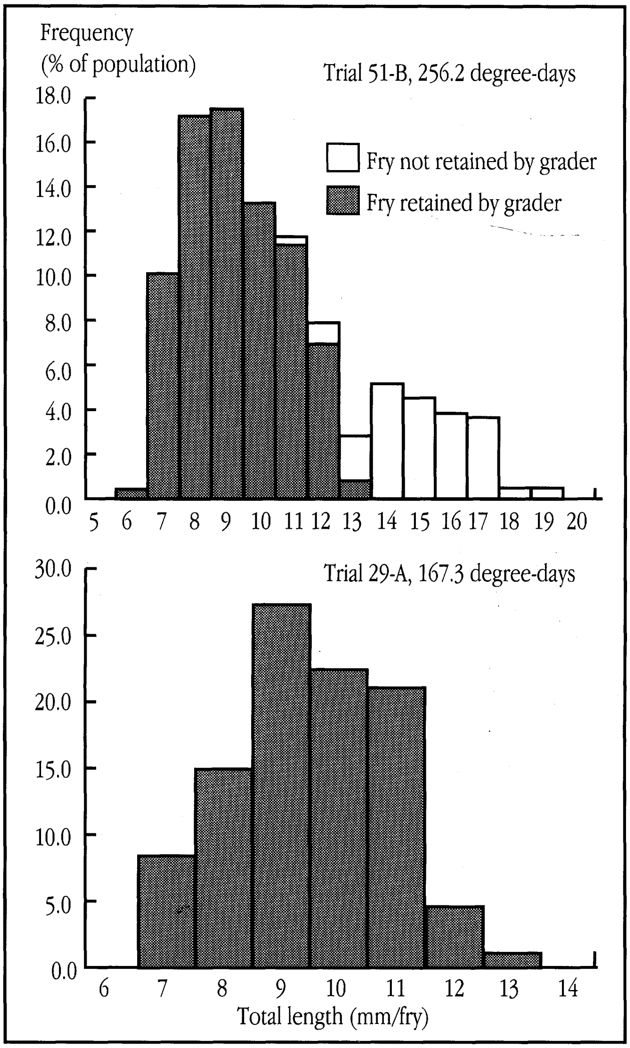


Figure 8. Size distribution of *O.niloticus* fry population from two trials to demonstrate effect of high (top) and low (bottom) cumulative degree-days. Number of fry not retained by the grader was estimated to be 98,000 and 109,000 fry/0.5 ha for Trials 51-B and 29-A, respectively. A total of 28,000 fry/0.5 ha were retained by the grader in Trial 51-B; no fry were retained in the other trial.

No fry produced between 140 and 195 degree-days were retained by the grader. Above 195 degree-days, number of fry retained by the grader (y) increased significantly with increased cumulative degree-days (x) ($y = 0.492x - 98.73$, $r^2 = 0.569$, $p = 0.001$; Figure 7).

Between 140 and 280 degree-days the number of fry not retained by the grader was not linearly dependent on cumulative degree-days. However, mean total fry harvest per gram of female was greater between 200 and 260 degree-days than between 140 and 200 degree-days. Two trials in the 270 to 280-degree-day interval resulted in low production, possibly because temperatures were too high. Fry not retained by the grader averaged (± SE) 9.5 ± 0.1 mm total length (TL) and fry retained by the grader were 14.2 ± 0.16 mm TL (Figure 8).

Total fry production and quantity of fry not retained by the grader were consistently higher between 195 and 260 degree-days. The percentage of fry retained by the grader (oversized fry) nearly doubled between 210 to 220 and 220 to 230 degree-days intervals. Therefore, it appears that the optimum cumulative degree-days for production of fry not retained on a 3.2-mm mesh (those suitable for hormonal sex reversal) and for efficient pond usage would be between 195 and 220 degree-days.

STUDY A3. EFFECTS OF FRY STOCKING RATE AND HORMONE TREATMENT DURATION ON PRODUCTION OF SEX-REVERSED *OREOCHROMIS NILOTICUS*

Sex reversal of *O. niloticus* fry at El Carao has been practiced in 1.6-mm ace nylon mesh hapas suspended in ponds and in outdoor cement tanks. Fry are fed a finely-ground hormone-treated ration (23 percent protein; 60 mg 17-α methyltestosterone (MT)/kg feed) daily in four feedings. Stocking rate of fry averages 4,300 fry per m^2 of water surface area (range: 2,000-5,200 fry/m^2). Hormone treatment generally lasts 28 days, and has resulted in ≥ 98 percent phenotypic males.

In Honduras, environmental conditions permit year-round operation although seasonal temperature differences may affect the efficacy of hormone treatment. The purpose of the following experiment was to determine effects of fry stocking rate and hormone treatment duration on sex-reversal of *Oreochromis niloticus* in hapas suspended in ponds influenced by seasonal temperature changes.

A completely randomized design in 2 x 3 factorial arrangement was used. Treatments tested were fry stocking rate (2,000, 4,000 or 6,000 fry/m2) and hormone treatment duration (21 and 28 days). Each treatment was replicated twice. Uniform-age, 9- to 11-mm total length fry were stocked into hapas (1 m x 1 m x 1 m; 1.6-mm ace nylon mesh). Number of fry was determined by visual comparison to a counted sample of 1,000 fry. MT (60 mg/kg feed) was incorporated into ground, sifted (560-µ mesh sieve), commercially available feed (23 percent protein). Feeding rates were 20 percent of biomass per day during week 1, 15 percent of biomass per day during week 2, 12 percent of biomass per day during week 3, and 10 percent of biomass per day during week 4. Daily ration was divided into four equal meals offered at two-hour intervals beginning at 8 a.m. Fry in replicate hapas within stocking rates were fed the same quantity of ration daily. Upon completion of the treatment period, hapas were completely harvested. A random sample of 500 to 1,000 treated fry were returned to their hapa for growth to about five cm, at which time gonads from about 200 fish were examined microscopically to determine sex ratio using the aceto-carmine squash method (Guerrero and Shelton, 1974). Maximum-minimum water temperatures were determined at 0.5-m depth six days/week. The trials were repeated seven times.

Sex reversal was not significantly affected by duration of hormone treatment nor by stocking rate, and averaged 100 percent males in all treatments (Table 2). Survival was variable, but did not differ significantly between treatment durations or among stocking rates.

There was no significant relationship between fry growth (g per day) and survival in any experiment. Final fry weight and length were inversely related to stocking rate (r^2 = 0.615 and r^2 = 0.581, respectively). Mean water temperature ranged from 23.5 to 28.5 °C during the seven trials. Efficacy of hormone treatment was not affected significantly in this temperature range.

TABLE 2. EFFECT OF STOCKING RATE AND HORMONE-TREATMENT DURATION ON GROWTH AND EFFICACY OF METHYLTESTOSTERONE (MT) TREATMENT FOR SEX REVERSAL

MT treatment duration	Stocking rate	Final weight	Final length	Efficacy
Days	*Fry/m²*	*g/fry*	*mm/fry*	*Pct. Males*
21	2,000	0.13	19.2	99.9
28	2,000	0.21	22.6	100.0
21	4,000	0.10	17.9	100.0
28	4,000	0.13	19.6	100.0
21	6,000	0.08	16.6	100.0
28	6,000	0.11	17.9	100.0

STUDY A4. REPRODUCTION OF GUAPOTE TIGRE (*CICHLASOMA MANAGUENSE*): EFFECTS OF MALE:FEMALE STOCKING RATIO AND TEMPERATURE

Production of tilapia populations comprised of ≥ 98 percent males has been consistently achieved using sex reversal technology. However, production of offspring by unwanted females during grow-out can be significant, and may have a negative impact on yield of marketable tilapia. Since the late 1980s, El Carao staff have been recommending use of guapote tigre (*Cichlasoma managuense*; 500/ha) a piscivorous cichlid native to Honduras, to control tilapia reproduction.

Guapote tigre is a nest breeder that can begin reproducing in ponds at a few months of age. Number of fry produced per female appears to be high; however, yields from reproduction ponds often are low probably because of predation on larvae by parents or older fingerlings. Reproduction may also be affected by stocking rates, ratios of male and females, and by environmental variables such as temperature. The objective of this study was to document effects of female:male broodstock ratios and temperature on the number of fry harvested from reproduction ponds.

Twelve trials were conducted between 28 September 90 and 26 August 91. Two 0.05-ha earthen ponds were used for each trial. Two treatments (1 F:1 M and 3 F:1 M) were randomly assigned to ponds in each trial. Guapote were stocked in each pond on the same day. Maximum-minimum water temperatures were determined at 0.5-m depth five days per week. Fish were fed a commercial fish or shrimp ration five days per week at one percent of total adult biomass. After 25 days, ponds were completely drained and harvested. Total fry harvests were weighed to the nearest gram on an electronic balance. A sample of 500 fry was weighed to determine average weight. Total number harvested was calculated as the quotient of harvest weight divided by average larval weight.

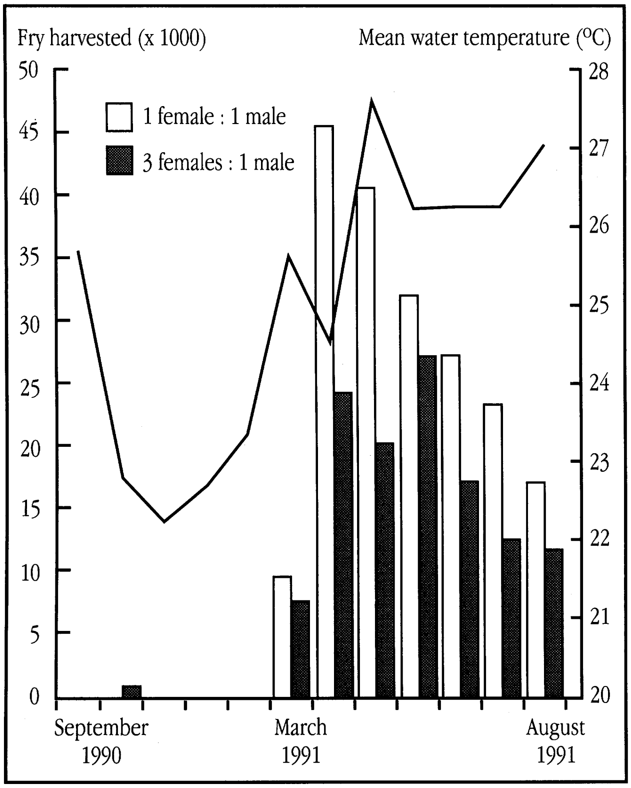


Figure 9. Number of fry harvested (vertical bars) and mean average water temperature (solid line) during reproduction of guapote tigre at two female:male ratios from September 1990 to August 1991.

Table 3. Stocking and Harvest of Guapote Tigre at Two Female:Male Ratios During Seven Reproduction Trials in 0.05-ha Earthen Ponds Between March 1991 and August 1991

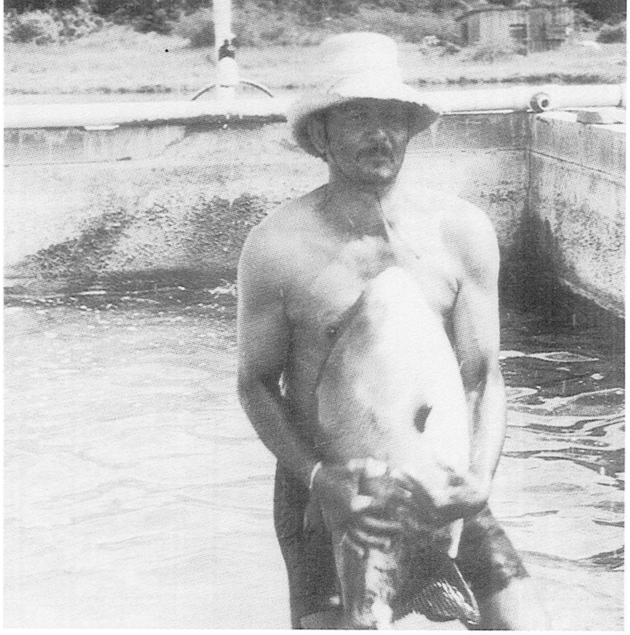
	Treatment	
Variable	1F:1M	3F:1M
Female number	102	225
Female weight, g	121	115
Male number	102	75
Male weight, g	171	164
No. fry	27,887	17,077
Fry/m^2	55.8	34.2
Fry/female	298	80
Fry/gram of female	2.5	0.7

The first five trials were conducted primarily during the cold season. Except for a few hundred fry harvested during the second month, there was no reproduction until mean monthly water temperatures rose above 24.5 °C (Figure 9). The number of fry, fry per female, and fry per gram of female harvested from the 1F:1M sex ratio was significantly greater than that of the 3F:1M ratio (Table 3). Lower harvest numbers at the 3F:1M ratio were probably related to greater predation pressure on the fry by parents. After reproduction started in March 1991, harvest number decreased with an increase of female biomass ($P < 0.05$).

FERTILIZATION STUDIES

All pond production research was conducted in 0.1-ha earthen ponds that had 75-cm average water depth. Male (manually-selected or sex-reversed) Nile tilapia (*Oreochromis niloticus*) fingerlings were stocked during all experiments. Fish growth was monitored monthly by seine sample of at least 10 percent of stocked fish. Any tilapia offspring in the sample was weighed and removed. Reported gross yield included weight of fingerlings removed during sampling for the period 1983 to 1988.

At El Carao, the rainy season extended from May through November, with peak rainfall from June to September. Such seasonal differences were thought to affect pond dynamics and fish yields, and therefore experiments for the first four years of the project were repeated during each season. Initiation and completion of either season varied from year to year and it was difficult to execute trials completely during a particular season. Usually one month of each experiment overlapped into the next season. Later it became apparent that temperature more than season affected fish yields at the El Carao site. The cool season ranged from September through February, and is characterized by water temperatures in the range of 21 to 25 °C in September to October and from 16 to 21 °C from November through February. During the warm season



Research station worker.

water temperatures range from 25 to 31 °C. Thus, beginning in 1990 experiments were conducted during the cool and warm seasons, respectively.

Triple superphosphate (46 percent P_2O_5), urea (46 percent N), diammonium phosphate (18 percent N, 46 percent P_2O_5), dairy cow manure or layer chicken litter were used as pond nutrient inputs. Chemical fertilizers were procured locally. Cow manure was obtained from the dairy unit, National Livestock Center, Ministry of Natural Resources, Comayagua. Fresh manure was scraped from the milking parlor beginning Saturday through Monday morning when it was applied to ponds as a thick slurry. Chicken litter, obtained from a local commercial layer operation, was purchased in bulk for each experiment and stored in woven plastic sacks under cover until it was broadcast over the pond surface. Chicken litter consisted of pine sawdust, manure, feathers and waste feed. Manure application rates were on a dry matter (DM) basis. Manure DM was determined prior to each fertilization.

Water quality analyses were performed according to methodologies given in Standard Methods (APHA, 1989) or Boyd (1979). Water samples were collected with a column sampler (Boyd, 1979); water samples from various locations within a pond were pooled and a subsample withdrawn for analysis. Primary productivity was determined in ponds using the free-water diurnal curve method. Dissolved oxygen was measured at four-hour intervals and at 0.25-m depth intervals using a polarographic dissolved oxygen meter. Measured values were corrected for oxygen diffusion across the air-water interface using an empirical relationship that related the oxygen transfer coefficient to wind speed (Boyd and Teichert-Coddington, 1992).

Economic evaluation of management systems tested is reported in the economic analysis section of this report.

STUDY B1. PRODUCTION OF TILAPIA IN PONDS FERTILIZED WITH PHOSPHORUS ONLY

This was the first PD/A CRSP experiment conducted in Honduras. It was designed to establish a baseline of data during dry and rainy seasons for tilapia ponds that received minimal nutrient inputs.

Ten and 12 ponds were used for the dry and rainy season study, respectively. Ponds were stocked with 10,000 tilapia/ha. Mean individual weight of fingerlings was 13.1 g and 10.4 g for the dry and rainy season studies, respectively. Ponds were fertilized with triple superphosphate (TSP; 46 percent P_2O_5; 8.7 kg TSP/ha) every two weeks. Both studies lasted 150 days.

Mean tilapia gross and net yield were significantly greater during dry season than rainy season (Table 4). Mean individual fish weight at stocking was different for each season; an analysis of covariance indicated no significant effect of stocking weight on gross yield. No seasonal difference in fish survival was observed. Mean early morning water temperatures were 24.7 °C and 25.7°C for dry and rainy seasons, respectively.

Mean net and gross primary productivity were significantly greater during the dry season than during the rainy season. There were adequate concentrations of inorganic nitrogen and phosphorus (Table 5) for high primary productivity, but photosynthesis apparently was limited by high clay turbidity. Combined tilapia yield (both seasons) was significantly correlated to net primary productivity ($r^2 = 0.795$) (Figure 10), indicating that higher tilapia yields might have been obtained with higher rates of primary production.

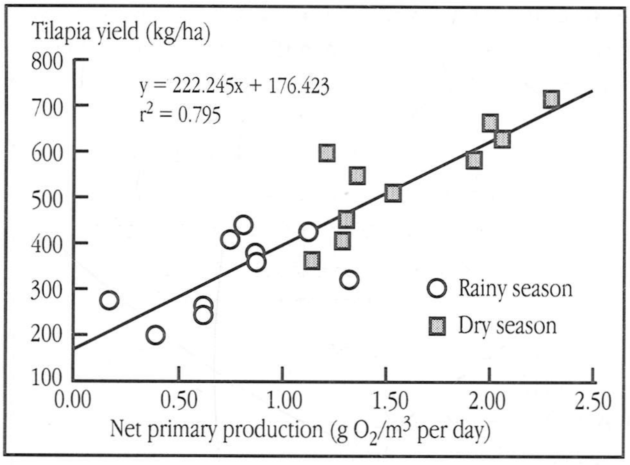


Figure 10. Relationship between mean tilapia yield after 150 days and net primary productivity in ponds fertilized with phosphorus only during dry and rainy season experiments.

TABLE 4. PRODUCTION RESULTS FROM 0.1-HA EARTHEN PONDS STOCKED WITH MALE *OREOCHROMIS NILOTICUS* (10,000/HA) AND FERTILIZED WITH TRIPLE SUPERPHOSPHATE. TEN PONDS WERE STOCKED DURING THE DRY SEASON AND 12 DURING THE RAINY SEASON

	Dry Season		Rainy Season		
Variable	Mean	S.E.	Mean	S.E.	t value
Gross yield, kg/ha/150 days	547	35.9	334	25.2	-4.84*
Net yield initial stock, kg/ha/150 days	416	34.6	289	32.9	-2.68*
Tilapia reproduction, kg/ha/150 days	4	3.0	94	26.5	3.08*
Survival, pct.	91.1	1.1	90.2	2.0	-0.41
Final individual weight, g/fish	60	3.8	37	2.8	-4.84*

* Seasonal means were significantly different ($P<0.05$).

TABLE 5. SUMMARY OF PRIMARY PRODUCTIVITY AND WATER QUALITY VARIABLE MEANS, BY SEASON, IN 0.1-HA EARTHEN PONDS STOCKED WITH MALE *OREOCHROMIS NILOTICUS* (10,000/HA) AND FERTILIZED WITH TRIPLE SUPERPHOSPHATE. TEN PONDS WERE STOCKED DURING THE DRY SEASON AND 12 DURING THE RAINY SEASON

	Dry season		Rainy season		
Variable	Mean	S.E.	Mean	S.E.	t value
Gross primary productivity, g 0_2/m^3/day	1.7	0.17	2.6	0.17	na
Net primary productivity, g 0_2/m^3/day	1.0	0.13	0.8	0.11	na
Early morning pH	8.32	9.47	8.14	9.31	4.11*
Total alkalinity, mg/L $CaCO_3$	106.7	5.0	85.5	4.3	-3.21*
Total hardness, mg/L $CaCO_3$	79.0	2.0	62.6	2.8	-4.76*
Ca^{2+} hardness, mg/L $CaCO_3$	63.0	1.2	51.0	2.5	-4.34*
Ammonia, mg/L NH_3-N	0.23	0.03	0.38	0.02	3.84
Nitrate, mg/L NO_3-N	1.27	0.06	1.49	0.04	2.99*
Soluble orthophosphate, mg/L PO_4-P	1.02	0.06	0.87	0.04	-2.14*

na Statistical test not appropriate.
* Seasonal means were significantly different ($P<0.05$).

Based on reports in the literature for phosphorus-fertilized fish ponds, fish yields were expected to average 1,000 kg/ha. The principal factor limiting fish production in the present experiments probably was low primary productivity that resulted from light-limitation caused by clay turbidity. Although incoming water generally had a slightly milky color, water appeared to be more turbid during the rainy season as a result of surface runoff. However, much of the turbidity probably was caused by the suspension of fine clay particles from the bottom muds by wind-induced water circulation.

STUDY B2. TILAPIA YIELD IN PONDS FERTILIZED WITH SIMILAR QUANTITIES OF NITROGEN AND PHOSPHORUS AS ORGANIC OR CHEMICAL FERTILIZER

Fertilization with phosphorus resulted in low tilapia yield (Study B1). High levels of clay turbidity in ponds apparently limited primary productivity and fish production. Organic fertilizers stimulate primary and secondary productivity in ponds, and also can precipitate clay turbidity. Higher quantities of inorganic N and P inputs also could stimulate primary production and fish yields. The objective of this study was to test the hypothesis that organic and chemical fertilization, based on similar N and P inputs, result in the same fish production.

This study was repeated during the dry and rainy seasons. Dry season treatments (four replicates/treatment) were layer chicken litter, dairy cow manure, and urea plus triple superphosphate. Rainy season treatments (six replicates per treatment) were chicken litter and urea plus triple superphosphate. Similar quantities of nitrogen and phosphorus were applied in each treatment except for cow manure which had a high N:P ratio (Table 6). Chemical fertilizer was not mixed with organic fertilizer to equalize N and P inputs.

Tilapia fingerlings were stocked into ponds at a rate of 10,000/ha. Fingerlings averaged 33 g and 17 g during the dry and rainy seasons, respectively. Dry and rainy season experiments were initiated on 16 January 1985 and 26 July 1985, respectively. Duration of each experiment was 150 days.

During the dry season, mean tilapia gross yield was significantly greater in the chicken litter treatment than in the other treatments, but dairy cow manure and chemical fertilizer treatment yields were not significantly different (Table 7). During the rainy season, tilapia yield was significantly greater in the chicken litter treatment than in the chemical fertilizer treatment (Table 7). Chicken litter applications also resulted in significantly greater tilapia yield than did chemical fertilizer applications when dry and rainy season data were pooled (Table 8). Tilapia net yield did not differ significantly between seasons (Table 8). Mean early morning water temperatures were 24.5°C and 25.7°C for dry and rainy seasons, respectively.

TABLE 6. SUMMARY OF NITROGEN, PHOSPHORUS AND POTASSIUM CONTENTS (PERCENT DRY MATTER [DM] OF NUTRIENT SOURCES AND NUTRIENT APPLICATION RATES DURING DRY AND RAIN SEASON FERTILIZER EXPERIMENTS IN PONDS STOCKED WITH NILE TILAPIA (10,000/HA)

Nutrient source	N - P - K[1]	Application rate	Total application, kg/ha	
			Nitrogen	Phosphorus
	Pct.	*kg DM/ha/week*		
Dry Season				
Layer chicken litter, 83.3% DM ...	2.75 - 2.46 - 2.33	500	302	270
Dairy cow manure, 21.3% DM.....	1.46 - 0.55 - 0.70	1,020	328	123
Urea	46.00 - 0.00 - 0.00	30.6	295	-
Triple superphosphate[2]	0.00 - 20.10 - 0.00	62.6	-	264
Rainy Season				
Layer chicken litter, 84.5% DM ...	2.48 - 1.70 - 2.53	500	260	179
Urea	46.00 - 0.00 - 0.00	31.3	302	-
Triple superphosphate..................	0.00 - 20.10 - 0.00	49.3	-	238

[1] N - P - K: Nitrogen - Phosphorus - Potassium content, dry matter basis.

[2] 46.00 percent P_2O_5.

TABLE 7. PRODUCTION DATA (MEAN ± S.E.) FROM 0.1-HA EARTHEN PONDS STOCKED WITH MALE *OREOCHROMIS NILOTICUS* (10,000/HA) THAT RECEIVED ORGANIC OR CHEMICAL FERTILIZER DURING THE DRY AND RAINY SEASONS

Treatment	Final weight	Survival	Gross yield	Net yield of initial stock	Net total yield
	g/fish	*Pct.*		*kg/ha/150 days*	
Dry Season					
Layer chicken litter	204 ± 8.1 a	96.9 a	2,075 ± 89 a	1,663 ± 65 a	1,759 ± 88 a
Dairy cow manure	172 ± 3.8 b	95.7 a	1,626 ± 39 b	1,272 ± 50 b	1,295 ± 45 b
Chemical fertilizer........	150 ± 9.0 b	93.6 a	1,513 ± 106 b	1,071 ± 96 b	1,194 ± 110 b
Rainy Season					
Layer chicken litter	183 ± 12.0 c	93.0 c	1,594 ± 72 c	1,426 ± 71 c	1,530 ± 84 c
Chemical fertilizer........	132 ± 10.0 d	92.9 c	1,153 ± 95 d	987 ± 96 d	1,301 ± 114 d

ab and cd Columns means within season followed by the same letter were not significantly different (P>0.05).

TABLE 8. COMPARISON OF DRY AND RAINY SEASON, AND TREATMENT YIELDS OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*; 10,000/HA) IN 0.1-HA PONDS FERTILIZED WITH CHICKEN LITTER OR CHEMICAL FERTILIZER

Variable	Mean weight		Survival	Gross yield	Net yield of intital stock	Total net yield
	Initial	Final				
	g/fish		*Pct.*		*kg/ha/150 days*	
Chicken Litter						
Dry season	34	204	96.9	2,075	1,663	1,759
Rainy season.................	17	160	93.0	1,594	1,426	1,531
Chemical Fertilizer						
Dry season	33	150	93.7	1,513	1,071	1,194
Rainy season.................	17	119	92.9	1,153	987	1,032
Treatment Means						
Chicken litter	23	178*	94.5	1,786*	1,521*	1,622*
Chemical fertilizer........	23	132	93.2	1,297	1,021	1,097
Seasonal Means						
Dry season	33*	177*	95.3	1,794*	1,367	1,477
Rainy season.................	17	140	92.9	1,373	1,207	1,281

* Means were significantly different (P<0.05).

Tilapia yields were positively correlated to primary productivity. Applications of chicken litter and chemical fertilizer resulted in higher primary productivity than did application of cow manure (Table 9). However, chicken litter resulted in significantly greater primary production than chemical fertilizer (Table 10). Greater biological oxygen demand, as indicated by community respiration, resulted from organic fertilizer (Tables 9 and 10). Organic matter helped clear clay turbidity that was apparently limiting photosynthesis, because gross primary productivity and Secchi disk visibility increased together.

Table 9. Mean Primary Productivity (g O_2/m^3 per day) and Community Respiration (g O_2/m^3 per day) in Ponds Fertilized with Chicken Litter or Chemical Fertilizer During the Dry and Rainy Season Experiments

Season	Primary productivity: Net	Primary productivity: Gross	Community respiration
Dry Season			
Layer chicken litter	1.92 ± 0.39 a	4.53 ± 0.79 a	5.36 ± 0.88 a
Dairy cow manure	0.77 ± 0.21 b	2.93 ± 0.44 b	4.20 ± 1.19 ab
Chemical fertilizer	1.84 ± 0.67 a	3.76 ± 1.08 ab	3.83 ± 2.05 b
Rainy Season			
Layer chicken litter	2.52 ± 0.20 c	7.44 ± 0.44 c	9.84 ± 0.48 c
Chemical fertilizer	1.61 ± 0.23 d	4.72 ± 0.64 d	6.21 ± 0.84 d

ab and cd Column means within season followed by the same letter were not significantly different ($P < 0.05$).

Table 10. Seasonal Comparison of Primary Productivity (g O_2/m^3 per day) and Community Respiration (g O_2/m^3 per day) in Ponds Fertilized with Chicken Litter or Chemical Fertilizer

Variable	Primary productivity: Net	Primary productivity: Gross	Community respiration
Chicken litter			
Dry season	1.92	4.53	5.36
Rainy season...........	2.52	7.44	9.84
Chemical fertilizer			
Dry season	1.84	3.76	3.83
Rainy season...........	1.61	4.72	6.21
Treatment means			
Chicken litter	2.28*	6.28*	8.05*
Chemical fertilizer...	1.71	4.33	5.25
Seasonal means			
Dry season	1.88	4.15*	4.60*
Rainy season...........	2.07	6.08	8.03

* Means are significantly different ($P \leq 0.05$)

Fertilizer type resulted in significant differences in water quality. Mean total alkalinity was significantly greater and mean pH, total ammonia nitrogen (TAN) and phosphorus were significantly lower in the chicken litter treatment than in the chemical fertilizer treatment (Table 11). Calcium carbonate present in the chicken litter and pond soils was dissolved by carbon dioxide generated by bacterial decomposition of chicken litter, thus increasing total alkalinity. Ammonia is a base which can increase pH; the proportion of un-ionized ammonia, which is toxic to fish, increases as pH rises. Large application of ammonia-based fertilizer may cause un-ionized ammonia concentration to threaten fish survival.

Dairy cow manure and chemical fertilizer were equally effective nutrient sources in tilapia grow-out ponds, while chicken litter was the most productive. Tilapia yield for the chemical fertilizer treatment was greater than that observed with phosphorus-only fertilization (Study B1); however, greater quantities of phosphorus, in addition to nitrogen, were added to ponds in the present study. No turbidity control was employed when phosphorus was the only nutrient added to ponds.

STUDY B3. TILAPIA PRODUCTION IN RESPONSE TO CHICKEN LITTER FERTILIZATION

Study B2 demonstrated chicken litter resulted in high fish yield. There were no known studies that systematically related tilapia yields to chicken litter input. Such data would be immediately applicable to the host country and provide a basis for economic analyses. The objective of this study was to quantify tilapia yields in ponds fertilized with chicken litter.

Table 11. Comparisons of Water Quality Means in Ponds Fertilized with Chemical Fertilizer or Chicken Litter

Treatment	pH	Total alkalinity (mg/L as $CaCO_3$)	Ammonia (mg/L NH_3-N)	Total phosphorus	Soluble orthophosphate
				(mg/L PO_4-O)	
Chicken litter					
Dry season	7.8	131.3	0.25	5.5	4.0
Rainy season.........	7.8	137.7	0.58	5.1	3.8
Chemical fertilizer					
Dry season	8.5	66.3	0.56	9.5	6.5
Rainy season.........	7.9	64.4	0.67	13.8	10.1
Treatment means					
Chicken litter	7.9*	135.2*	0.45*	5.3*	3.9*
Chemical fertilizer	8.0	65.1	0.62	12.1	8.7
Seasonal means					
Dry season	8.0	98.8	0.40*	7.5	5.2
Rainy season.........	7.9	101.0	0.62	9.5	6.9

*Means within heading are significantly different ($P \leq 0.05$).

Layer chicken litter (CL) was applied to ponds weekly at rates of: 125 kg, 250 kg, 500 kg or 1,000 kg

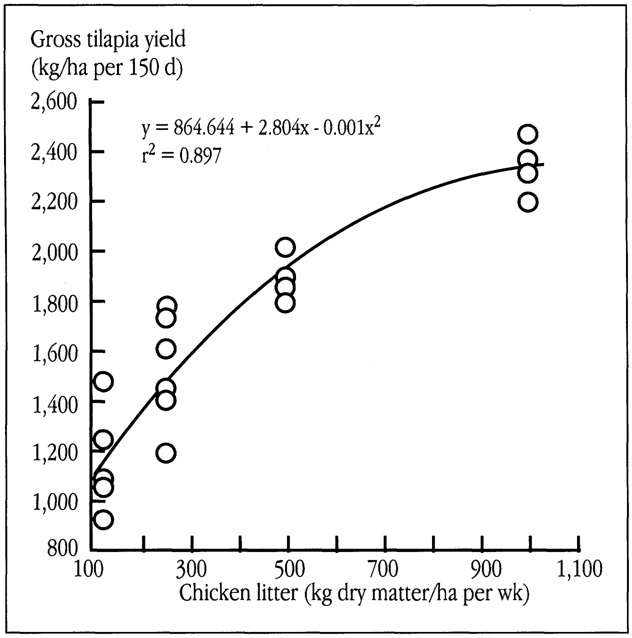


Figure 11. Nile tilapia production function in relationship to chicken litter input in 0.1-ha earthen ponds in Honduras. Rainy and dry season data are combined.

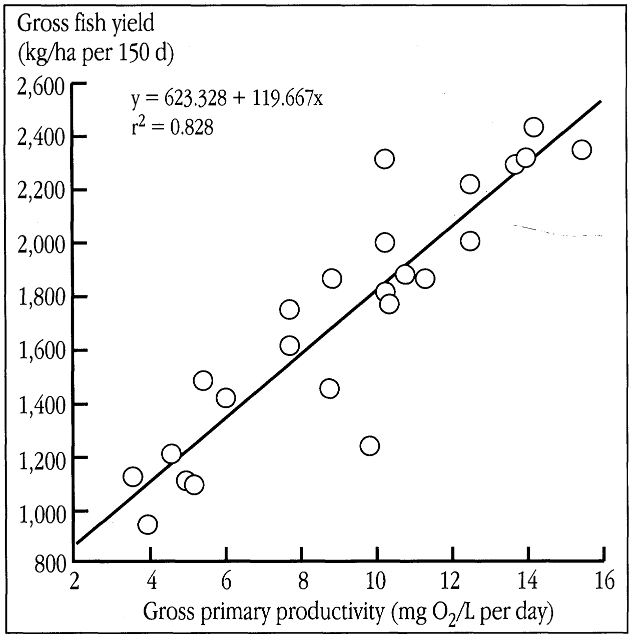


Figure 12. Relationship between gross tilapia yield and gross primary productivity in 0.1-ha earthen ponds fertilized weekly with layer chicken litter. Data from rainy and dry seasons.

DM/ha. The study was repeated during the rainy and dry seasons. Three 0.1-ha earthen ponds were randomly assigned to each treatment during each season. Nile tilapia were stocked at 10,000/ha. Mean fingerling weight (g/fish) was 26.1 and 36.6 during the rainy and dry season, respectively. Rainy and dry season experiments were started on 5 June 1986 and 7 February 1987, respectively, and lasted 150 and 152 days, respectively.

Tilapia yield increased from 934 to 2,451 kg/ ha, and from 1,085 to 2,363 kg/ha during the rainy and dry seasons, respectively, as weekly CL input increased from 125 to 1,000 kg DM/ha. Gross tilapia yield (y) increased curvilinearly as manure application rate (x) increased ($y = 864.6 + 2.80x - 0.001x^2$, $r^2 = 0.897$) (Figure 11). No seasonal differences in gross or net tilapia yield were observed (Table 12). Greater quantities of tilapia offspring were harvested during the rainy season, indicating that the larger the fingerling at sexing, the more effective the separation of sexes. Tilapia yield was positively correlated with net primary production ($r^2 = 0.828$), gross primary production (Figure 12), and chlorophyll *a* concentration ($r^2 = 0.836$).

TABLE 12. SEASONAL COMPARISONS OF NILE TILAPIA PRODUCTION DATA (MEAN ± S.E.) FROM 0.1-HA EARTHEN PONDS FERTILIZED WEEKLY WITH CHICKEN LITTER (CL) ON A DRY MATTER BASIS

Variable	Rainy season	Dry season	t-Value
125 kg CL/ha per week			
Gross yield, kg/ha	1,179 ± 162	1,145 ± 52	0.198
Reproduction, kg/ha	61 ± 12	43 ± 25	0.639
Net yield, kg/ha	915 ± 164	781 ± 53	0.774
Survival, pct.	94.1 ± 0.6	92.9 ± 0.9	1.110
Individual weight, g/fish	115 ± 15.4	117 ± 6.4	-0.130
250 kg CL/ha per week			
Gross yield, kg/ha	1,649 ± 112	1,426 ± 122	1.348
Reproduction, kg/ha	158 ± 10	35 ± 18	5.963**
Net yield, kg/ha	1,381 ± 117	1,050 ± 111	2.052
Survival, pct.	92.7 ± 2.8	96.7 ± 3.3	-0.912
Individual weight, g/fish	155 ± 10.0	143 ± 9.7	0.858
500 kg CL/ha per week			
Gross yield, kg/ha	1,890 ± 60	1,915 ± 45	-0.338
Reproduction, kg/ha	185 ± 21	41 ± 21	4.887**
Net yield, kg/ha	1,643 ± 76	1,543 ± 43	1.157
Survival, pct.	93.0 ± 1.0	91.1 ± 0.8	1.408
Individual weight, g/fish	177 ± 3.4	203 ± 4.8	-4.352**
1,000 kg CL/ha per week			
Gross yield, kg/ha	2,324 ± 70	2,333 ± 15	-0.124
Reproduction, kg/ha	221 ± 68	51 ± 43	2.127
Net yield, kg/ha	2,046 ± 76	1,964 ± 17	1.063
Survival, pct.	96.6 ± 0.8	84.8 ± 0.6	11.620**
Individual weight, g/fish	209 ± 7.6	268 ± 7.1	-5.690**

**Seasonal means were significantly different (P<0.01).

Mean net primary production ranged from 1.15 to 6.45 and from 1.49 to 7.90 g O_2/m^3 per day during the rainy and dry seasons, respectively. Net and gross primary production and community respiration all increased significantly with increasing rates of fertilization. Dry-season net primary production for the 500 and 1,000 kg/ha per week treatments was greater than that for the rainy season (Table 13). Water quality concentrations generally increased as chicken litter application rate increased (Table 14). Season did not significantly affect water quality variables. Mean dissolved in-

Table 13. Seasonal Comparison of Primary Productivity and Community Respiration Treatment Means g O_2/m^3 per day; ± S.E.) in 0.1-ha Earthen Ponds Stocked with *Oreochromis niloticus* and Fertilized with Chicken Litter (CL)

Variable	Rainy season	Dry season	t-Value
125 kg CL/ha per week			
Community respiration	5.68 ±0.79	6.66 ±0.67	-0.96
Net primary productivity	1.46 ±0.21	2.29 ±0.27	-2.44
Gross primary productivity	4.31 ±0.55	5.62 ±0.61	-1.60
250 kg CL/ha per week			
Community respiration	9.49 ±1.39	8.29 ±1.16	0.66
Net primary productivity	3.31 ±0.66	2.97 ±0.74	0.34
Gross primary productivity	8.04 ±1.28	7.11 ±1.29	0.52
500 kg CL/ha per week			
Community respiration	11.60 ±0.31	12.11 ±0.41	-1.01
Net primary productivity	4.03 ±0.32	5.51 ±0.31	-3.32*
Gross primary productivity	9.83 ±0.47	11.57 ±0.51	-2.52
1000 kg CL/ha per week			
Community respiration	13.92 ±1.06	13.93 ±0.65	-0.01
Net primary productivity	5.37 ±0.61	7.44 ±0.24	-3.19*
Gross primary productivity	12.33 ±1.12	14.40 ±0.57	-1.66

*Seasonal means were significantly different ($P<0.05$)

Table 14. Means of Water Quality Analyses for Samples Collected Weekly from Ponds Stocked with *Oreochromis niloticus* at 10,000/ha and Fertilized with Different Rates of Chicken Litter

	Weekly chicken litter application							
	125 kg/ha		250 kg/ha		500 kg/ha		1,000 kg/ha	
Variable	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
Soluble orthophosphate, mg/L PO_4-P	1.73	1.94	3.59	2.99	4.17	4.33	3.79	5.80
Total phosphorus, mg/L PO_4-P	2.32	2.44	4.53	3.45	5.40	5.33	5.23	7.38
Organic nitrogen, mg/L	1.26	1.33	1.68	1.47	2.07	2.28	2.48	2.74
Ammonia-nitrogen, mg/L NH_3-N	0.06	0.05	0.07	0.04	0.07	0.05	0.07	0.09
Nitrate-nitrogen, mg/L NO_3-N	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Nitrate-nitrogen, mg/L NO_2-N	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002
Total alkalinity, mg/L $CaCO_3$	101.89	127.58	134.26	126.77	140.25	161.99	160.62	199.70
Chlorophyll *a*, mg/m^3	30.58	50.66	69.96	60.82	115.89	112.98	160.27	175.62
Secchi disk visibility, cm	11.3	16.0	15.9	19.6	16.3	17.3	20.8	23.7
6:00 a.m. dissolved oxygen, mg/L	2.62	2.96	1.42	2.39	0.62	1.00	0.30	0.66
6:00 a.m. water temperature, °C	25.4	24.7	25.5	24.9	25.8	24.9	26.0	25.1

organic nitrogen concentration was low which indicated that primary productivity may have been nitrogen-limited. Indeed, Studies B5 and B6 demonstrated that primary production and fish yields could be increased by supplemental nitrogen fertilization.

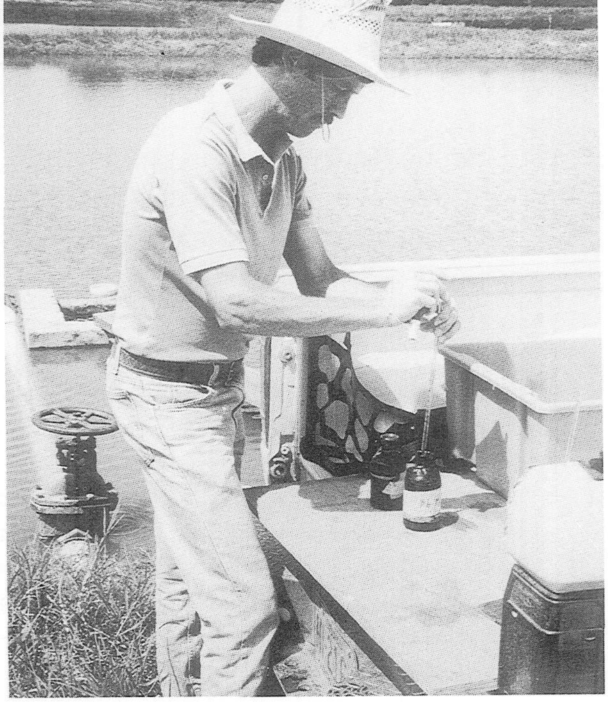
Study B2 demonstrated that chicken litter, applied at 500 kg/ha per week, resulted in greater fish yield than fresh cow manure or high doses of chemical fertilizer alone. This study demonstrated that tilapia yield was increased further through greater applications of chicken litter. At the highest rate of CL fertilization, 1,000 kg DM/ha per week (equivalent to 143 kg DM/ha per day) were being applied to the pond.

STUDY B4. TILAPIA YIELD IN PONDS STOCKED WITH 20,000 FISH/HA AND FERTILIZED WEEKLY WITH CHICKEN LITTER (1,000 KG DM/HA)

Previous fertilization trials were conducted at a fish stocking rate of 10,000/ha. However, many Honduran fish farmers routinely stock fertilized ponds at 20,000 fish/ha. Results of Study B3 demonstrated that the highest tilapia yield was obtained in ponds fertilized with chicken litter weekly at 1,000 kg DM/ha. The objective of this study was to ascertain the effect of doubling stocking rate on fish yield and average individual weight in ponds fertilized weekly with chicken litter at 1,000 kg DM/ha.

On 17 July 1988, three ponds were stocked with tilapia fingerlings (16.5 g/fish) at a rate of 20,000/ha. Ponds were fertilized weekly with layer chicken litter at 1,000 kg DM/ha. Ponds were harvested after 150 days.

At harvest, mean gross yield was 2,203 kg/ha, while the mean net yield was 1,873 kg/ha. Fish survival averaged 92 percent. Mean gross yield was similar to that obtained during Study B3 (2,262 kg/ha). The effect of stocking rate on final fish size was clear: mean individual weight at 20,000/ha was 120 g/fish, half that obtained at 10,000 fish/ha. Fish harvested from this experiment were barely of marketable size. A longer production cycle probably would have demonstrated even greater growth depression at the higher density. In maunured ponds, the lower stocking rate appears advisable for commercial production.


Dr. David Teichert-Coddington performing water analyses.

STUDY B5. SUPPLEMENTAL NITROGEN FERTILIZATION OF ORGANICALLY FERTILIZED PONDS

Study B3 suggested that primary productivity and fish yield in organically fertilized ponds at El Carao were limited by dissolved inorganic nitrogen concentration. The objective of this study was to determine if supplementation of organic fertilization with nitrogen fertilizer would increase primary productivity and tilapia yield.

Six ponds were stocked on 13 February 1990 with Nile tilapia at 10,000/ha, and guapote tigre (*Cichlasoma managuense*) at 250/ha to prey upon any tilapia offspring produced. All ponds were fertilized weekly with chicken litter at 750 kg DM/ha, and three ponds also received urea fertilizer (46-0-0) weekly at 10 kg N/ha. Ponds were harvested 126 days after stocking. Chlorophyll *a*, total ammonia nitrogen (TAN), total phosphorus, and filterable orthophosphate were determined on a regular basis.

Gross fish yield and average fish size at harvest were not significantly greater in urea-fertilized ponds (Table 15). Mean chlorophyll *a* and TAN were significantly greater in ponds treated with urea, whereas total phosphorus and filterable orthophosphate were significantly less (Table 15). Nitrogen supplementation increased dissolved inorganic nitrogen concentrations and plankton biomass. Lower filterable orthophosphate resulted from greater phosphorus uptake by phytoplankton.

TABLE 15. TILAPIA PRODUCTION AND WATER QUALITY DATA (MEAN ± S.E.) FROM 0.1-HA EARTHEN PONDS STOCKED WITH MALE *OREOCHROMIS NILOTICUS* AND FERTILIZED WITH CHICKEN LITTER (750 KG DRY MATTER/HA PER WEEK) OR CHICKEN LITTER SUPPLEMENTED WITH UREA (10 KG N/HA PER WEEK)

	Treatment	
Variable	Manure only	Manure plus urea
Gross yield, kg/ha per 126 d	1,401 ± 22	1,527 ± 132
Mean individual weight, g/fish	166 ± 2.4	177 ± 5.0
Survival, pct.	84 ± 1.1	86 ± 5.9
Chlorophyll *a*, mg/m^3	344 ± 32.9	471 ± 13.0*
Total ammonia-nitrogen, mg/L NH_3-N	0.09 ± 0.011	0.16 ± 0.016*
Filterable orthophosphate, mg/L PO_4-P	2.66 ± 0.118	1.93 ± 0.168*
Total phosphorus, mg/L PO_4-P	4.40 ± 0.274	3.48 ± 0.198

*Treatment means were significantly different ($P<0.05$); horizontal comparisons only.

STUDY B6. VARIATION OF NUTRIENT INPUT C:N RATIO BY SUPPLEMENTING ORGANICALLY FERTILIZED PONDS WITH NITROGEN

Organically fertilized ponds in Honduras have consistently low concentrations (< 0.1 mg/L) of total ammonia- and nitrate-nitrogen. Low dissolved inorganic nitrogen concentrations may indicate nitrogen-limitation of primary productivity. Results of Study B5 suggested the possibility for increasing primary production and tilapia yield by supplementing organic fertilizers with nitrogen. The objective of this research was to quantify the effect of different rates of nitrogen supplementation on primary productivity and tilapia yield in organically fertilized ponds.

Twelve ponds were randomly assigned to four treatments. All ponds were fertilized weekly with chicken litter at 750 kg DM/ha. In addition, urea was applied to achieve C:N ratios of 11:1 (corresponds to no supplemental N), 8:1, 6:1, or 4:1. Urea application rates were calculated based on frequent determinations of manure nitrogen and organic carbon. Ponds were stocked on 26 February 1991 with tilapia fingerlings at 20,000/ha. *Cichlasoma managuense* fingerlings were stocked at 500/ha to prey upon any tilapia reproduction. All ponds were harvested 154 days after stocking.

Mean total nitrogen and organic carbon composition of chicken litter was 2.3 and 25.0 percent, respectively. Total weekly nitrogen inputs, including supplemental urea, ranged from 17.1 kg/ha for control ponds to 46.9 kg/ha for C4:N1 ponds (Table 16). Response of fish yield to increased levels of supplemental nitrogen was discontinuous (Table 16) with large variation in some treatments. Only the C6:N1 ratio resulted in significantly increased fish yield compared with the control. These yields were

TABLE 16. WEEKLY INPUTS OF CARBON AND NITROGEN AS CHICKEN LITTER, AND NITROGEN AS UREA TO MAINTAIN C:N RATIOS OF 8:1, 6:1 OR 4:1 COMPARED WITH 11:1 FOR ONLY CHICKEN LITTER (CONTROL). MEAN (± S.E.) GROSS YIELD AND INDIVIDUAL WEIGHT OF *OREOCHROMIS NILOTICUS* STOCKED IN 0.1-HA EARTHEN PONDS AT 20,000 MALES/HA FOR 154-DAYS GROW-OUT PERIOD

Treatment	Chicken litter C	Chicken litter N	Supplemental N	Total N	Gross fish yield	Mean weight
	kg/ha	*kg/ha*	*kg/ha*	*kg/ha*		*g/fish*
C11:N1 (Control)	187.8	17.1	0.0	17.1	2,825 ± 97.1	154 ± 10.1
C8:N1	187.8	17.1	6.3	23.3	2,764 ± 192.9	150 ± 10.1
C6:N1	187.8	17.1	14.1	31.1	3,685 ± 94.1	222 ± 1.49
C4:N1	187.8	17.1	29.9	46.9	2,709 ± 508.8	166 ± 19.5

substantially higher than previously recorded yields from fertilized ponds at El Carao. Analyses were complicated by complete fish mortalities in one replicate pond of each treatment except the control. The first die-off occurred during the second month in treatment C6:N1, 12 hours after ponds were fertilized with urea. A spike in un-ionized ammonia was suspected, although early morning total ammonia (< 0.1 mg/L) and pH (8.2) were low two days before the kill. The weekly urea dose for all treatments subsequently was divided into two applications per week. A 95 percent fish mortality in pond B9 (treatment C8:N1) occurred during the last month of the study; fish growth had been good up to that point. A complete mortality in pond B10 (treatment C4:N1) occurred during the last month, following several months of low growth (Figure 13) apparently induced by a heavy blue-green algae bloom. Mean fish yield showed a tendency to increase with increasing chlorophyll *a* and primary productivity, but correlations were not significant.

Blue-green algae (*Anacystis* sp.) became dominant in pond B10 within six weeks of stocking. A thick surface scum formed, and eventually covered half the pond. Fish growth ceased after 2 to 3 months, although primary productivity was high and early morning dissolved oxygen concentrations were not lower than other ponds. Stress from a combination of blue-green algae toxicity and relatively high early morning total ammonia (1.02 mg/L) and pH (8.9) were the presumed causative factors of the fish mortality. Pond B7 (treatment C4:1N) also developed a heavy blue-green surface scum, and fish yield (2,191 kg/ha) in this pond was relatively low compared to 3,186 kg/ha in the remaining replicate pond, where blue-green algae were not apparent. A blue-green algae scum developed to a much lesser extent on pond B5 (treatment C6:N1), but was not encountered on other ponds in this treatment. These were the first persistent blooms of blue-green algae recorded at El Carao during the PD/A CRSP. High nitrogen input apparently promoted blue-green algae growth.

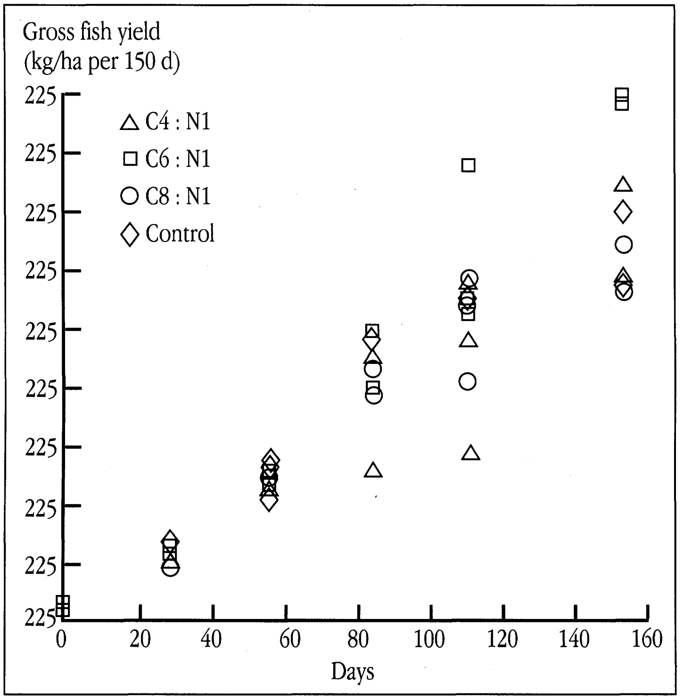


Figure 13. Tilapia growth in ponds fertilized with only chicken litter (C11:N1, control), or chicken litter with supplemental urea to maintain C:N ratios at 8:1, 6:1, or 4:1.

STUDY B7. SUBSTITUTION OF INORGANIC NITROGEN AND PHOSPHORUS FOR CHICKEN LITTER IN PRODUCTION OF TILAPIA

Nitrogen supplementation of organically fertilized fish ponds can increase primary productivity and fish yields. Results of Study B6, where the C:N ratio of organic fertilizer was manipulated, suggested that weekly total N input near 25 kg/ha would increase fish production without wasting nitrogen. The objective of this study was to ascertain if organic inputs could be decreased through substitution with inorganic N and P.

The study was repeated during cool and warm seasons of the year. The methodology was equal during both seasons except where indicated. Ponds were randomly assigned to treatments, each replicated three times. Chicken litter was applied weekly to ponds at 750 (CL750), 500 (CL500), 250 (CL250), or 0 (CL0) kg DM/ha during the cool season, and 500, 250, or 0 kg DM/ha during the warm season. Urea was applied to maintain weekly total

Table 17. Mean Weekly Inputs of Urea and Diammonium Phosphate (DAP) for Different Rates of Chicken Litter Application (kg dry matter/ha per week)

	Cool season		Warm season	
Treatment	Urea	DAP	Urea	DAP
	kg/ha	*kg/ha*	*kg/ha*	*kg/ha*
750	29.7	0	-	-
500	37.5	0	33.5	9.5
250	41.3	9.9	37.6	15.4
0	40.6	31.0	39.5	26.8

N inputs at about 25 kg/ha. Diammonium phosphate (DAP) was added as needed to maintain N:P ratios of at least 4:1. Manure was frequently analyzed for nitrogen and phosphorus. Fifty-five and 100 percent of the N and P, respectively, in chicken litter was assumed available for plankton use during the cool season. During the warm season, 50 percent of N and P in manure was assumed to be available for phytoplankton. Mean weekly inputs of inorganic fertilizer during cool and warm seasons are summarized in Table 17. Nitrogen and phosphorus constituted 2.4 and 1.7 percent, respectively, of chicken litter dry matter during the cool season, and 2.4 and 1.3 percent during the warm season.

Ponds were stocked with tilapia fingerlings at 20,000/ha. During the warm season all fish were normal colored Nile tilapia, but during the cool season, half of the tilapia were normal colored *O. niloticus* and half were red tilapia that had been crossed repeatedly with *O. niloticus* (Study D4). Guapote tigre (*Cichlasoma managuense*) fingerlings were stocked at 500/ha to predate on tilapia reproduction. Cool- and warm-season studies began on 5 September 1991 and 12 March 1992, respectively; each study lasted 152 days.

Cool season (September 1991 - February 1992)

Mean gross fish yields and individual weights were not significantly different among treatments (Table 18). Mean individual weights of normal colored and red tilapia were similar, but mean gross yield of normal colored tilapia (1,353 kg/ha) was 75 percent greater than yield of red tilapia

Table 18. Summary of Fish Production Data from 0.1-ha Earthen Ponds in Honduras. Ponds were Fertilized Weekly with Chicken Litter at 0, 250, 500 or 750 kg/ha. Urea and Diammonium Phosphate were Applied Weekly to Maintain Total N Input of 25 kg/ha and an N:P Ratio of 4:1. Duration of each Experiment was 152 d

	Nile tilapia			Red tilapia			Guapote tigre*			Tilapia offspring	Gross fish yield
Treatment	Yield	Weight	Survival	Yield	Weight	Survival	Yield	Weight	Survival		
	kg/ha	*g/fish*	*Pct.*	*kg/ha*	*g/fish*	*Pct.*	*kg/ha*	*g/fish*	*Pct.*	*kg/ha*	*kg/ha*
Cool season experiment											
CL 0	1,057 a	118 a	87 a	783 a	127 a	63 a	5	31	29	19	1,865 a
CL 250	1,507 a	172 a	88 a	838 a	172 a	50 a	5	34	29	1	2,350 a
CL 500	1,567 a	166 a	94 a	859 a	174 a	49 a	8	30	40	2	2,435 a
CL 750	1,312 a	140 a	94 a	609 a	148 a	41 a	5	35	28	25	1,950 a
Warm season experiment											
CL 0	2,045 a	118 b	85 a	--	--	--	5	21	49	29	2,079 a
CL 250	2,317 a	162 ab	71 a	--	--	--	6	32	36	16	2,339 a
CL 500	3,560 a	231 a	77 a	--	--	--	4	58	17	20	3,584 a

* *Chichlasoma managuense.*

ab Means in columns within experiments followed by the same letter are not significantly different (P>0.05).

Table 19. Means of Water Quality Variables in 0.1-ha Earthen Ponds in Honduras. Ponds Were Fertilized Weekly with Chicken Litter at 0, 250, 500 or 750 kg Dry matter/ha. Urea and Diammonium Phosphate were Applied Weekly to Maintain Total N Input of 25 kg/ha and an N:P Ratio of 4:1. Duration of Each Experiment was 152 d.

Treatment	pH	Total alkalinity	Organic nitrogen	Total ammonia	Total phosphorus	Filterable orthophosphate	Seechi disk visibility	Chlorophyll *a*	Net primary production
		mg/L $CaCO_3$	*mg/L*	*mg* NH_3*-N/L*	*mg/L*	*mg* PO_4*-P/L*	*cm*	*mg/*m^3	*mg* 0_2*/L per d*
Cool season experiment									
CL 0	9.58 a	67.5 c	3.44 c	0.403 b	2.64 b	1.69 a	13.6 a	495 a	9.6 b
CL 250	9.64 a	89.5 b	3.95 b	0.311 b	2.67 b	1.38 a	12.2 a	703 a	11.3 a
CL 500	9.50 a	99.2 b	4.12 b	0.199 a	2.85 b	1.45 a	11.4 a	812 a	12.9 a
CL 750	9.45 a	126.1 a	4.42 a	0.153 a	3.70 a	1.80 a	10.6 a	888 a	12.6 a
Warm season experiment									
CL 0	9.85 a	80.7 a	3.14 c	0.323 a	1.99 b	1.16 a	19.5 b	333 b	8.1 b
CL 250	9.45 a	92.0 a	3.59 b	0.280 a	2.69 b	1.37 a	13.5 a	613 a	11.4 a
CL 500	9.61 a	103.6 a	3.90 a	0.169 a	2.77 b	1.30 a	12.2 a	705 a	12.3 a

(772 kg/ha). Yield differences between the two types of tilapia were related to survival. Mean survival of normal colored tilapia (90.9 percent) was 79 percent greater than that of red tilapia (50.8 percent). Red tilapia suffered a greater rate of predation by ospreys as witnessed by field workers. Also, our experience is that the red tilapia does not survive handling and environmental stress as well as the normal colored tilapia (see Study D4).

Covariant analyses of fish growth indicated significant differences among treatments. Growth was curvilinear for both normal colored and red tilapia in all treatments except CL250, where it was linear. Growth stopped after the 4th month in the CL0 treatment.

Net primary production, chlorophyll *a* , total-P, organic-N, total alkalinity, and total hardness significantly decreased with decreasing litter input; total ammonia and Secchi disk visibility significantly increased with decreasing litter input (Table 19). There were no significant differences among treatments for pH or filterable orthophosphate (Table 19).

WARM SEASON (MARCH - AUGUST 1992)

Mean individual weight of tilapia in CL500 was significantly greater than weight of fish in CL250 and CL0 (Table 18). Gross fish yield at the highest level of organic fertilization was 53 and 72 percent greater than at the intermediate and lowest levels, respectively. However, differences were not statistically significant, with high coefficients of variation at the intermediate (42 percent) and lowest (48 percent) organic fertilization levels. Mean yield of the CL250 treatment was lowered by 55 percent mortality in one replicate.

Analysis of covariance indicated that the slopes of mean fish growth curves were significantly different among the three treatments ($P < 0.0001$). Fish growth in ponds receiving no chicken litter practically stopped after three months. Growth of fish in the two manured treatments was linear, although growth in the CL 250 treatment appeared to slow during the last six weeks.

Net primary production, chlorophyll *a* , total-P, organic-N, total alkalinity, and total hardness significantly decreased with decreasing litter input; total ammonia and Secchi disk visibility significantly increased with decreasing litter input (Table 19). There were no significant differences among treatments for pH or filterable orthophosphate.

Except for CL0, fish yields were generally lower during the cold season relative to the hot season. Poorer yields in the cold season can be attributed to lower survival and growth. Fish yields for the non-manured treatment were similar during both seasons; cessation of fish growth before harvest indicated that carrying capacity had been reached. Lower temperatures during the cold season delayed achievement of carrying capacity until the 4th month, whereas it was reached in three months during the hot season.

Primary productivity was similar during both seasons for each level of CL input. During each season, primary productivity decreased with decreasing CL input. The reduction in productivity was not related to a lack of N and P, however. Total ammonia nitrogen actually increased with decreased CL input because of lack of absorption by phytoplankton. Filterable orthophosphate was not different among treatments; furthermore, orthophosphate levels were high in all ponds and presumably would not limit productivity. Chicken litter may have provided a micronutrient that was limiting phytoplankton growth. A more probable explanation was that decomposition of chicken litter made more CO_2 available for phytoplankton use. Correlation of alkalinity and hardness levels with increasing CL input supports this supposition. Carbon dioxide increases the dissolution of calcite and dolomite, thereby forming bicarbonate (alkalinity) and Ca^{2+} and Mg^{2+} (hardness). Higher CL inputs resulted in more CO_2 evolution, which increased total alkalinity and total hardness. Phytoplankters would have had greater CO_2 available to them directly or indirectly through the bicarbonate-carbonate system. Availability of CO_2 through the alkalinity system decreases drastically, however, at the high pH values measured during these trials, thereby accentuating low CO_2 problems in non-organically fertilized ponds.

Primary productivity was clearly benefited by organic fertilization during both seasons. It appears from the cold season study that weekly CL inputs beyond 500 kg/ha were not correlated with higher increases of primary productivity. Fish yield was not benefited by higher primary productivity during the cold season, because colder temperatures and reduced fish densities would not allow fish biomass to take advantage of higher nutrient availability. However, fish clearly benefited from higher natural productivity during the hot season.

Substitution of inorganic N for organic inputs has allowed for weekly chicken litter fertilizer rates to be reduced from 750 to 500 kg/ha without a decrease in fish production. Less organic input implies less biological oxygen demand, which in turn may decrease community respiration rates that have resulted in nocturnal hypoxia. Results of Study E2 demonstrated that chronic hypoxia can decrease tilapia yields.

COMBINED FERTILIZATION AND FEED STUDIES

Many fish farmers use commercially-formulated rations in order to obtain faster growth and greater fish yields. Fish feed is expensive and may not actually improve profitability of fish farming, even if greater yields and larger fish result. Published data indicate that efficiency of nutritionally incomplete feeds can be increased greatly if supplemented by natural food organisms stimulated by pond fertilization. We undertook a series of studies to quantify how best to combine feeds with fertilizers in semi-intensive tilapia monoculture ponds. Formulated feed, a pelleted marine shrimp feed, used in this research was procured locally. Economic evaluation of management systems tested is reported in the economic analysis section of this report.

STUDY C1. EFFECT OF STOCKING RATE ON YIELD OF TILAPIA OFFERED A FORMULATED DIET

Stocking rates for monosex growout of tilapia traditionally range from 10,000 to 20,000 fish/ha in ponds managed with neither water exchange nor mechanical aeration. Under these conditions 150- to 400-g fish are harvested after five to six months of grow-out. In rural areas and in smaller cities in Honduras fish weighing 150 to 200 g are easily sold, while larger fish (400 g) are sold more easily in metropolitan areas. It is well known that stocking rate affects the average size of fish at harvest, but this relationship is influenced by the quality and quantity of nutrient input. The objective of this study was to determine the effect of stocking rates on monosex production of tilapia offered a prepared ration.

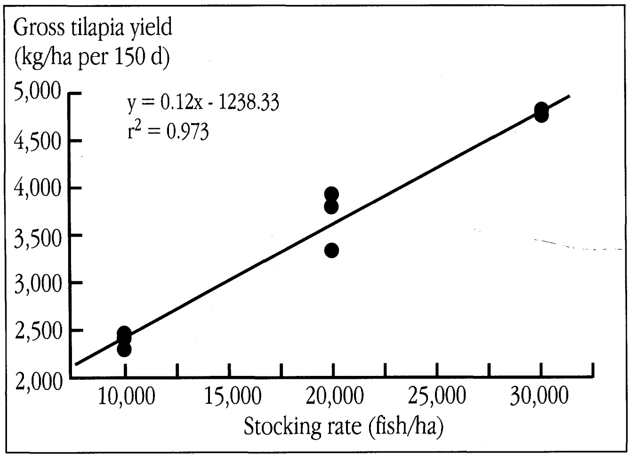


Figure 14. Relationship between gross tilapia yield and stocking rate in 0.1-ha earthen ponds. Experiment lasted 150 days and fish were fed a 23 percent protein formulated diet.

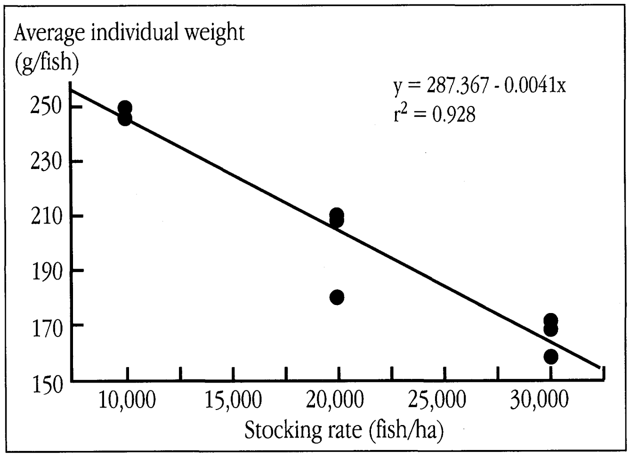


Figure 15. Relationship between mean individual fish weight at harvest and stocking rate. Nile tilapia were reared for 150 days in 0.1-ha earthen ponds and fed a formulated ration (23 percent protein).

Nine ponds were used for this completely randomized design study where stocking rates of 10,000, 20,000 and 30,000 tilapia/ha were tested. Tilapia fingerlings with average weight of 17 g were stocked into ponds on 17 July 1987. Ponds were fertilized once with chicken litter (1,000 kg DM/ha) upon initiation of the experiment. Fish were fed a 23 percent protein pelleted ration six days per week. Feeding rates, based on the tilapia biomass in each pond, were 7 percent during the first month, 5 percent during the second month, and 3 percent during months three to five. The feeding rate was adjusted monthly based upon seine samples and assuming 100 percent survival. All ponds were harvested 150 days after stocking. The feed conversation ratio (FCR) was calculated from the total amount of feed offered fish divided by net fish production.

Mean gross fish production increased significantly as stocking rate increased (Figure 14), varying from 2,410 to 4,817 kg/ha (Table 20). Tilapia survival was similar among treatments, averaging 95 percent. Mean individual fish size ranged from 166 to 249 g at harvest, and decreased linearly as the stocking rate increased (Figure 15). Fish production was proportional to

TABLE 20. SUMMARY (MEAN ± S.E.) OF HARVEST DATA AND FEED CONVERSION RATIO (FCR) FOR PRODUCTION OF MALE OREOCHROMIS NILOTICUS STOCKED INTO 0.1-HA EARTHEN PONDS AT THREE RATES. FISH WERE FED A 23 PERCENT PROTEIN PELLETED RATION

Stocking rate	Final size	Survival	Gross yield	Net yield	FCR
fish/ha	*g/fish*	*Pct.*	*kg/ha per 150 days*		
10,000	249 ± 0.7 a	97.1 ± 1.8 a	2,410 ± 47 a	2,245 ± 46 a	2.0 ± 0.11 a
20,000	200 ± 9.9 b	92.5 ± 0.8 a	3,708 ± 188 b	3,379 ± 186 b	2.7 ± 0.01 c
30,000	166 ± 3.9 c	96.4 ± 1.9 a	4,817 ± 10 c	4,323 ± 16 c	2.4 ± 0.05 b

abc Column means followed by the same letter were not significantly different (P>0.05).

stocking rate because the tilapia biomass did not reach the critical standing crop in any treatment. Mean FCR varied from 1.96 to 2.74. The high FCR observed in the 20,000 tilapia/ha treatment may have been influenced by lower observed fish survival.

Since no preferential price has been established for larger fish to date, production at the 10,000 tilapia/ha rate was not justified. Mean fish size at the high stocking rate was near to the apparent minimum size accepted by consumers and culture during cooler times of the year may result in smaller fish, making commercialization more difficult. High yields of readily marketable fish were obtained at a stocking rate of 20,000 tilapia/ha.

STUDY C2. PRODUCTION OF TILAPIA USING COMBINATIONS OF CHICKEN LITTER AND FEED

Previous experience indicated that tilapia growth in organically fertilized ponds decreased with time because available natural food no longer sustained fast growth. Feed utilization efficiency might be improved if a fertilizer could be used to stimulate natural pond productivity during the early part of the culture period, followed by a more expensive, formulated feed as the culture period progressed. The objective of this study was to test the effects of several combinations of chicken litter and feed in the production of tilapia.

Nine ponds were used for this completely randomized design study where the production systems tested were: feed only (FO); layer chicken litter only (1,000 kg DM/ha per week) for the first 60 days, followed by feed only (3 percent of tilapia biomass) (CL/F); layer chicken litter (500 kg DM/ha per week) and feed (1.5 percent of the tilapia biomass) throughout the duration of the experiment (CL+F). Tilapia fingerlings (mean weight of 19 g) were stocked into ponds at 20,000 fish/ha on 20 January 1988. Fertilization was initiated once ponds were full. Fish were fed a pelleted ration (23 percent protein) six days per week. Feeding rate was adjusted monthly based upon pond seine samples and assuming 100 percent survival. In the feed only treatment, the feeding rate, as a percent of the tilapia biomass in each pond, was 7 percent for the first two weeks, 5 percent for the next two weeks, and 3 percent thereafter. Ponds were harvested 151 days after stocking.

Fish harvest demonstration at research station.

At harvest it became apparent that fish loss had occurred in two ponds shortly before harvest because the total weight and number of fish harvested was well below that of the remaining replicates, but average fish weight was similar, indicating that low survival was not related to stocking. Data from these ponds was excluded from the statistical analyses and subsequent discussion.

Mean gross fish yield was similar in all treatments, ranging from 4,351 to 5,305 kg/ha (Table 21). Net fish yield did not differ significantly among treatments, but mean net fish yield in FO treatment was 24 percent higher than CL + F and 12 percent higher than CL/F (Table 21).

TABLE 21. MEAN (± S.E.) FINAL SIZE, SURVIVAL, YIELD, AND FEED CONVERSION RATIO (FCR) FOR PRODUCTION OF MALE *OREOCHROMIS NILOTICUS* (20,000/HA) IN 0.1-HA EARTHEN PONDS RECEIVING DIFFERENT COMBINATIONS OF CHICKEN LITTER AND FEED

Treatment[1]	Final size	Survival	Gross yield	Net yield	FCR
	g/fish	*Pct.*	*kg/ha per 150 d*		
FO	262 ± 19.1 a	86.9 ± 2.6 a	5,305 ± 351 a	4,946 ± 350 a	1.8 ± 0.14 a
CL + F	251 ± 2.3 a	82.3 ± 2.3 a	4,351 ± 220 a	3,984 ± 218 a	1.0 ± 0.01 b
CL/F	284 ± 2.8 a	81.4 ± 4.3 a	4,794 ± 311 a	4,430 ± 310 a	1.5 ± 0.01 ab

[1] FO:feed only; CL + F: layer chicken litter (500 kg DM/ha per week) and feed, both throughout the duration of the experiment; CL/F; layer chicken litter only (1,000 kg DM ha per week) for the first 60 days, followed by feed only.

ab Column means followed by the same letter were not significantly different (P>0.05).

After 30 days, primary productivity in the CL/F treatment was significantly greater than in the remaining treatments (Table 22). Fish growth during the first month did not differ among treatments. Thus, tilapia growth in the CL/F treatment

Table 22. Mean (± S.E.) Primary Productivity and Community Respiration (g O_2/m^3 per day) for Specified Time Intervals in 0.1-ha Earthen Ponds Stocked with male *Oreochromis niloticus* (20,000/ha) and Receiving Feed Only and Combinations of Chicken Litter and Feed

	Primary productivity		
Treatment[1]	Gross	Net	Community respiration
DAYS 1 to 30			
FO	7.74 ± 0.34 b	3.19 ± 0.37 b	7.74 ± 0.34 b
CL + F	9.47 ± 0.42 b	4.37 ± 0.45 ab	9.47 ± 0.42 ab
CL/F	13.39 ± 0.42 a	6.46 ± 0.45 a	13.39 ± 0.42 a
DAYS 1 to 60			
FO	6.98 ± 0.47 c	2.94 ± 0.25 c	8.07 ± 0.82 c
CL + F	9.91 ± 0.58 b	4.39 ± 0.31 b	11.04 ± 1.00 b
CL/F	13.72 ± 0.58 a	6.61 ± 0.31 a	14.21 ± 1.00 a
DAYS 61 to 151			
FO	11.69 ± 1.06 b	6.33 ± 0.74 b	10.72 ± 1.25 b
CL + F	13.77 ± 1.30 b	7.47 ± 0.91 a	12.61 ± 1.53 ab
CL/F	16.80 ± 1.30 a	9.45 ± 0.91 a	14.76 ± 1.53 a
151-d GROW-OUT PERIOD			
FO	10.12 ± 1.42 b	5.20 ± 1.07 b	9.84 ± 1.20 c
CL + F	12.49 ± 1.74 b	6.44 ± 1.31 b	12.09 ± 1.47 b
CL/F	15.77 ± 1.74 a	8.50 ± 1.31 a	14.57 ± 1.47 a

[1] FO:feed only; CL + F: layer chicken litter (500 kg DM/ha per week) and feed, both throughout the duration of the experiment; CL/F: layer chicken litter only (1,000 kg DM ha per week) for the first 60 days, followed by feed only.

abc Means followed by the same letter were not significantly different (P>0.05). Vertical comparisons within time period only.

resulted from primary production, whereas primary production and feed contributed to fish growth in the other two treatments. After 60 days, mean individual weight in the FO treatment (94 g/fish) was significantly greater than the 74 g/fish in the CL/F treatment, which indicated that available natural food in CL/F ponds was insufficient to maintain rapid growth. Although gross primary productivity was significantly greater for the CL/F treatment during the first 60 days (Table 22), the addition of feed thereafter was necessary to maintain fast growth. Mean tilapia standing crop on day 61 in CL/F ponds was estimated at 1,496 kg/ha. Initiation of supplemental feeding in the CL/F treatment significantly increased tilapia growth from a mean of 1.0 g per day on day 61 to 2.0 g per day on day 91. At harvest, no significant difference in mean fish size among treatments was observed and average final size for fish from all treatments was 265 g/fish.

Feed conversion ratio (FCR) varied significantly among treatments (Table 21). FCR for the feed only treatment (1.8) was greater than the 1.0 FCR for the chicken litter plus feed treatment. The FCR of 1.0 in the latter treatment was attributed to the contribution of natural food, stimulated by the organic fertilization. An intermediate FCR was observed for the chicken litter followed by feed treatment, indicating feed was not necessary during the first two months of growout. Substituting feed with intensive, organic fertilization during the first two months of growout resulted in a 27 percent reduction in total feed requirement compared to the feed only treatment. Further feed savings were achieved with the chicken litter plus feed treatment where the mean total feed utilization was 3,764 kg/ha, or 42 percent of that for the feed only treatment. Results of economic analysis (economic analysis section) indicated that net returns were higher where chicken litter was substituted for feed. It should be noted that the FCR for the feed only treatment was less than the FCR reported for the same stocking rate in Study C1, implying that the initial feeding rates, of 7 percent and 5 percent of the tilapia biomass, were high.

STUDY C3. SUPPLEMENTAL FEEDING OF TILAPIA AT VARIOUS RATES

Study C2 demonstrated that a combination of organic fertilization and supplemental feeding resulted in similar fish yields and better feed conversion than where feed only was used. The objective of this study was to determine a practical rate of supplemental feeding to increase profitability.

Oreochromis niloticus fingerlings (18 g) were stocked into ponds at 10,000/ha. Twelve ponds were randomly assigned to four treatments. Treatments were: chicken litter only, or chicken litter plus feed (23 percent protein) at 0.5, 1, or 2 percent of fish biomass. Chicken litter was applied to ponds weekly at 500 kg DM/ha. Feed was offered to fish six days per week, and quantities were adjusted weekly based on projected growth between monthly samples of fish weight. The experiment was initiated on 11 August 1988 and was terminated 132 days later.

At harvest, mean individual weights were 132, 136, 162, and 170 g/fish for 0, 0.5, 1, and 2 percent feed treatments, respectively. Mean gross yields were 1,234, 1,261, 1,473, and 1,604 kg/ha per 132 days, respectively. Mean individual weight and gross yield for the 1 and 2 percent feed treatments were significantly greater than for the other two treatments. Fish production was low compared to other years at El Carao, especially considering that fish were offered a commercial ration in addition to fertilization. This study was carried out during the cold season when water temperatures frequently fell below optimal growth levels. Water temperatures as low as 17.4 °C were recorded. Growout during the hot season would have provided better information regarding potential benefits of supplemental feeding.

STUDY C4. DELAYS IN INITIATION OF SUPPLEMENTAL FEEDING

In Study C2, initiation of supplemental feeding 60 days after stocking yielded 12 percent less fish but required 27 percent less feed than the treatment where feed was offered from the beginning of the trial. These results suggested that supplemental feeding might be initiated even later, especially at lower stocking rates, without reducing fish yield. The objective of this experiment was to determine the effect of substituting chicken litter for feed for progressively longer periods on tilapia yield.

Four treatments were assigned to 12 ponds. Treatments tested were: (1) weekly applications of chicken litter at 1,000 kg DM/ha; (2) chicken litter (1,000 kg ha per week) for the first month, followed by feeding; (3) chicken litter (1,000 kg DM ha per week) for two months, followed by feeding; and (4) chicken litter (1,000 kg DM ha per week) for three months, followed by feeding. Feed (25 percent protein) was offered six days per week at 3 percent of fish biomass per day. Ponds were stocked with tilapia (average weight 28 g) at 10,000/ha and guapote tigre (*Cichlasoma managuense*) at 450 fish/ha to control tilapia reproduction. Ponds were stocked on 27 July 1989 and harvested 147 days later.

TABLE 23. MEAN (± S.E.) GROSS YIELD, FINAL INDIVIDUAL WEIGHT AND SURVIVAL OF TILAPIA STOCKED AT 10,000/HA IN 0.1-HA EARTHEN PONDS THAT RECEIVED COMBINATIONS OF CHICKEN LITTER AND FEED APPLICATIONS

Treatment	Gross yield	Individual weight	Survival
	kg/ha per 147 days	*g/fish*	*Pct.*
Chicken litter only	1,779 ± 80 a	206 ± 9.1 a	86 ± 0.1 a
Chicken litter 1 month, then feed	2,349 ± 142 b	276 ± 16.2 b	85 ± 3.0 a
Chicken litter 2 months, then feed	2,196 ± 101 b	256 ± 8.6 b	85 ± 1.2 a
Chicken litter 3 months, then feed	2,223 ± 170 b	258 ± 16.7 b	86 ± 2.0 a

ab Means within column followed by the same letter were not significantly different ($P<0.10$)

Gross tilapia yield and mean individual weight were significantly less in ponds fertilized with only chicken litter (Table 23). Initiating feeding after one month, however, provided no significant advantage over waiting three months to begin feeding. These results confirmed those of earlier studies at El Carao, which demonstrated that tilapia yields could be increased with feeds, but that feeding efficiency could be increased significantly by substituting organic fertilization for feeding during the early part of the grow-out cycle. Tilapia yields in this study were lower than those attained in earlier research where chicken litter was substituted for feed because a lower stocking rate was used. Tilapia stocking rate should be at least two fish/m^2 when feed is used (economic analysis section).

OTHER SPECIES STUDIES

Monosex culture of tilapia has been practiced in Honduras since the early 1980s. While the goal of monosex production has been to eliminate the production of tilapia offspring during the grow-out cycle, a few female tilapia were stocked inadvertently and resulted in some reproduction. A native predator fish was selected to be co-stocked with tilapia to prey upon tilapia offspring. Stocking of more than one species with nonoverlapping food habits results in greater fish yields. A series of studies was conducted to investigate polyculture systems of interest in Honduras that were based on native and exotic species.

TABLE 24. SUMMARY OF TILAPIA REPRODUCTION AND GUAPOTE TIGRE YIELD RESULTS WHEN GUAPOTE WERE STOCKED AT FIVE PERCENT OF STOCKED TILAPIA TO PREY UPON TILAPIA OFFSPRING PRODUCED

Tilapia stocking rate	Guapote stocking rate	Tilapia reproduction	Guapote		
			Mean weight	Gross yield	Survival
No./ha	*No./ha*	*kg/ha*	*g/fish*	*kg/ha per 150 d*	*Pct.*
2,500	125	232 a	172 a	16.7 a	65.0 a
10,000	500	11 b	117 b	36.1 b	61.5 a
20,000	1,000	2 b	87 c	53.2 c	61.3 a

abc Means within columns followed by different letter are significantly different ($P < 0.01$).

STUDY D1. RELATIONSHIP BETWEEN GUAPOTE TIGRE STOCKING RATE AND TILAPIA REPRODUCTION

Sex reversal and manual separation of male fish from mixed-sex populations usually are not 100 percent effective in excluding females from the grow-out pond. Guapote tigre (*Cichlasoma managuense*), a native cichlid piscivore, were included regularly in grow-out ponds after 1987 to control tilapia reproduction. Guapote initially were stocked at rates of one per 10 to 20 tilapia, depending on guapote availability. The objective of this study was to determine if optimum stocking rate of a predator was a function of tilapia stocking rate.

Twelve ponds were assigned randomly to three treatments. Treatments tested were tilapia stocking rates of 2,500, 10,000, and 20,000/ha. Tilapia fingerlings (29 g) were stocked in ponds on 3 February 1989. Two replicate ponds per treatment were stocked with sex-reversed males, and the remaining two ponds were stocked with males that had been manually selected from a mixed-sex population. Guapote fingerlings (22 g) were stocked in all ponds at one fish per 20 tilapia stocked. Ponds were fertilized weekly with CL at 750 kg DM/ha. Ponds were harvested after 150 days. Tilapia production data are reported in Study E3.

Guapote controlled tilapia reproduction more effectively at the moderate and high tilapia stocking rates than at the low stocking rate (Table 24). Survival was not different among treatments. Mean individual guapote weight increased with decreasing tilapia stocking rate, while guapote yield increased with increasing tilapia stocking rate. We concluded that insufficient guapote to control reproduction were stocked at the low tilapia stocking rate, while more guapote than necessary were stocked in the high tilapia stocking rate treatment.

Adequate numbers of guapote are needed to patrol a given pond area regardless of tilapia stocking rate. Insufficient numbers of guapote will result in poor reproduction control, while excessive numbers of guapote stocked will result in small guapote at harvest. Large numbers of similar-sized guapote fingerlings are difficult to produce in ponds (Study A4) because they are predacious. Therefore, the minimum number of guapote necessary to control reproduction are desired for stocking with tilapia. The stocking rate of 500 guapote/ha resulted in good control of tilapia reproduction. Subsequent tests at this same guapote stocking rate have yielded consistently good results, even when individual size of guapote fingerlings stocked was reduced to one to five g.

Study D2. Influence of Feed and Organic Fertilization on Polyculture of Tambaquí and Tilapia

In Honduras there was interest in determining the growth response of tambaquí (*Colossoma macropomum*) when co-stocked with tilapia in organically fertilized ponds. There was evidence that tambaquí did not grow well in the absence of supplemental feed. The objective of this experiment was to quantify growth of tambaquí in polyculture with tilapia in ponds receiving only organic fertilization or a combination of organic fertilization and supplemental feed.

Six ponds were stocked on 13 February 1990 with tilapia (13-g average weight) at 10,000/ha, tambaquí (*Colossoma macropomum*; 40-g average weight) at 1,500/ha, and guapote tigre (*Cichlasoma managuense*) at 250/ha to control tilapia reproduction. Three ponds were fertilized weekly with chicken litter at 1,000 kg DM/ha for the first six weeks, and then at 750 kg TS/ha for the remainder of the study. The remaining three ponds were fertilized weekly with chicken litter at 500 kg DM/ha, and fish were offered a pelleted ration (25 percent protein) at about 1.5 percent of tilapia biomass per day, six days per week. Ponds were harvested on 19 June 1990, 126 days after stocking.

Mean average weights of tilapia and tambaquí, and mean gross fish yields were significantly greater in fed ponds (Table 25). Tambaquí were 422 percent larger where supplemental feed was used compared to organic fertilization alone, whereas tilapia were only 39 percent larger in the supplemental feed treatment. Tambaquí grew little and did not reach a marketable size in ponds that received only organic fertilization. The optimal stocking ratio is unknown. The practical implication of this study is that fish farmers should not stock tambaquí unless a formulated ration is used.

Table 25. Summary of Harvest Data (Mean ± S.E.) from 0.1-ha Earthen Ponds Stocked with Nile Tilapia and Tambaqui (*Colossoma macropomum*) that Received Weekly Applications of Organic Fertilizer and Where Fish Were or Were Not Offered a Supplemental Feed

	Treatment	
Variable	Organic fertilization only	Organic fertilization plus supplemental feed
Tilapia		
Gross yield, kg/ha per 126 d	1,355 ± 102	1,921 ± 40*
Individual weight, g/fish	167 ± 10	232 ± 16*
Survival, pct.	81 ± 2.3	83 ± 4.4
Tambaqui		
Gross yield, kg/ha per 126 d	76 ± 22	350 ± 70*
Individual weight, g/fish	86 ± 27	447 ± 71*
Survival, pct.	60 ± 2.6	52 ± 2.3

*Treatment means were significantly different (P<0.05). Horizontal comparisons only.

STUDY D3. GROWTH OF *CICHLASOMA MACULICUADA* CO-STOCKED WITH TILAPIA AND GUAPOTE TIGRE

Cichlasoma maculicauda is a native cichlid found at sizes greater than 300 g in lakes and rivers in Honduras. Fingerling *Cichlasoma maculicauda* (five to 25 g) were obtained from a fingerling production facility in Olancho (Eastern Honduras). This fish has a small mouth and filiform teeth, and was reported to graze on the pond bottom, for which it appeared to be a suitable fish for pond culture. The fingerlings were stocked in a fertilized pond and received a daily ration of formulated feed. After 9 to 12 months in the pond reproduction was observed. Fingerlings produced in the pond were used in a subsequent grow-out trial.

Cichlasoma maculicauda (12-g average weight) were stocked at 290/ha with tilapia and guapote in a study to determine the effect of minimal oxygen concentration (Study E4). Ponds were organically fertilized for the first two months with chicken litter (1,000 kg DM/ha per week). Thereafter, fertilization was stopped and fish were offered a 20 percent-protein pelleted feed. Ponds were harvested after 148 days.

TABLE 26. MEAN (± S.D.) YIELD AND SURVIVAL OF *CICHLASOMA MACULICUADA* IN 0.1-HA EARTHEN PONDS THAT RECEIVED NO MECHANICAL AERATION OR AERATION THAT BEGAN WHEN DISSOLVED OXYGEN CONCENTRATIONS WERE 10 PERCENT OR 30 PERCENT OF SATURATION

Treatment	Mean weight (g/fish)	Pct. survival	Yield (kg/ha per 148 d)
Control	53 ± 12.9	47 ± 38	8 ± 7
10% saturation	80 ± 5.6	64 ± 5.3	15 ± 0.3
30% saturation	87 ± 4.2	79 ± 15.0	20 ± 3
Contrast			
Control vs. aeration	HS*	NS	S
10% vs. 30%	NS	NS	NS

*NS - not significant (P>0.05); S - significant (P<0.05); HS - highly significant (P < 0.01).

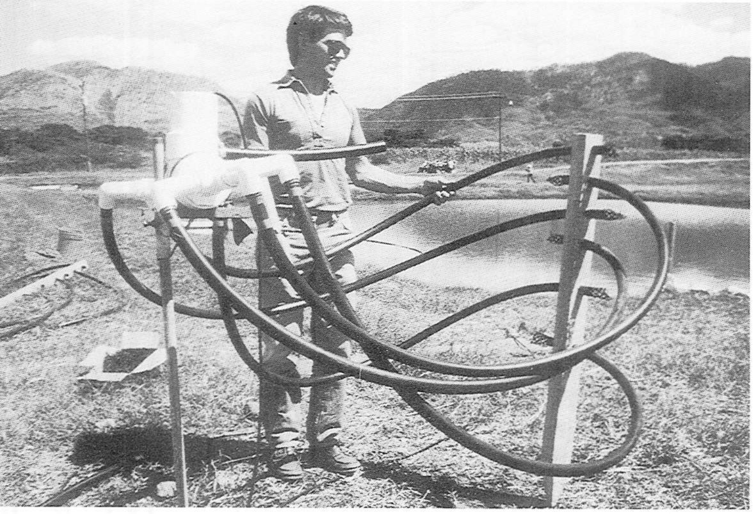
Growth of *Cichlasoma maculicauda* was slow in all treatments, despite aeration and a combination of natural foods and formulated diet (Table 26). Mean individual weight at harvest did not exceed 83 g, despite the low fish stocking rate. Low dissolved oxygen concentrations appeared to inhibit *Cichlasoma maculicauda* growth and survival. Poor performance of *Cichlasoma maculicauda* in this trial indicated their growth is too slow for commercial aquaculture.

STUDY D4. COMPARATIVE GROWTH OF COMMUNALLY STOCKED RED AND WILD-TYPE TILAPIA

Red tilapia is rapidly becoming popular as a culture fish in Honduras. El Carao has had two different lines of red tilapia with greatly different appearances and culture characteristics. The first line, introduced from Mexico, was presumed to have originated from a commercial producer of red tilapia in Florida. This fish was pink and bred true, but because of low fecundity, poor growth and low resistance to handling, its use was discouraged. In 1989, a commercial farm in Honduras imported a red tilapia from Geneva, Alabama; this fish apparently originated with L. L. Behrends, National Fertilizer Development Center in Muscle Shoals, Alabama, who back-crossed several generations of red off-spring with *Oreochromis niloticus* parents. The red color originated from the Florida red tilapia. The Alabama red did not produce 100 percent red off-spring, but its growth and resistance to handling were superior to the Mexican line. The objective of this study was to compare growth characteristics of the Alabama red strain to wild-type *O. niloticus*.

Three ponds each were stocked communally on 8 August 1990 with 500 red and 500 wild-type male tilapia. Red and wild-type fingerlings averaged 8 and 7 g, respectively. Ponds were fertilized with chicken litter (1,000 kg DM/ha per week) for the first two months. Thereafter, fertilization was stopped and fish were fed a commercial shrimp ration (20 percent protein) 6 days per week at 3 percent of fish biomass. All ponds received equal quantities of inputs. Ponds were completely drained and fish harvested 148 days after stocking.

Mean gross yield of wild-type tilapia (1,133 kg/ha) was significantly greater than that of red tilapia (456 kg/ha). However, mean individual weight of wild-type (252 g) did not differ from that of red tilapia (253 g). Yield of red tilapia was significantly affected by lower survival, which averaged 37 and 83 percent, for red and wild-types, respectively. Red tilapia survival was low partly because of predation by ospreys that visited ponds daily. The ponds farthest away from human activity suffered the poorest survival. Lack of resistance to handling, especially at the fingerling stage, also was suspected of reducing survival. Results of other studies with red tilapia showed these fish to survive poorly in growout ponds, even in the absence of bird predation (see Study B7). These results indicated that growth potential of red tilapia was similar to that of wild-types, but consistently low survival would make this red tilapia less suitable for pond culture. Low ambient temperatures during the last two months of the cycle probably slowed growth and contributed to reduced total yields.



Dr. Bart Green assembling automated water sampler.

MISCELLANEOUS STUDIES

Economic evaluation of management systems tested is reported in the economic analysis section of this report.

STUDY E1. PRODUCTION OF NILE TILAPIA AND HYBRID TILAPIA IN EARTHEN PONDS

In the early 1980s monosex tilapia culture in Honduras was based on manually-selected Nile tilapia or hybrid tilapia (*O. niloticus* x *O. urolepis hornorum*). There were conflicting reports regarding production characteristics of the two fish, which were theoretically all male. The objective of this research was to compare growth and production of male Nile tilapia to male hybrid tilapia.

Each treatment was randomly assigned to three ponds. Fish were stocked into ponds at 10,000 fish/ha on 31 August 1983 and harvested after 90 days. Nile and hybrid fingerlings averaged 7 and 11 g, respectively. Ponds were fertilized on six occasions with 46 kg/ha of 20-20-0 (N-P-K). Fish were fed a formulated fish ration (23 percent protein; 3 percent of fish biomass) five days per week.

Net fish yields were 1,197 and 1,141 kg/ha for Nile and hybrid tilapia, respectively, and did not differ significantly between treatments. Likewise, mean individual weight at harvest were 134 and 131 g, respectively, and did not differ significantly. Although the hybrid tilapia initial mean weight was significantly greater, an analysis of covariance indicated no significant effect on final individual weight. Survival averaged 94.9 percent and 95.6 percent for Nile and hybrid tilapia, respectively. While, no differences were observed in production characteristics between the two fish, maintenance of the two pure-line species required for hybrid production is more difficult than where no hybrid is produced. Further, pure-line fingerling production is more prolific.

STUDY E2. EFFECT OF POND SIZE ON TILAPIA PRODUCTION

Aquacultural research frequently is carried out in small (≤ 0.1 ha) experimental ponds. However, research ponds generally are smaller than ponds operated by commercial fish farmers. The purpose of this study was to determine the effect of pond size on fish yield.

Three 0.05-ha and three 0.2-ha ponds were stocked with fingerling hybrid tilapia (*O. niloticus* x *O. urolepis hornorum*; average weight = nine g/fish) at 20,000 fish/ha. Ponds had similar histories of previous management. All ponds were constructed with imported soil; ponds soils were assumed to be similar. Ponds were fertilized weekly with chicken litter (381 kg DM/ha). Fish were fed corn gluten (12 percent protein, 4 percent fat, 16 percent carbohydrate, 5 percent ash and 12 percent moisture) at 7 percent of the fish biomass Monday through Friday. Ponds were stocked on 9 September 1985 and harvested 126 days later.

Gross yield averaged 2,502 and 2,736 kg/ha for the 500- and 2,000-m^2 ponds, respectively. Treatment means were not significantly different. Mean individual weight at harvest was 150 and 159 g, respectively. Tilapia offspring produced during the growout cycle represented 9 percent of each treatment's gross yield. Survival averaged 76 percent and 79 percent for the 0.05- and 0.2-ha ponds, respectively, and did not differ significantly. We concluded that pond size, within the size range tested, did not affect fish yield in the two treatments.

STUDY E3. TESTING FOR ANABOLIC GROWTH RESPONSE OF ANDROGEN-TREATED TILAPIA DURING TREATMENT, NURSERY AND GROW-OUT PHASES

The predominant monosex fingerling production technology currently employed in Central America is hormonal sex reversal, where an androgen, generally 17-α methyltestosterone (MT), is incorporated into locally available commercial rations. MT treatment for sex reversal of tilapia may also induce an anabolic growth response. The objective of this study was to compare the growth of control and MT-treated tilapia during consecutive androgen-treatment, nursery, and grow-out phases in earthen ponds under conditions that likely would be used on commercial, semi-intensive tilapia farms in Central America.

Recently hatched *Oreochromis niloticus* fry were stocked into hapas suspended in a 0.2-ha earthen pond.

Control and MT-treated treatments each were randomly assigned to four large (2 x 2.5 x 1 m) and two small (1 x 2 x 1 m) hapas (1.6-mm ace nylon mesh). Water depth in hapas averaged 0.6 m. Hapas were stocked with 4,500 fry/m^2. Average total length (± SD) for 500 fry was 9.8 ± 2.3 mm. Total weight of 500 fry was 4.65 g. Water temperature during the hormone-treatment period averaged 26.1 °C.

Fry in both treatments were fed a ground, sieved (560-μ mesh) commercial shrimp diet (21.4 percent crude protein). MT was incorporated into the sex-reversal diet at a rate of 60 mg/kg feed by dissolving it in 0.5-L denatured ethanol/kg feed, and thoroughly mixing with the feed. Control feed was mixed with 0.5-L androgen-free denatured ethanol/kg feed. Both feeds were oven dried and refrigerated until fed. Fry were fed seven days per week at a daily rate of 20 percent tilapia biomass during the first week, decreasing progressively to 10 percent of the biomass during the fourth week. Hapas were harvested 28 days after stocking on 28 October 1988.

Control or MT-treated fry were stocked into two 0.2-ha earthen ponds each on 28 October 1988 at a rate of 125,000 fry/ha. Fry in both treatments averaged 0.1 g. Prior to stocking, ponds were fertilized once with 2,000 kg DM/ha of layer chicken litter. Chicken litter was applied weekly at 1,000 kg DM/ha during the first month and then at 500 kg DM/ha thereafter. Fingerlings were fed a pelleted diet (23 percent crude protein) six days per week. Daily feeding rate was 10 percent of mean fish biomass per treatment during the first month, decreasing progressively until a maximum daily feeding rate of 55 kg/ha was achieved. Water temperature in ponds averaged 24.5 °C. All ponds were harvested by draining 94 days after stocking.

Growth and yield during growout of male control and male MT-treated fish at three stocking rates were investigated using a completely randomized design in 2 x 3 factorial arrangement. Twelve ponds were stocked with 2,500, 10,000, or 20,000 fish/ha on 3 February 1989. Initial individual weight averaged 29 g for both control and MT-treated fish. Chicken litter was broadcast over the surface of all ponds weekly at a rate of 750 kg DM/ha. Guapote tigre, *Cichlasoma managuense* (22 g/fish) was stocked into ponds on 7 February 1989 at a rate equivalent to 5 percent of the tilapia stocked to control tilapia reproduction. Ponds were harvested by draining after 150 days. Water temperature in ponds averaged 26.6 °C.

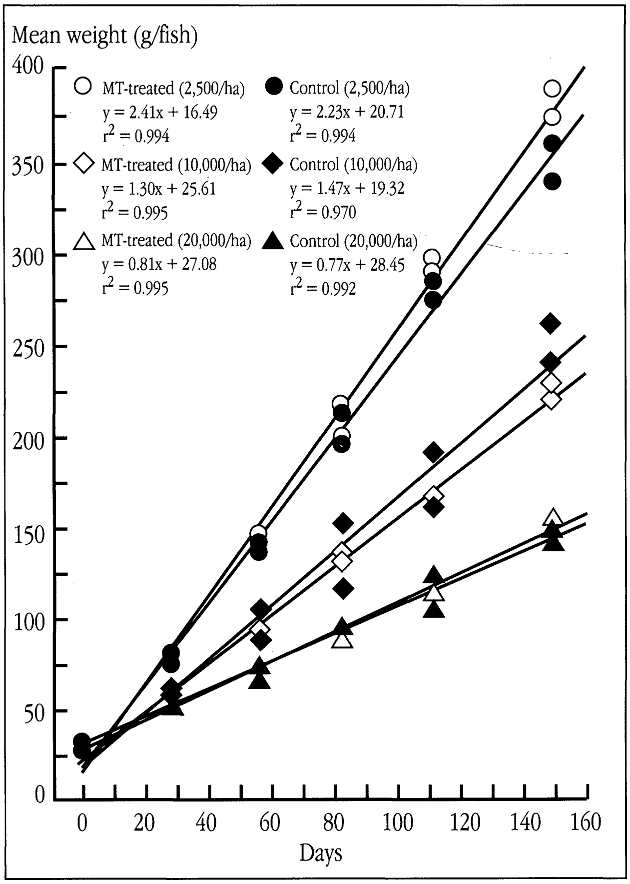


Figure 16. Growth of control and MT-treated males *Oreochromis niloticus* stocked at three rates in 0.1-ha earthen ponds during the 150-day grow-out phase. Ponds were fertilized weekly with chicken litter (750 kg DM/ha).

Androgen-treatment and nursery phase growth data were logarithm transformed for linear regression analysis. Survival data were arcsine transformed for analysis. Data were analyzed using t-test (treatment and nursery phases), Chi-square analysis (nursery phase sex ratio), two-factor ANOVA where the factors were treatment and stocking rate (grow-out phase), contrasts (grow-out phase), linear regression (all phases), and covariance analysis for heterogeneity of slopes (all phases).

Slopes of control and MT-treated fry growth curves were not significantly different during androgen treatment. After the 28-day treatment phase, control and MT-treated fry both averaged 0.1 g/fry. Final total length did not differ significantly between treatments and was 18.3 mm and 18.9 mm, respectively.

No significant difference between slopes of growth curves for control and MT-treated fingerlings was detected during the nursery phase. No significant differences in harvest data were detected between treatments. At harvest, mean individual fingerling weights were 22.5 g and 26.2 g for control and MT-treated fish populations, respectively. However, respective mean weights for males were 29.5 and 29.7 g/fish. Females present in both populations were significantly smaller than males. Control and MT-treated females averaged 21.5 and 23.7 g/fish, respectively. Control

TABLE 27. PRODUCTION DATA FOR HAND-SELECTED AND SEX REVERSED MALE OREOCHROMIS NILOTICUS AFTER A 150-DAY GROWOUT IN 0.1-HA PONDS FERTILIZED WEEKLY WITH CHICKEN LITTER AT 750 KG DRY MATTER/HA

Treatment	Stocking rate	Final weight	Survival	Gross total yield	Net total yield	Reproduction
	Fish/ha	*g/fish*	*Pct.*	*kg/ha per 150 d*		
Control[1]	2,500	352 a	85.0 a	968 c	898 c	221 a
MT-treated	2,500	383 a	88.9 a	1,091 c	1,016 c	243 a
Control	10,000	251 b	69.8 a	1,730 b	1,438 b	10 b
MT-treated	10,000	228 b	92.1 a	2,105 b	1,805 b	12 b
Control	20,000	145 c	83.6 a	2,428 a	1,812 a	0 b
MT-treated	20,000	151 c	85.6 a	2,570 a	1,963 a	4 b

[1] Manually-selected male fish.

abc Means within columns followed by different letters are significantly different ($P<0.05$).

fish averaged 51.3 percent males, not significantly different from the expected 1:1 male:female ratio. MT-treated fish averaged 96.8 percent males. After 94 days, gross tilapia yield averaged 1,548 kg/ha and 1,613 kg/ha for the control and MT-treated treatments, respectively.

During growout, slopes of growth curves for control males and MT-treated males within each stocking rate were not significantly different except at the low stocking rate, where MT-treated fish grew faster (Figure 16). However, at harvest average fish weights for control and MT-treated males, within each stocking rate, were not significantly different. No significant differences in production data were detected between treatments within stocking rates (Table 27). The treatment by stocking rate interaction was not significant.

Growth of control and MT-treated Nile tilapia was similar. No anabolic response to MT treatment was detected during the hormone-treatment phase, or during any production phase for 244 days subsequent to MT-treatment. The use of MT for masculinization of tilapia fry was efficacious and resulted in populations comprised of 97 percent males. Thus, farmers using semi-intensive culture techniques should not expect an anabolic response subsequent to sex reversal.

STUDY E4. TILAPIA YIELD IMPROVEMENT BY MAINTAINING CRITICAL OXYGEN CONCENTRATIONS IN PONDS

Tilapia endure low dissolved oxygen concentration by rising to the pond surface to pass oxygen-rich water across their gills. At El Carao, tilapia have been documented to endure dissolved oxygen concentrations near 0 mg/L for up to six hours. Stress from chronic hypoxia was suspected to reduce tilapia growth, even in the absence of fish mortality. Supplemental aeration could maintain DO levels above those detrimental to tilapia growth. However, the critical oxygen concentration at which to begin aeration was not known. Indiscriminate use of aerators increases operating costs. The objectives of this study were to determine the critical DO level at which to initiate aeration in order to minimize operational time, and to determine if aeration affected primary productivity and other water quality variables.

Nine 0.1-ha ponds were randomly assigned to three treatments. Vertical pump aerators (0.5 HP AIR-O-LATOR) in six ponds were activated when DO reached 30 percent or 10 percent of saturation. There was no aeration in the remaining three ponds. Individual aerators were activated automatically by a computerized data-logging system. Aerators were operated for one-hour intervals until pond DO exceeded the critical level.

Ponds were stocked on 8 August 1990 with 24-g male tilapia at 20,000/ha, 1-g guapote tigre (*Cichlasoma managuense*) at 500/ha, and 12-g *Cichlasoma maculicauda* at 290/ha. The maculicauda was a native cichlid being tested for potential as pond culture fish (Study D3). Ponds were fertilized only with chicken litter at 1,000 kg DM/ha per week for the first two months of growth. Thereafter, fish were fed a commercial shrimp ration (20 percent crude protein) six days per week at 3 percent of tilapia biomass in the fastest growing treatment. All ponds received equal quantities of inputs. Duration of the experiment was 148 days.

Aeration resulted in significantly greater fish gross yield and larger fish than no aeration, but there were no differences in fish yield between levels of aeration (Table 28). Beneficial effect of aeration was most evident during the last six weeks (Figure 17). These data indicate that aeration was not necessary until the end of the experiment when high inputs resulted in prolonged periods of low DO. Aerators in both aerated treatments began functioning during the first month of growth. Yields among non-aerated ponds were much more variable than yields among aerated ponds, indicating that low-oxygen stress may contribute to the large variation within treatments in tilapia production. Minimal use of aerators can be used to increase tilapia production under conditions of low DO, however, such use must be economically justified.

Table 28. Mean (± S.E.) Yield of *Oreochromis niloticus, Cichlasoma managuense* (Guapote) and *Cichlasoma maculiacuada* After 148 Days in Ponds Without Oxygen Regulation (Control), or with Minimum Dissolved Oxygen Concentration Maintained at 10 Percent or 30 Percent of Saturation by Aeration.

Treatment	Tilapia yield	Maculicauda yield	Guapote yield	Tilapia reproduction	Gross fish yield	Mean tilapia weight	Tilapia survival
			kg/ha			*g/fish*	*Pct.*
Control	3,404 ± 383	8 ± 4	20 ± 6	41 ± 16	3,473 ± 404	194 ± 15.5	87 ± 3.1
10%	4,133 ± 130	15 ± 0	18 ± 1	34 ± 11	4,201 ± 139	229 ± 2.7	90 ± 2.1
30%	4,269 ± 176	19 ± 4	19 ± 4	32 ± 1	4,340 ± 182	235 ± 3.9	91 ± 2.3

Table 29. Means (± S.E.) of Selected Water Quality Variables in Ponds Without Oxygen Regulation (Control), or with Minimum Dissolved Oxygen Concentrations Maintained at 10 Percent or 30 Percent of Saturation by Aeration

Treatment	Chlorophyll *a*	Secchi disk visibility	Organic N	Total ammonia	Suspended solids	Volatile solids
	µg/L	*cm*	*mg NH_3-N/L*		*mg/L*	
Control	274 ± 7.3	16.4 ± 0.11	3.43 ± 0.03	0.074 ± 0.013	433 ± 15	167 ± 10
10%	322 ± 17.9	13.3 ± 0.20	3.49 ± 0.02	0.117 ± 0.015	492 ± 9	180 ± 12
30%	342 ± 53.8	12.5 ± 0.94	3.41 ± 0.15	0.122 ± 0.012	538 ± 33	174 ± 8

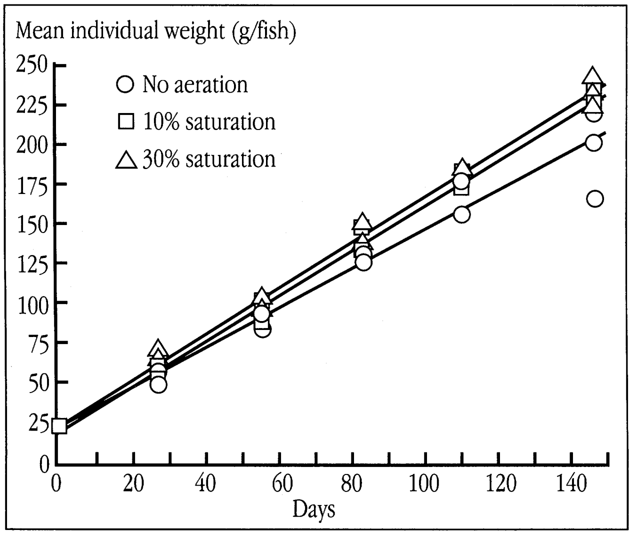


Figure 17. Mean weight of Nile tilapia during 140 days of culture in 0.1-ha earthen ponds without aeration, or with aeration starting at 10 percent or 30 percent of dissolved oxygen saturation.

Aeration resulted in small, but significant increases in total suspended solids (clay turbidity) and total ammonia-N, but there were no significant differences for organic-N, chlorophyll *a* , or total volatile solids (Table 29).

On-farm Testing of PD/A CRSP Fish Production Systems

The goal of PD/A CRSP aquacultural research has been to increase fish production and profitability for small- and medium-scale commercial producers by using technology that enhances natural productivity of ponds with locally available nutrient inputs. PD/A CRSP research results have been disseminated at local, regional, and international scientific meetings, in regular lectures at local vocational-agricultural schools, at technology-transfer days at El Carao, through formulation of pond management plans for producers who buy fingerlings at El Carao, and in scientific publications. The next step was to transfer the production technologies to the farmer. On-farm testing of production systems would validate research findings, and serve as a teaching tool for extensionists.

In early 1991, the Honduras PD/A CRSP team developed and implemented a program that linked producers in the northern and central regions of Honduras with PD/A CRSP technologies. Participating small- to medium-scale commercial producers were interested in maximizing profitability by refining their production technology. This group of farmers participated in the field trials of PD/A CRSP production systems developed in Honduras and Thailand.

Staff of another technology transfer program, the USAID/Honduras and MNR Land Use and Productivity Enhancement (LUPE) project collaborated with PD/A CRSP in promoting aquacultural development. The LUPE program worked with hillside farmers to promote watershed conservation and sustainable agriculture in the southern and central regions of Honduras. Many of the farmers that participated in the LUPE project had few resources such as fertilizers available to them; use of compost as a fish pond nutrient, as developed in the Rwanda PD/A CRSP, could be tested in these hillside ponds.

Peace Corps/Honduras had an on-going fish culture project that placed Peace Corps volunteers (PCVs) with MNR. The goal of Peace Corps/Honduras Fish Culture Project was to improve the economic and nutritional status of the resource-limited rural population in Honduras through sustainable fish culture production. Thus, PCVs would test PD/A CRSP fish production systems on private farms provided the implementing farmers were interested and had access to production inputs.

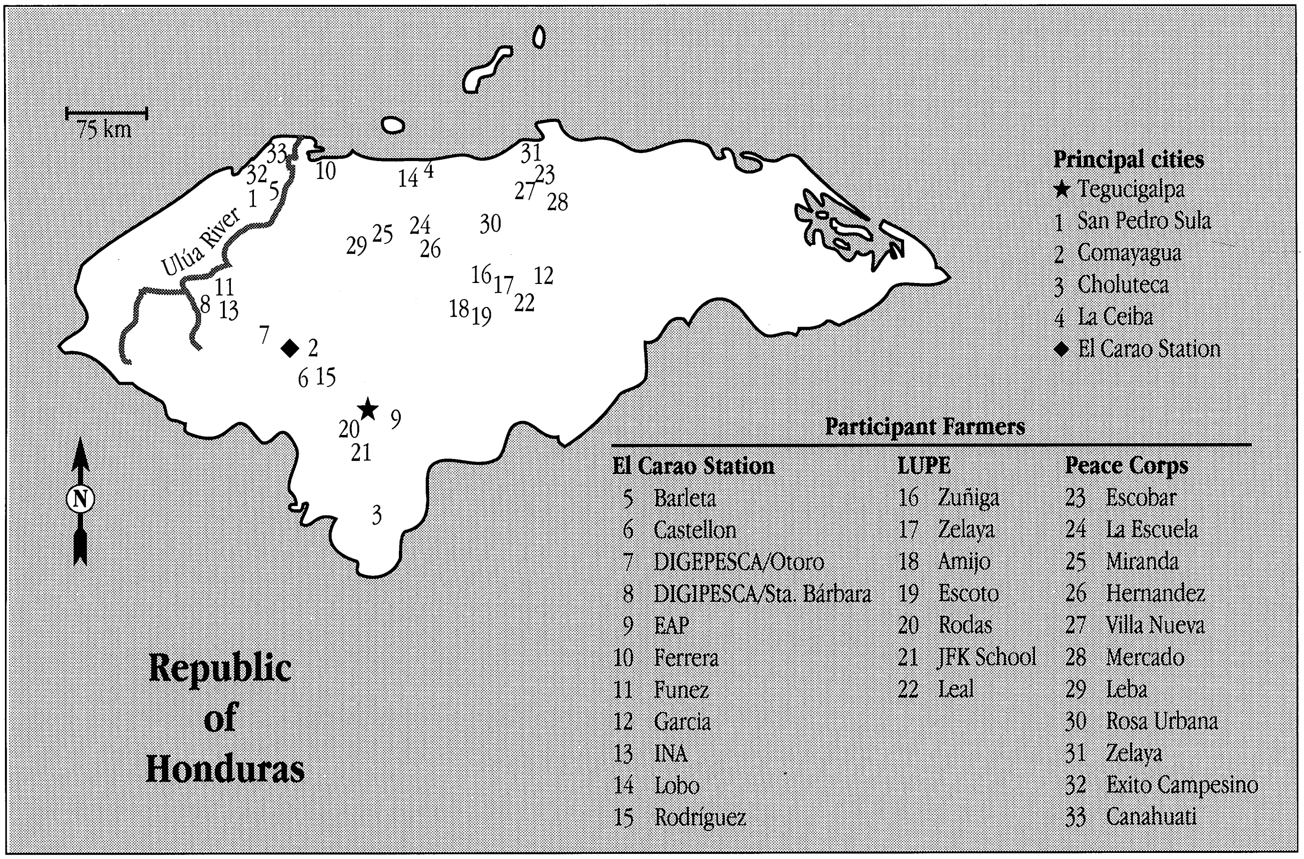


Figure 18. Map of Honduras that shows approximate locations of major cities and of farms that participated in the PD/A CRSP on-farm trials.

PROJECT DESIGN AND IMPLEMENTATION

The two components of this activity were on-farm trials and short courses in aquaculture for participant extensionists and farmers. An initial short course preceded the farm trials. A second seminar was offered upon completion of trials to summarize and discuss trial results. Honduran PD/A CRSP personnel were responsible for identification and selection of small- and medium-scale commercial fish farmers to participate in the on-farm trials. Participant farmers each assigned two ponds for use in trials, which allowed two production systems to be compared. Each participating farmer and a PD/A CRSP representative signed a contract that stipulated the responsibilities of each party. MNR extension personnel associated with PD/A CRSP made monthly visits to participant farmers to collect data, water samples and to provide technical assistance.

LUPE extension personnel identified farmers participating in the LUPE project to participate in on-farm trials. Only one pond per farm would be used to test PD/A CRSP technologies. LUPE extension personnel were responsible for supervising data collection by and providing regular technical assistance. A Honduran PD/A CRSP aquaculture specialist accompanied LUPE extension agents on farm visits at least once each month. During each visit, the PD/A CRSP aquaculture specialist would collect data, water samples and provide technical assistance.

Peace Corps/Honduras was only collaterally involved in testing PD/A CRSP production systems on farm. PCVs were responsible for collecting production data at each of their sites, but they were not obligated to test PD/A CRSP fish production systems. In practice, greatly different situations made it difficult to standardize inputs and management systems.

In July 1991, a one week short course in aquaculture was presented to 17 participating fish farmers and extensionists in order to provide them with a more thorough understanding of aquaculture and the on-farm trials in which they were about to participate. In addition, a producer from La Villa, Comayagua, and four DIGEPESCA employees from Comayagua attended the Thursday session on production systems, economics and the field trials. Course participants were provided with reference materials and a Secchi disk.

THREE PRODUCTION SYSTEMS TESTED ON-FARM WERE:

CHEMICAL FERTILIZATION

Nitrogen and phosphorus, as chemical fertilizer, were the only nutrient inputs to ponds. Nitrogen and phosphorus were applied weekly at 30 kg/ha and 8 kg/ha, respectively. Ammonium phosphate (18-46-0) and urea (46-0-0) were the commonly available chemical fertilizers, therefore weekly fertilization rates were 40 kg/ha and 49.5 kg/ha, respectively. The weekly fertilizer dose was divided in half, with a three-day interval between application of each half dose. Fertilizer was dissolved in bucket of pond water, which was then dispersed over the pond surface.

Ponds were stocked with male *Oreochromis niloticus* fingerlings at 20,000/ha, and fingerling *Cichlasoma managuense* at 500/ha to control tilapia reproduction.

ORGANIC FERTILIZATION

Animal manure was the only pond nutrient input. Fresh cattle or swine manure was mixed with pond water and the manure slurry was applied to ponds; chicken litter, when used, was broadcast over the pond surface. Manure application rate was 500 kg/ha per week on a dry matter basis.

Ponds were stocked with male *Oreochromis niloticus* fingerlings at 10,000/ha and fingerling *Cichlasoma managuense* at 500/ha to control tilapia reproduction.

An alternative fertilization regime increased weekly manure applications to 750 kg/ha and included urea (25 kg/ha weekly) application. Urea dose was divided in half, with a three-day interval between application of each half dose. Tilapia stocking rate was increased to 20,000/ha.

FERTILIZATION FOLLOWED BY FEED

Chicken litter was applied to ponds at a rate of 750 kg dry matter/ha per week. Urea was also applied weekly at 25 kg/ha; the weekly dose was divided in half, with a three-day interval between application of each half dose. Both fertilizers were applied during the first 12 weeks of growout, after which fertilization was suspended and feeding was initiated. Fish were fed a commercial, pelleted fish feed (25 percent protein) daily at a rate of 3 percent of fish biomass. Daily feeding rate was adjusted monthly based on average fish weight, determined by seine sample, assuming 100 percent fish survival. Daily feed allowance did not exceed 100 kg/ha.

Ponds were stocked with male *Oreochromis niloticus* fingerlings at 20,000/ha, and fingerling *Cichlasoma managuense* at 500/ha to control tilapia reproduction.

The PD/A CRSP, through the El Carao National Fish Culture Research Center in Comayagua, provided at no cost the tilapia and guapote fingerlings necessary to stock ponds. All other production costs were borne by the farmer. Field data were collated and analyzed by PD/A CRSP personnel at El Carao. Production trials were to last 150 days. Prior to stocking ponds, total alkalinity in pond water was analyzed to determine the need for lime; liming was considered unnecessary if total alkalinity exceeded 20 mg/L as $CaCO_3$.

A total of 13 small- and medium-scale commercial fish farmers was selected to participate in the on-farm trials through direct linkage with El Carao (Figure 18). Most producers tested two production systems on their farm: *chemical fertilization* and *fertilization followed by feed.* Ten farmers completed the trials but only seven adhered to the management system. Two farmers initiated a second series of trials, repeating the *fertilization followed by feed* at stocking rates of 20,000 to 30,000/ha.

LUPE extension personnel selected seven farmers to participate in the trials in September 1991 (Figure 18). Farmers collected animal manures for pond nutrient input. Only one farmer completed the trial; supervision and data collection at all farms suffered because of severe administrative problems in the LUPE project.

Peace Corps Volunteers worked with 13 client farmers (Figure 18). Farmers did not test PD/A CRSP production systems, but rather used a variety of fish culture practices, with nutrient inputs such as termite nests, manure, wheat bran, rice-polishing, and waste or cracked corn. Ponds were often co-stocked with other fish species, especially tambaquí (*Colossoma macropomum*); *Cichlasoma managuense*, to control tilapia reproduction, was stocked by less than 20 percent of the farmers.

RESULTS OF ON-FARM TRIALS

SMALL TO MEDIUM SCALE FARMERS

Mean fish yields after 157 days were 2,413 and 1,785 kg/ha for the *fertilization followed by feed* and *chemical fertilization* systems, respectively (Table 30). These means included data from all producers even though deviation from the work plan was suspected when water quality measurements, e. g., ammonia and Secchi disk visibility, were below expected values for the management system being tested. The predominant reason for noncompliance appeared to be that the farm owner was not directly involved in daily pond management, but rather relied on a farm manager who did not share the owner's commitment to the trials.

Mean yields increased to 2,890 and 2,180 kg/ha in 162 days for the *fertilization followed by feed* and *chemical fertilization* systems, respectively, when data from noncomplying farmers were excluded from the analysis (Table 30). Mean final tilapia size also increased slightly (Table 30); tilapia of this size were marketable in Honduras. The minimum size fish Honduran consumers accepted was 100 to 125 g. Fish smaller than this were difficult to market in urban areas, but reports from rural areas indicated that it was possible to sell fish as small as 50 g.

TABLE 30. ON-FARM TRIAL PRODUCTION RESULTS FOR SMALL TO MEDIUM SCALE TILAPIA FARMERS

Producer	Treatment[1]	Pond area	Date stocked	Stocking rate	Duration	Mean fish weight	Gross yield	Survival
		m^2		*fish/ha*	*days*	*g/fish*	*kg/ha*	*Pct.*
Barleta	Fert. + feed	2,400	16 Apr. 91	30,000	163	154	2,373	51
Castellon	Fert. + feed	2,400	23 Aug. 91	20,000	152	153	2,429	79
EAP	Fert. + feed	900	4 Oct. 91	18,000	180	215	3,173	82
Ferrera	Fert. + feed	230	21 May 91	30,000	176	108	3,149	98
Funez[2]	Fert. + feed	234	15 May 91	20,000	146	75	1,457	97
Garcia	Fert. + feed	650	4 June 91	20,000	148	204	3,838	94
INA[2]	Fert. + feed	875	15 May 91	20,000	146	108	2,163	85
Lobo[2]	Fert. + feed	200	18 June 91	20,000	153	64	756	59
Rodriguez	Fert. + feed	800	7 June 91	20,000	161	192	2,381	62
Means	*all farmers*	965		22,000	158	141	2,413	79
	compliant farmers	1,230		23,000	163	171	2,890	78
Barleta	Chemical	2,400	16 Apr. 91	30,000	163	58	1,591	91
Castellon	Chemical	2,400	23 Aug. 91	20,000	152	117	2,153	92
EAP	Chemical	900	4 Oct. 91	18,000	180	182	3,054	93
Funez[2]	Chemical	234	15 May 91	20,000	146	97	1,531	79
Garcia	Chemical	1,250	4 June 91	20,000	148	154	1,511	49
INA[2]	Chemical	875	15 May 91	20,000	146	59	1,060	86
Lobo[2]	Chemical	200	18 June 91	20,000	153	63	790	63
Rodriguez	Chemical	4,837	7 May 91	17,000	161	170	2,588	80
Means	*all farmers*	1,650		20,625	156	113	1,785	79
	compliant farmers	2,377		21,000	161	136	2,180	81

[1] Fert. + feed: Organic fertilizer then feed; Chemical: chemical fertilization only; see text for details.
[2] Farmers known to have deviated from work plan.

TABLE 31. MEAN WATER QUALITY VARIABLES IN PONDS ON SMALL- TO MEDIUM-SCALE TILAPIA FARMS DURING ON-FARM TRIALS

	Total alkalinity				Total ammonia	
Farmer	Feed and fert.	Chemical	Feed and Fert.	Chemical	Feed and fert.	Chemical
	mg/L as $CaCO_3$		*pH*		*mg/L* NH_3*-N*	
Barleta	68	145	10.0	9.0	0.20	0.38
Castellon	56	82	9.5	10.0	0.42	0.12
Ferrera	-	56	-	8.3	-	0.07
Funez	86	120	8.5	8.0	0.02	0.16
Garcia	103	120	8.7	8.0	0.67	0.44
INA	95	112	10.0	8.0	0.16	0.07
Lobo	39	47	7.0	6.8	0.07	0.05
Rodriguez	86	137	9.0	8.5	0.47	0.43
Mean	76	102	7.8	7.6	0.29	0.21

In each treatment, tilapia mean weight at each sampling was regressed against time to obtain a general indication of growth across farms (Figure 19). The regression equations were:

$Y = 0.803X + 5.859, R^2 = 0.661$, for *fertilization followed by feed*, and

$Y = 0.639X + 9.949, R^2 = 0.626$, for *chemical fertilization*,

where Y equals mean individual weight (g/fish) and X equals day number. Observed fish growth was about 25 percent higher in the *fertilization followed by feed* system. The variability observed in the data can be attributed to noncompliance to the work plan, stocking rate differences, and site differences.

Results of water quality analyses are shown in Table 31. Mean total ammonia concentrations and pH were similar in both treatments. Observed mean total alkalinity was greater in the *fertilization followed by feed* system.

The range of yields obtained by farmers (Table 30) were comparable to the range of yields obtained on the Experiment Station. The total quantity of inputs used by

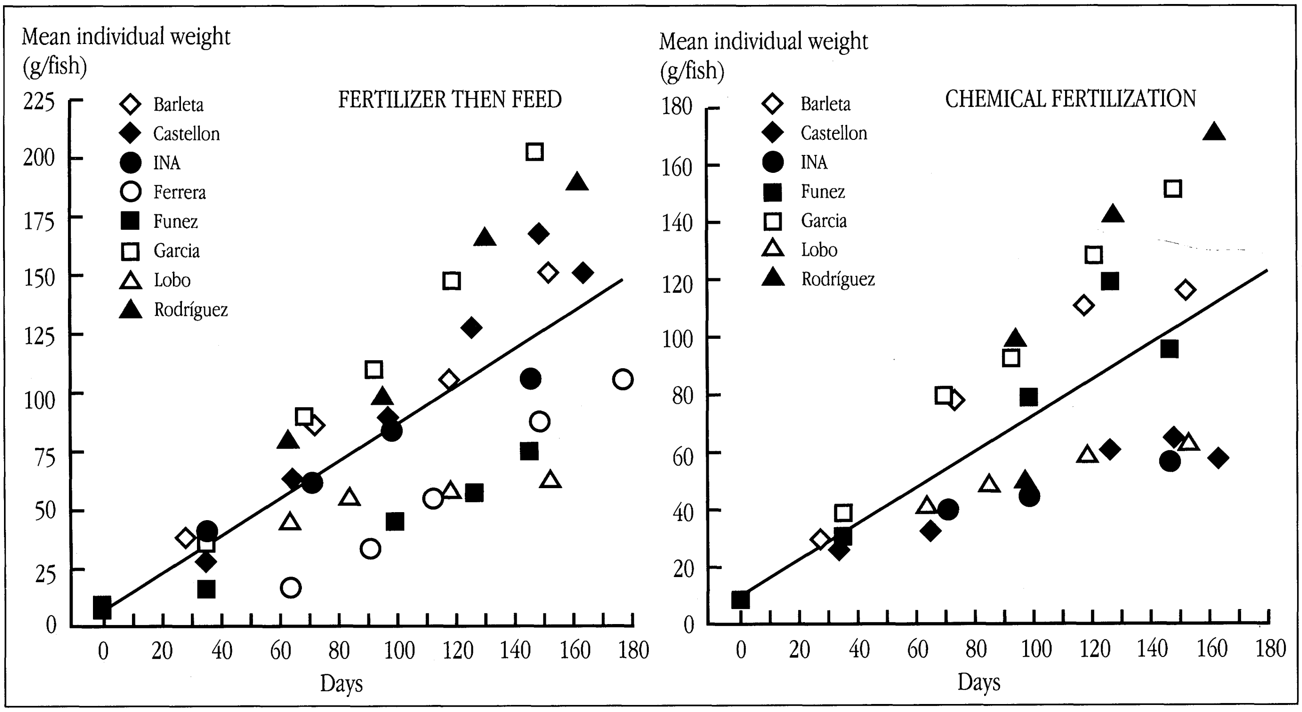


Figure 19. Growth of tilapia during on-farm conducted in collaboration with small to medium scale commercial tilapia farmers in Honduras. Management systems used were: fertilization followed by feed (left) and chemical fertilization (right).

each farmer during the trials is shown in Table 32. Our observation was that farmers who adhered strictly to the work plan obtained the greatest yields, barring unexpected fish mortality.

TABLE 32. INPUTS USED DURING ON-FARM TRIALS BY SMALL- TO MEDIUM-SCALE TILAPIA FARMERS

Producer	Treatment	Chemical fertilizer		Chicken litter	Feed
		Urea	18-46-0		
		kg	*kg*	*kg*	*kg*
Barleta	Fertilization then feed	60	0	2,422	196
Castellon	Fertilization then feed	60	0	1,995	635
EAP	Fertilization then feed	23	0	1,640	574
Ferrera	Fertilization then feed	9	0	234	72
Funez[1]	Fertilization then feed				
Garcia	Fertilization then feed	16	0	1,097	218
INA[1]	Fertilization then feed				
Lobo[1]	Fertilization then feed			592	0
Rodriguez	Fertilization then feed	24	0	738	340
Means	**all farmers**	**28**	**0**	**1,180**	**243**
	compliant farmers	**34**	**0**	**1,297**	**292**
Barleta	Chemical fertilization	337	250	0	0
Castellon	Chemical fertilization	290	218	0	0
EAP	Chemical fertilization	156	206*	0	0
Funez[1]	Chemical fertilization				
Garcia	Chemical fertilization	145	109	0	0
INA[1]	Chemical fertilization				
Lobo[1]	Chemical fertilization	27	0	0	0
Rodriguez	Chemical fertilization	610	448	0	0
Means	**all farmers**	**282**	**205**	**0**	**0**
	compliant farmers	**345**	**256**	**0**	**0**

[1] Producers known to have deviated sharply from standardized workplans.
* Fertilizer 0-20-0.

Partial enterprise budgets were developed for each production system based on mean data from farmers who complied with the work plan (Table 33). Average income above input costs was $930 and $407/ha per 162-day growout cycle (US$1 = Lempiras 5.40, July 1992) for the *fertilization followed by feed* and *chemical fertilization* systems, respectively. A farmer that utilized the *fertilization followed by feed* system would need to have a greater amount of available capital, and would have more capital at risk.

Results of the second trials showed that increasing the fish stocking rate from two to three/m^2 did not increase total yields at either of the two farms. Gross tilapia yield at Ferrera's farm was 2,866 kg/ha in 122 days. After 167 days tilapia yields at Garcia's farm were 3,779 and 3,259 kg/ha for the two fish/m^2 and three fish/m^2 stocking rates, respectively. Feed conversion efficiency at one of the farms indicated that increased density was not accompanied by a proportionate increase in feed use. Efficiency was 1.03 kg feed/kg gain for the higher density and 1.50 at the lower density at Garcia's farm. A reluctance to increase feed inputs necessary for good growth resulted in small, marginally marketable fish at the higher density. Income above variable costs was less at the higher density.

Table 33. Partial Enterprise Budget per 1 ha Pond for Two Different Pond Management Strategies Used by Small- to Medium-Scale Commercial Farmers During On-Farm Trials. Values in Honduran Lempiras (L.5.40 = $1 U.S.)

Description	Unit cost	Unit	Fertilization plus feed Quantity	Cash	Chemical fertilization Quantity	Cash
Income						
adult tilapia	7.17	kg	2,890	20,721	2,180	15,631
Total Income				**20,721**		**15,631**
Variable costs						
fingerlings						
tilapia	0.10	each	23,000	2,300	21,000	2,100
guapote	0.15	each	500	75	500	75
plastic bags	6.00	each	47	282	43	258
feed (20% protein)	76.70	45-kg sack	53	4,065	0	0
fertilizer						
chicken litter	2.28	27-kg sack	400	912	0	0
urea	69.00	45-kg sack	7	483	33	2,277
18-46-0	82.00	45-kg sack	0	0	24	1,968
transport						
fingerlings	200.00	60-km trip	1	200	1	200
feed	200.00	60-km trip	1	200	0	0
chicken litter	200.00	60-km trip	2	400	0	0
fertilizer	200.00	60-km trip	0	0	1	200
field labor						
day	14.00	day	87	1,218	72.5	1,015
night	24.50	night	162	3,969	162	3,962
irrigation water	25.00	ha-m	2	50	2	50
interest on variable capital	0.23	year	0.5	1,544	0.5	1,321
Total Variable Costs				**15,698**		**13,433**
Income Above Variable costs				**5,024**		**2,198**

Table 34. Production Results from Peace Corps Volunteer Assisted Traditionally-Managed Fish Ponds

Producer	Pond area	Date stocked	Stocking rate	Duration	Mean tilapia weight	Tilapia yield	Other fish yield	Gross yield	Tilapia survival
	m²		*fish/ha*	*Days*	*g/fish*	*kg/ha*	*kg/ha*	*kg/ha*	*Pct.*
Canahuati	600	27 Aug. 91	22,500	*	*	*	*	*	*
Canahuati	600	27 Aug. 91	22,500	*	*	*	*	*	*
Escobar	235	20 Nov. 91	4,468	145	90	314	0	314	78
Exito Campesino	1,500	23 Oct. 91	23,300	*	*	*	*	*	86
Hernandez	150	*	*	*	55	1,093	0	1,093	*
La Escuela	330	*	*	145	104	523	41	564	*
Leba	395	11 May 91	8,481	339	168	1,382	0	1,382	97
Miranda	325	5 Nov. 91	12,308	162	80	862	0	862	87
Mercado	350	*	*	*	109	785	441	1,226	34
Rosa Urbana	480	22 Aug. 91	20,167	234	183	2,249	229	2,479	61
Villa Nueva	80	*	*	*	93	1,116	0	1,116	*
Zelaya	1,000	22 Aug. 91	25,000	235	146	2,321	319	2,640	64
Zelaya	350	Mar. 91	20,000	237	195	2,785	377	3,163	71
Means	492		17,636	214	122	1,343	117	1,484	72

LUPE FARMERS

The LUPE farmer who completed the farm trial harvested 1,048 kg/ha of tilapia after 207 days. This farmer made weekly applications of fresh cow manure at only 100 kg/ha (dry matter basis); and weekly urea fertilization of 20 kg/ha was suspended during the final six weeks.

PEACE CORPS FARMERS

Mean tilapia yield was 1,343 kg/ha after an average grow-out period of 211 days; other fish yield averaged 117 kg/ha, for a gross fish yield of 1,484 kg/ha (Table 34). Fish yield varied from 315 to 3,163 kg/ha. In discussions with the PCVs it became apparent that fish yield varied in relation to the amount of inputs used, i. e., adherence to a management plan. Farmers that consistently provided nutrient inputs to the pond obtained yields that approximated those achieved by the small- and medium-scale commercial farmers. Tilapia size at harvest averaged 122 g, similar to sizes obtained by small/medium scale farmers. Lack of data did not allow tilapia growth to be characterized, but experience suggests that the grow-out period was too long, that significant fish growth had ceased before fish were harvested. Thus, factors of production (ponds, inputs, farmer's labor, etc.) were underutilized.

Little economic data were available for this group of farmers. Few inputs were purchased, and it was not possible to assign an accurate economic value to inputs collected from the field, e. g., manure, termite nests, etc. Thus, it was impossible to conduct an economic evaluation of the traditional fish production system.

Table 35. Comparison of Selected Production Parameters Between the Traditional System and the Fertilization Followed by Feed and Chemical Fertilization Systems Used by Fish Culturists During On-Farm Trials in Honduras

Production system	Stocking rate	Pct. difference relative to traditional system	Grow-out duration	Pct. difference relative to traditional system	Annual tilapia yield	Pct. difference relative to traditional system
	Fish/m²		*Days*		*kg/ha/yr.*	
Traditional system	1.9	--	189	--	2,579	---
Fert. followed by feed compliant farmers	2.3	+21	163	-14	6,496	+152
Chemical fertilization compliant farmers	2.1	+11	161	-15	4,904	+90

COMPARISON OF PRODUCTION SYSTEMS

In Honduras, pond management practices characterized by varied and sporadic nutrient inputs and growout cycles that are considerably longer than 150 days can be collectively considered as the "traditional production system." This includes non-compliant small- and medium-scale commercial farmers and subsistence farmers. These producers provide a basis against which to compare the impact of the PD/A CRSP production systems. Twofold increases in tilapia yield relative to the traditional system were obtained by farmers using PD/A CRSP production systems (Table 35). Other important differences between the traditional and PD/A CRSP systems were that with the traditional system stocking rate was about 16 percent lower and the grow-out duration was about 15 percent longer (Table 35).

SUMMARY

Results of on-farm trials with the small- and medium-scale tilapia farmers demonstrated that the PD/A CRSP technologies were more productive than the traditional tilapia production system used in Honduras. The limited enterprise budget analysis indicated that both PD/A CRSP systems resulted in significant income above variable costs, an indicator of the economic viability of the systems. It should be noted that the PD/A CRSP production systems tested in this trial were not developed for subsistence fish farmers, but rather for small- to medium-scale commercial fish farmers who have the capability to purchase the necessary inputs. It is this group of fish farmers whom we feel will have the greatest impact on freshwater aquaculture in Honduras.

ECONOMICS OF HONDURAS PD/A CRSP POND MANAGEMENT SYSTEMS

Profitability of 41 production systems having differing nutrient input regimes in Honduras between 1983 to 1992 was evaluated by enterprise budget analysis. Enterprise budget items for the various treatments are discussed and net returns were calculated using prices and financial conditions in Honduras for 1992.

Positive net returns in U.S. Dollars (Lempiras 5.4 = U.S.$) and return on investment (percentages) demonstrated the variety of viable enterprise choices available to Honduran fish farmers under varying economic conditions. Fish yields were dependent on input type and quantity. Various inputs were transformed through production yields and associated infrastructural needs into cash receipts, input costs and fixed costs. Income above variable cost calculation was significant because it represented short-term viability of the operation. Positive income above variable costs is a short term measure indicating that operations should continue even with an overall loss (net returns) because shutting down operations would only increase overall loss. Long term viability of the operation though would need to have positive net returns. As interest rates, prices and availability of inputs change, a knowledgeable farmer recognizes that changing production systems could positively affect profits. An analysis of profitability for the 41 different tilapia production systems could assist the farmer in making economic decisions.

TREATMENT CATEGORIES

Five categories of nutrient input regimes were researched in Honduras: (1) *Chemical Fertilization* ; (2) *Organic Fertilization*; (3) *Organic plus Chemical Fertilization*; (4) *Organic Fertilization plus Supplemental Feed*; and (5) *Feed Only* (Table 36). Stocking rates varied from 2,500 to 30,000 male *Oreochromis niloticus* /ha of pond surface area. Production inputs centered around the choice of chemical fertilizers, organic fertilizers, formulated diets, combinations thereof, stocking rates, use of aeration and season. Prices for these production inputs may vary over time and local conditions. Chemical fertilizer prices can vary depending on their local availability and the degree that other

TABLE 36. NUTRIENT INPUT CATEGORIES, TREATMENT NAMES, STOCKING RATES, NUTRIENT INPUTS AND STUDY NUMBER FOR HONDURAS PD/A CRSP RESEARCH, 1983 TO 1992

Category	Treatment	Stocking rate[1]	Nutrient inputs
Chemical fertilization			
	Chem fert/cycle I	10,000/ha	8.7 kg TSP[2]/ha every 2 weeks; Study B1
	Chem fert/cycle II	10,000/ha	Weekly: 30.6 kg Urea/ha + 62.6 kg TSP/ha; Study B2
	N+P/C	20,000/ha	Weekly: 40.6 kg Urea/ha + 31.0 kg DAP[3]/ha; cool season control; Study B7
	N+P/W	20,000/ha	Weekly: 39.5 kg Urea/ha + 26.8 kg DAP/ha; warm season control; Study B7
Organic fertilization			
	Cow manure	10,000/ha	Weekly: 1,020 kg Cow manure/ha, dry matter basis; Study B7
	2,500/ha + CL	2,500/ha	Weekly: 750 kg CL[4]/ha; Study E3
	10,000/ha + CL	10,000/ha	Weekly: 750 kg CL/ha; Study E3
	20,000/ha + CL	20,000/ha	Weekly: 750 kg CL/ha; Study E3
	CL 125	10,000/ha	Weekly: 125 kg CL/ha; Study B3
	CL 250	10,000/ha	Weekly: 250 kg CL/ha; Study B3
	CL 500	10,000/ha	Weekly: 500 kg CL/ha; Study B3
	CL 1,000	10,000/ha	Weekly: 1,000 kg CL/ha; Study B3
	CL 1,000 @ 2	20,000/ha	Weekly: 1,000 kg CL/ha; Study B4
	CL 750/no urea	10,000/ha	Weekly: 750 kg CL/ha; control for CL 750/urea; Study B5
	CL 750/no sub	10,000/ha	Weekly: 750 kg CL/ha; control for CL 750/*x* sub; Study C4
	C:N control	20,000/ha	Weekly: 750 kg CL/ha; control for C_x:N_y; Study B6
	CL 500/no feed	10,000/ha	Weekly: 500 kg CL/ha; control for CL 500/*x*% feed; Study C3
Organic plus chemical fertilization			
	CL 750/Urea	10,000/ha	Weekly: 750 kg CL/ha + 10 kg N/ha as urea; Study B5
	C8:N1	20,000/ha	Weekly: 750 kg CL/ha + 6.3 kg N/ha as urea; Study B6
	C6:N1	20,000/ha	Weekly: 750 kg CL/ha + 14.1 kg N/ha as urea; Study B6
	C4:N1	20,000/ha	Weekly: 750 kg CL/ha + 29.9 kg N/ha as urea; Study B6
	CL 750/N+P/C	20,000/ha	Weekly: 750 kg CL/ha + 29.7 kg Urea/ha; cool season; Study B7
	CL 500/N+P/C	20,000/ha	Weekly: 500 kg CL/ha + 37.5 kg Urea/ha; cool season; Study B7
	CL 250/N+P/C	20,000/ha	Weekly: 250 kg CL/ha + 41.3 kg Urea/ha + 9.9 kg DAP/ha; cool season; Study B7
	CL 500/N+P/W	20,000/ha	Weekly: 500 kg CL/ha 33.5 kg Urea/ha + 9.5 kg DAP/ha; warm season; Study B7
	CL 250/N+P/W	20,000/ha	Weekly: 250 kg CL/ha 37.6 kg Urea/ha + 15.4 kg DAP/ha; warm season; Study B7
Organic fertilization plus supplemental feed			
	CL 500/0.5% feed	10,000/ha	Weekly: 500 kg CL/ha. Daily: feed (0.5% fish biomass); Study C3
	CL 500/1.0% feed	10,000/ha	Weekly: 500 kg CL/ha. Daily: feed (1.0% fish biomass); Study C3
	CL 500/2.0% feed	10,000/ha	Weekly: 500 kg CL/ha. Daily: feed (2.0% fish biomass); Study C3
	CL 750/1 mon. sub.	10,000/ha	Weekly (first 30 d): 750 kg CL/ha. Daily (begin. day 31): feed (3.0% fish biomass); Study C4
	CL 750/2 mon. sub.	10,000/ha	Weekly (first 60 d): 750 kg CL/ha. Daily (begin. day 61): feed (3.0% fish biomass); Study C4
	CL 750/3 mon. sub.	10,000/ha	Weekly (first 90 d): 750 kg CL/ha. Daily (begin. day 91): feed (3.0% fish biomass); Study C4
	CL 60/feed	20,000/ha	Weekly (first 60 d): 1,000 kg CL/ha. Daily (begin. day 61): feed (3.0% fish biomass); Study C2
	CL plus feed	20,000/ha	Weekly: 500 kg CL/ha. Daily: feed (1.5% fish biomass); Study C2
	No aeration/sub.	20,000/ha	Weekly (first 60 d): 1,000 kg CL/ha. Daily (begin. day 61): feed (3.0% fish biomass); Study E4
	10% sat./sub.	20,000/ha	Weekly (first 60 d): 1,000 kg CL/ha. Daily (begin. day 61): feed (3.0% fish biomass); Study E4
	30% sat./sub.	20,000/ha	Weekly (first 60 d): 1,000 kg CL/ha. Daily (begin. day 61): feed (3.0% fish biomass); Study E4
Feed only			
	10,000/ha + feed/C	10,000/ha	Daily: feed (3.0% fish biomass); cool season; Study C1
	20,000/ha + feed/W	20,000/ha	Daily: feed (3.0% fish biomass); warm season; Study C2
	20,000/ha + feed/C	20,000/ha	Daily: feed (3.0% fish biomass); cool season; Study C1
	30,000/ha + feed/C	30,000/ha	Daily: feed (3.0% fish biomass); cool season; Study C1

[1] Male *Oreochromis niloticus*.

[2] Triple superphosphate fertilizer (0-46-0).

[3] Diammonium phosphate fertilizer (18-46-0).

[4] Chicken litter applied on dry matter basis.

agricultural users compete for fertilizers. Animal manures are usually less expensive than chemical fertilizers or formulated diets. Manure value is usually based upon the labor of collection plus transportation and profit margin. In these production trials, chicken litter was bagged and delivered to the experiment station by a local entrepreneur. Formulated fish feeds were relatively expensive inputs compared to chemical and organic fertilizers.

ENTERPRISE BUDGET ANALYSIS

BUDGET PREPARATION

Full-cost enterprise budgets included use of 1992 Honduran prices for market value of fish, variable costs and fixed costs. Use of all variable and fixed inputs, including credit, was assumed. Table 37 depicts representative enterprise budgets for the five nutrient input categories. Cash receipts were obtained from the sale of adult tilapia, adult *C. managuense* and tilapia fingerlings. Variable input items included: fingerlings, feed, fertilizer, transport of materials, aeration electricity and interest on operating costs . Quantities of some variable inputs were similar for all treatments; these inputs were: irrigation water, day and night field labor, and transport of fingerlings (one trip for all treatments stocking less than 30,000 fish/ha, otherwise two trips were required). Aeration costs were calculated by multiplying aerator kilowatt usage by the number of hours of aerator operation multiplied by the kw/h electrical cost. Fish production cycles were approximately five months for all treatments. Enterprise budgets were annualized on a per hectare basis for comparative purposes.

TABLE 37. REPRESENTATIVE FULL-COST ENTERPRISE BUDGET FOR EACH OF THE FIVE NUTRIENT INPUT CATEGORIES EVALUATED FOR TILAPIA PRODUCTION PONDS IN HONDURAS. VALUES IN U.S. DOLLARS PER HECTARE PER SIX-MONTH PRODUCTION CYCLE

	Unit cost/ price	Chemical fertilization only (N+P/W)		Manure only (20,000/ha/ manure)		Manure plus chemical fertilization (C6:N1)		Manure plus supplemental feed (CL plus feed)		Feed only (feed only)	
Description		Quantity	Cash	Quantity	Cash	Quantity	Cash	Quantity	Cash	Quantity	Cash
Cash receipts											
adult tilapia	1.43	2,045	2,924	2,497	3,570	3,640	5,204	4,021	5,749	4,470	6,390
adult guapote	1.43	5	7	53	76	12	17				
tilapia repro	0.10	29	3	2	0	12	1	302	31	780	79
Total cash receipts			2,934		3,646		5,222		5,779		6,470
Variable costs											
fingerlings											
tilapia	0.02	20,000	370	20,000	370	20,000	370	20,000	370	20,000	370
red tilapia	0.03										
guapote	0.03	500	14	1,000	28	500	14				
plastic bags	1.11	41	46	42	47	41	46	40	44	40	44
feed	12.04							84	1,011	200	2,407
fertilizer											
chicken litter	0.37			692	256	694	257	352	130		
cow manure	0.00										
urea	12.59	19	239			7	88				
18-46-0	15.19	13	197								
0-46-0	17.04										
transport											
fingerlings	37.04	1	37	1	37	1	37	1	37	1	37
feed	37.04							1	37	1	37
chicken litter	37.04			4	148	4	148	2	74		
cow manure											
fertilizer	37.04	1	37								
aeration											
field labor											
day	2.59	75	194	75	194	75	194	75	194	75	194
night	4.54	150	681	150	681	150	681	150	681	150	681
irrigation water	4.63	1	5	1	5	1	5	1	5	1	5
interest on variable capital	0.23		209		203		212		297		434
Total variable costs			**2,030**		**1,969**		**2,051**		**2,881**		**4,210**
Income above variable costs			904		1,677		3,171		2,898		2,260

Table 37, Continued. Representative Full-Cost Enterprise Budget for Each of the Five Nutrient Input Categories Evaluated for Tilapia Production Ponds in Honduras. Values in U.S. Dollars Per Hectare Per Six-Month Production Cycle

	Unit cost/ price	Chemical fertilization only (N+P/W)		Manure only (20,000/ha/ manure)		Manure plus chemical fertilization (C6:N1)		Manure plus supplemental feed (CL plus feed)		Feed only (feed only)	
Description		Quantity	Cash	Quantity	Cash	Quantity	Cash	Quantity	Cash	Quantity	Cash
Fixed costs											
Interest on bldg. and equipment	0.23	4,939	1,136	4,939	1,136	4,949	1,136	5,310	1,221	4,939	1,136
Depreciation on bldg. and equip.			139		139		139		164		139
Other	0.28	8	2	8	2	8	2	8	2	8	2
Total fixed costs			**1,277**		**1,277**		**1,277**		**1,387**		**1,277**
Total costs			3,307		3,246		3,329		4,268		5,488
Net returns to land and management											
Dollars			**-373**		**399**		**1,893**		**1,511**		**982**
Dollars/yr.			**-746**		**799**		**3,787**		**3,022**		**1,965**
Return to average investment					16		77		57		40

In Honduras, the 1992 interest rate for agricultural loans was 23 percent. Because all trials were conducted at the experiment station no actual borrowing of money occurred, however, farmers may or may not need access to credit. The 23 percent interest rate represents an opportunity cost in the determination of economic profitability or efficient resource utilization.

Fixed costs included depreciation and interest on buildings and equipment, and an annual cost for pond

Table 38. Building and Equipment Depreciation and Interest Charge on Average Investment for Five Nutrient Input Categories in Honduras 1983 to 1992. All Values are in U.S. Dollars (U.S. $1 = Lempiras 5.40 in July 1992)

					Depreciation Charges (U.S. $)[1]				
Item	Value	Proportion charged	Salvage value	Useful life	Chemical fertilization	Organic fertilization	Chemical plus organic fertilization	Org. Fert. plus supplemental feed[2]	Feed only
	U.S. $	*Pct.*	*Pct.*	*Yrs.*					
Storage building[3]	740	100	0	15	49.38	49.38	98.76	98.76	49.38
Pick-up truck[4]	7,407	10	10	10	66.67	66.67	66.67	66.67	66.67
D.O. meter[5]	900	100	10	5	162.00	162.00	162.00	162.00	162.00
Electric aerator	400	100	10	5	---	---	---	[72.00]	---
Pond/harvest basin	11,111	0	100	20	0.00	0.00	0.00	0.00	0.00
Annual depreciation	---	---	---	---	278.05	278.05	327.43	327.43 [399.43]	278.05
Depreciation per 6-month production cycle	---	---	---	---	139.03	139.03	163.72	163.72 [199.72]	139.03
Interest on building and equipment[6]	---	---	---	---	1,136.07	1,136.07	1,221.26	1,221.26 [1,271.86]	1,221.26

[1] Straight-line depreciation was used and calculated as: (Price-Salvage value)/(Useful life).

[2] There were two aeration treatments in this category that required one aerator; values in brackets include additional depreciation and interest charges for the aerator.

[3] One storage building for treatments using feed or fertilizer; two storage buildings were required for treatments that combined feed or fertilizer with manure.

[4] Pick-up truck was charged to the fish farm enterprise 10% of the time.

[5] Dissolved oxygen meter (at U.S. cost plus import dury) was included.

[6] Interest on building and equipment was calculated as: ((cost + salvage value)/2) x 23%.

maintenance (Table 38). Calculations included one storage building for treatments using feed or fertilizer and two storage buildings when feed or chemical fertilizer was used in combination with manure to store inputs separately. One truck was charged to the fish farming enterprise 10 percent of the time and one dissolved oxygen meter was included (at U.S. cost plus import duty). Buildings and equipment were charged at the prevailing 23 percent interest rate using a straight line method of depreciation and the same rate was applied on average investment items. It was assumed the land was already owned and there were existing ponds so no costs were included for these items. Ponds were not depreciated. Subtracting variable and fixed costs from the cash receipts resulted in a net return to land, existing ponds and operator's labor and management. This is referred to as "net returns" in discussion hereafter unless specifically stated otherwise.

Breakeven cost is a ratio between variable or total costs divided by total fish production. The result is a fish market price required to cover variable or total costs. Positive (negative) deviation between the breakeven cost and the actual fish selling price (U.S. $1.43/kg) will be the profit (loss) margin. Any breakeven cost of production covering variable costs that is less than the market price for tilapia will show a profit in the short run. Likewise, when breakeven costs of production covering variable and fixed costs are lower than the selling price, then long term profitability has been achieved.

Table 39. Summary Economic Returns per Hectare per Six-month Production Cycle and Performance From Enterprise Budget Analyses of Tilapia Production Pond Nutrient Input Regimes in Honduras Between 1983 and 1992. Tilapia Market Price in 1992 was U.S. $1.43 Per Kilogram. Currency Exchange Rate at the Time of Analysis was U.S. $1 = 5.40 Lempiras

Treatment	Income above variable costs	Net returns to land and management	Return to average investment	Breakeven cost per kilogram of fish to cover: Variable costs	Breakeven cost per kilogram of fish to cover: Variable and fixed costs
	U.S. $	*U.S. $*	*Pct.*	*U.S. $*	*U.S. $*
Chemical fertilization					
Chem Fert/Cycle I	-679.86	-1,957.00	-79	2.97	5.87
Chem Fert/Cycle II	-102.06	-1,379.00	-56	1.51	2.50
N+P/C	562.19*	-715.00	-29	1.13	1.82
N+P/W	904.19*	-373.00	-15	0.99	1.62
Organic fertilization					
Cow manure	1,071.24*	-206.00	-8	0.77	1.56
2,500/ha + CL	-306.85	-1,584.00	-64	1.87	3.48
10,000/ha + CL	1,057.87	-220.00	-9	0.90	1.57
20,000/ha + CL	1,676.75	399.00	16	0.79	1.30
CL 125	324.81*	-953.00	-39	1.16	2.25
CL 250	818.43	-459.00	-19	0.90	1.74
CL 500	1,167.07	-110.00	-4	0.82	1.49
CL 1,000	1,507.84	230.00	9	0.79	1.34
CL 1,000 @ 2	1,082.59*	-195.00	-8	0.94	1.52
CL 750/no urea	704.21*	-573.00	-23	1.01	1.79
CL 750/no sub	876.29*	-401.00	-16	0.97	1.69
C:N control	2,040.56	763.00	31	0.70	1.16
CL 500/no feed	169.62*	-1,108.00	-45	1.29	2.37
Organic plus chemical fertilization					
CL 750/urea	798.88*	-478.00	-19	1.00	1.71
C8:N1	1,918.17	641.00	26	0.73	1.20
C6:N1	3,170.84	1,893.00	77	0.56	0.91
C4:N1	1,676.88	400.00	16	0.81	1.28
CL 750/N+P/C	611.70	-666.00	-27	1.12	1.78
CL 500/N+P/C	1,465.28	188.00	8	0.83	1.36
CL 250/N+P/C	1,362.44	85.00	3	0.85	1.40
CL 500/N+P/W	3,026.02	1,749.00	71	0.58	0.94
CL 250/N+P/W	1,302.65	25.00	1	0.87	1.42
Organic fertilization plus supplemental feed					
CL 500/0.5% feed	337.58*	-1,050.00	-40	1.19	2.18
CL 500/1.0% feed	493.81	-893.00	-34	1.13	1.97
CL 500/2.0% feed	289.75*	-1,097.00	-41	1.27	2.04
CL 750/1 mon. sub.	402.71*	-984.00	-37	1.29	1.88
CL 750/2 mon. sub.	307.02*	-1,080.00	-41	1.31	1.95
CL 750/3 mon. sub.	693.80	-693.00	-26	1.14	1.77
CL 60/feed	2,798.85	1,412.00	53	0.82	1.12
CL plus feed	2,898.06	1,511.00	57	0.72	1.06
No aeration/sub.	1,145.96*	-241.00	-9	1.10	1.51
10% sat./sub.	2,134.19	660.00	24	0.92	1.28
30% sat./sub.	2,286.11	812.00	29	0.90	1.25
Feed only					
10,000/ha + feed/C	835.48*	-442.00	-18	1.08	1.61
20,000/ha + feed/W	2,259.72	982.00	40	0.94	1.23
20,000/ha + feed/C	1,023.80*	-254.00	-10	1.15	1.50
30,000/ha + feed/C	2,014.59	737.00	30	1.01	1.28

* Income above variable cost was positive when net returns to land and management was negative. Positive income above variable costs is a short-term measure that indicates that operations should be continued even with an overall loss because shutting down operations would increase the overall loss. Long-term viability of the operation would require positive net returns.

RESULTS FROM ENTERPRISE BUDGET ANALYSIS

None of the four *Chemical Fertilization* treatments had positive net returns, although treatments *N+P/C* and *N+P/W* had positive income above variable costs (Table 39). Positive income above variable cost indicates a viable operation in the short run. Changes in the financial climate, e.g. lower interest rates on operating capital or lowered input prices or higher fish marketing prices, could transform a negative net return into a positive value. Thus, enterprises with short term positive results and negative long-term net returns should not be completely ruled out for future consideration. The two treatments with tilapia stocked at 10,000/ha had greater losses than the two treatments where tilapia stocking rates were 20,000/ha.

Breakeven costs to cover variable and total (variable plus fixed costs) costs for each treatment are shown in Table 39. Using the *N+P/C* treatment as an example, the $1.13 breakeven price to cover variable costs is less than the 1992 Honduran tilapia market price of $1.43, indicating a positive, short run profit margin of $0.30/kg of fish produced. Breakeven selling price of tilapia to cover variable costs for the *Chem Fert/Cycle II* treatment was $1.51, greater than the prevailing tilapia market price ($1.43) and an example of a negative profit margin in the short run.

Only three of the 13 *Organic Fertilization* treatments had positive net returns: *20,000/ha + CL*, *C:N control* and *CL 1,000* (Table 39). The treatment with tilapia stocked at 2,500/ha had the greatest negative net returns, as well as negative income above variable costs. Organic fertilization as the sole nutrient input for tilapia production was not economically feasible under 1992 economic conditions in Honduras. However, it should be noted that eight of nine treatments with negative net returns had positive incomes above variable costs.

Seventy-eight percent of treatments in the *Organic Plus Chemical Fertilization* category had positive net returns (Table 39). One treatment with a negative net return, *CL 750/Urea*, was stocked at 10,000 tilapia/ha, while all but one of the other treatments had positive net returns when stocked at 20,000 fish/ha. Both treatments that exhibited negative net returns had positive income above variable costs. Temperature effects on production between seasons were clearly evident where treatments were tested both seasons.

Analysis of the first seven *Organic Fertilization Plus Supplemental Feed* treatments resulted in negative net returns (Table 39). A stocking rate of 10,000 tilapia per hectare was common among these seven treatments. Treatments stocked at 20,000 tilapia per hectare yielded positive net returns except for the *No aeration/sub.* treatment that had positive income above variable costs but negative net returns. The economics of nightly or emergency aeration were not determined during these experiments, but should be investigated in future research.

Four treatments comprised the *Feed Only* category (Table 39). Negative net returns were obtained in the treatment where tilapia were stocked at 10,000/ha, which suggests again a minimum stocking rate of 20,000 tilapia/ha for profitable fish culture especially where prepared rations are used. Seasonal effects likely were responsible for differences in net returns observed for the two treatments stocked at 20,000 tilapia/ha. The warm-season treatment (20,000/ha + feed/W) had positive net returns while the cool-season treatment (20,000/ha + feed/C) had negative net returns. Positive net returns also were obtained for the treatment stocked with 30,000 tilapia/ha, the highest stocking rate tested. Further research should be conducted on the effect on yields of seasonal variation and on the use of higher stocking rates (> 20,000 tilapia/ha), particularly when commercial fish rations are used.

SUMMARY OF ENTERPRISE BUDGET ANALYSIS

Figure 20 graphically summarizes individual treatments within nutrient input categories that have positive net returns. The *Chemical Fertilization Only* category is not represented because no treatment had positive net returns.

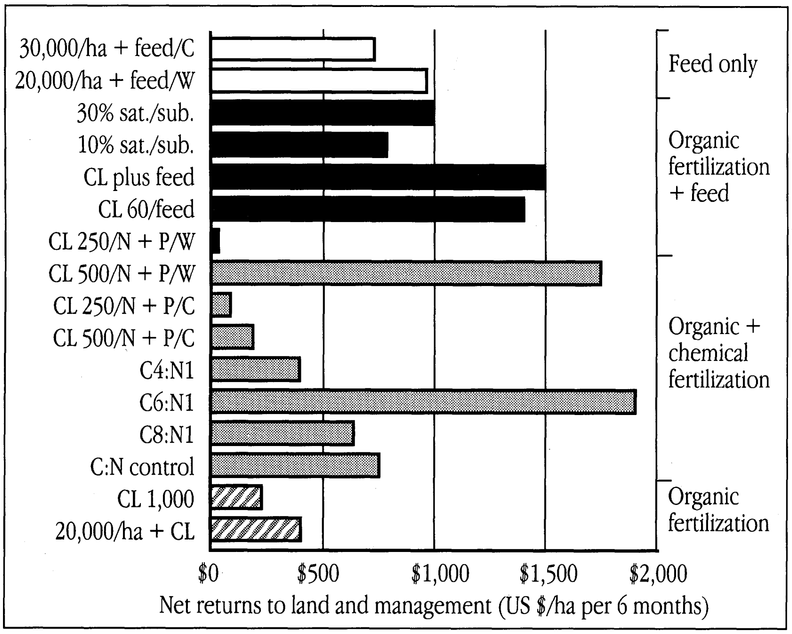


Figure 20. Tilapia pond management strategies in Honduras that had positive net returns to land and management.

Thus, in the Honduran context use of only chemical fertilizers for production of tilapia is not profitable, at least for fertilizer quantities tested and interest rates used in this budget analysis. Some treatments from each of the other four nutrient-input categories are represented in Figure 20. All treatments with positive net returns used stocking rates of at least 20,000 tilapia/ha. This result strongly indicates that stocking 10,000 tilapia/ha does not fully utilize available pond food resources and at a higher stocking rate additional fish yield is possible using the same amount of inputs.

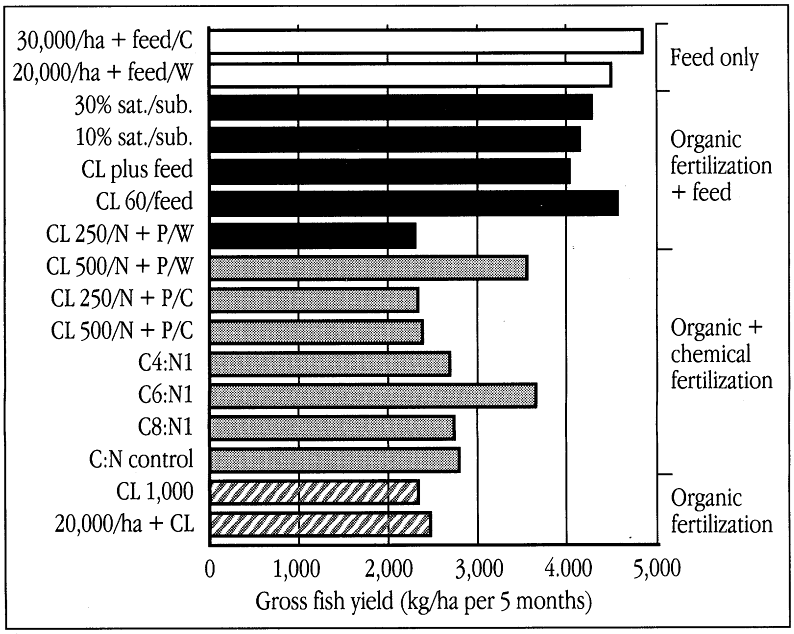


Figure 21. Comparisons of gross fish yields in relation to different pond management strategies in Honduras.

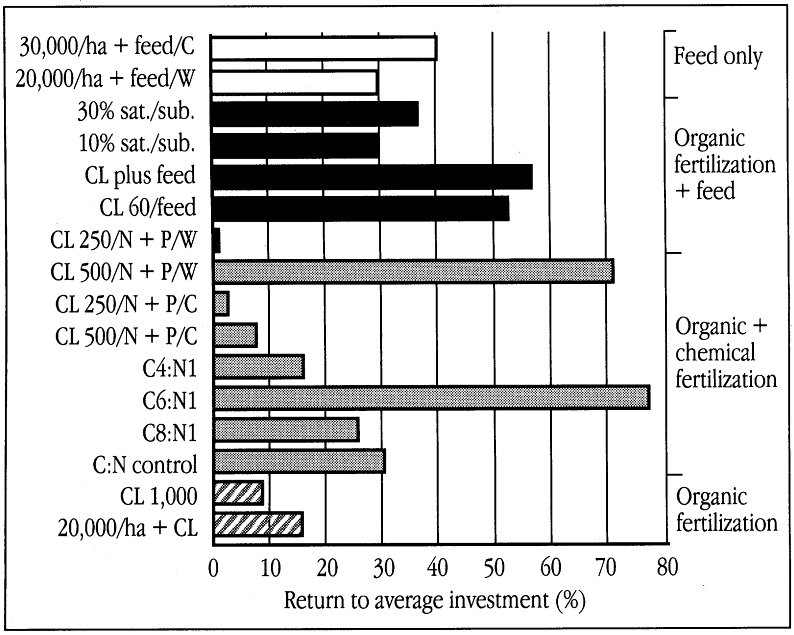


Figure 22. Comparison of returns to average investment in relation to different tilapia pond management strategies in Honduras.

Treatments that utilized organic or chemical fertilizers as nutrient inputs had lower production costs than treatments that used formulated feeds exclusively throughout the five-month cycle because fertilizers had lower unit costs. Formulated fish feeds are expensive primarily because of the cost of protein included in the diet. Competition for protein feed sources with land livestock activities, the expense of construction and operation of feed mills, transportation of feed ingredients to the mill and product to market, packaging, and intermediary-stage value added steps all contribute to the relatively higher cost of formulated feeds. Chemical fertilizers have similar cost stages but there are no feed spoilage problems such as those associated with formulated feeds. However, chemical fertilizer prices often are subsidized by governments as a stimulus to production agriculture. Manures as a source of pond nutrients probably have the least add-on expenses included in its final price or cost (real or opportunity). Labor to collect, bag and transport are the main items determining the prices for chicken litter and cow manure used in these experiments.

The use of formulated feeds, stocking rates of 20,000 and 30,000 fish/ha of pond surface area and aeration increased fish yield (Figure 21). However, it is likely that critical standing crop or carrying capacity of ponds were not attained with these management practices because of the low stocking rates. Stocking rates in the range of 30,000 to 60,000 fish/ha of pond surface area need to be investigated.

The production system with the greatest amount of production is not always the most profitable enterprise. Comparing the summary of positive net returns in Figure 20 with the summary of production yields in Figure 21, it can be seen that production from treatment *C6:N1* was lower than six other treatments (*CL60/feed, CL plus feed, 10 percent sat./sub, 30 percent sat./sub, 20,000/ha + feed/W* and *30,000/ha + feed*) but net returns from *C6:N1* was greater than all other treatments. Conversely, the *30,000/ha + feed/C* treatment had the greatest production yield (Figure 21), but only resulted in intermediate net returns when compared to other treatments (Figure 20). It is the cost of intensified inputs, such as additional fingerlings at higher stocking rates, the greater quantity and quality of nutrients required, aeration equipment and associated electricity costs, etc., that decreased the greater sales revenue amount to an overall intermediate net return. Thus, variable costs and new equipment required will determine if greater fish production results in higher profits to the enterprise.

Table 40. Effect of Varying Cost of 45.4-kg Sack of Commercial Fish Feed on Short-Term (Income Above Variable Costs) and Long-Term (Net Returns to Land and Management) Profitability of Aquaculture Enterprises in Honduras. Values are in U.S. Dollars Per Six-Month Production Cycle

	Commercial fish feed price (per 45.4 kg)					
	Income above variable costs			Net returns to land and management		
Treatment	-20 pct. ($9.63)	1992 price ($12.04)	+ 20 pct. ($14.44)	-20 pct. ($9.63)	1992 price ($12.04)	+20 pct. ($14.44)
CL 60/feed	3,190	2,799	2,407	1,804	1,412	1,020
20,000/ha + feed/W	2,797	2,260	1,723	1,519	982	446
CL plus feed	3,124	2,898	2,673	1,736	1,511	1,285
CL 500/0.5% feed	370	338	305	-1,017	-1,050	-1,082
CL 500/1.0% feed	564	494	424	-824	-893	-963
CL 500/2.0% feed	443	290	137	-944	-1,097	-1,250
CL 750/1 mon. sub.	722	403	83	-665	-984	-1,304
CL 750/2 mon. sub.	575	307	39	-812	-1,080	-1,349
CL 750/3 mon. sub.	884	694	503	-503	-693	-884
10,000/ha + feed/C	1,099	836	572	-179	-442	-705
20,000/ha + feed/C	1,574	1,024	474	297	-254	-804
30,000/ha + feed/C	2,629	2,015	1,400	1,352	737	123
No aeration/sub.	1,543	1,146	749	156	-241	-638
10% sat./sub.	2,531	2,134	1,737	1,058	660	263
30% sat./sub.	2,683	2,286	1,889	1,210	812	415

Table 41. Effect of Varying Cost of 50-kg Sack of Urea Fertilizer on Short-Term (Income Above Variable Costs) and Long-Term (Net Returns to Land and Management) Profitability of Aquaculture Enterprises in Honduras. Values are in U.S. Dollars Per Six-Month Production Cycle

	Urea fertilizer price (per 50 kg)					
	Income above variable costs			Net returns to land and management		
Treatment	-20 pct. ($10.07)	1992 price ($12.60)	+20 pct. ($15.11)	-20 pct. ($10.07)	1992 price ($12.60)	+20 pct. ($15.11)
Chem Fert/Cycle II	-60	-102	-144	-1,337	-1,379	-1,422
CL 750/urea	827	799	771	-450	-478	-507
C8:N1	1,927	1,918	1,910	649	641	632
C6:N1	3,191	3,171	3,151	1,913	1,893	1,874
C4:N1	1,719	1,677	1,635	442	400	357
CL 750/N+P/C	654	612	570	-624	-666	-708
CL 500/N+P/C	1,516	1,465	1,415	238	188	137
CL 250/N+P/C	1,419	1,362	1,306	141	85	29
N+P/C	618	562	506	-659	-715	-771
CL 500/N+P/W	3,071	3,026	2,981	1,794	1,749	1,704
CL 250/N+P/W	1,353	1,303	1,252	76	25	-25
N+P/W	958	904	851	-320	-373	-427

Season affected fish yields, which in turn caused changes in profitability. In the *Feed Only* category two similar experiments (*20,000/ha + feed*) run in different seasons, warm/rainy and cool/dry, resulted in positive and negative net returns, respectively. The three greatest net returns recorded, for treatments *C6:N1*, *CL Plus Feed* and *CL60/Feed*, occurred during the warm/rainy season. However, seasonal effects were not always the sole factor to influence profitability; season by treatment interactions also appeared to affect profitability. For example, the cool/dry-season *N+P/C* treatment resulted in high losses, while the *CL500/N+P/C* treatment produced positive net returns. However, *CL500/N+P/W* (warm/rainy season) produced net returns almost ten times higher than *CL500/N+P/C*. Treatment *CL250/N+P/C* (cool/dry season) had higher net returns than treatment *CL250/N+P/W* (warm/rainy season). Effect of seasonal variation on fish yield in Honduras also should be investigated more thoroughly.

Percentage return on investment (ROI) values for treatments having positive net returns ranged from one percent to 77 percent (Figure 22). ROI values are important because potential investors use these values for comparison to alternative investment opportunities.

SENSITIVITY ANALYSES

Sensitivity analyses were conducted for the major production inputs, adult tilapia sales price and variable capital interest rate. Rather than use historical price patterns, which were unavailable, to indicate upper and lower limits for sensitivity analyses, price ranges were estimated through interviews with Honduran and expatriate aquacultural officials. Ranges then were increased slightly to be more encompassing. Sensitivity analyses were used to determine how specific price changes affected short- and long-term profitability of 41 enterprises (Table 36).

TABLE 42. EFFECT OF VARYING SALES PRICE OF MARKETABLE TILAPIA ON SHORT-TERM (INCOME ABOVE VARIABLE COSTS) AND LONG-TERM (NET RETURNS TO LAND AND MANAGEMENT) PROFITABILITY OF AQUACULTURE ENTERPRISES IN HONDURAS. VALUES ARE IN U.S. DOLLARS PER SIX-MONTH PRODUCTION CYCLE

	Marketable tilapia sales price (per kg)					
	Income above variable costs			Net returns to land and management		
Treatment	-25 pct. ($1.07)	1992 price ($1.43)	+25 pct. ($1.80)	-25 pct. ($1.07)	1992 price ($1.43)	+ 25 pct. ($1.80)
Chem Fert/Cycle I	-837	-680	-523	-2,114	-1,957	-1,800
Chem Fert/Cycle II	-563	-102	359	-1,841	-1,379	-918
Cow Manure	493	1,071	1,649	-784	-206	372
CL 125	-88	325	738	-1,366	-953	-539
CL 250	272	819	1,365	-1,005	-459	88
CL 500	490	1,168	1,844	-787	-110	-566
CL 1,000	680	1,508	2,336	-598	230	1,059
CL 1,000 @ 2	299	1,083	1,866	-978	-195	589
2,500/ha + CL	-590	-307	-24	-1,868	-1,584	-1,301
10,000/ha + CL	380	1,058	1,736	-898	-220	459
20,000/ha + CL	789	1,677	2,565	-488	399	1,287
CL 750/no urea	124	704	1,284	-1,153	-573	7
CL 750/urea	162	799	1,436	-1,115	-478	158
CL 60/feed	1,191	2,799	4,407	-196	1,412	3,020
20,000/ha + feed/W	670	2,260	3,849	-607	982	2,572
CL plus feed	1,468	2,898	4,328	81	1,511	2,941
CL 500/no feed	-250	169	589	-1,527	-1,108	-688
CL 500/0.5% feed	-163	338	839	-1,551	-1,050	-549
CL 500/1.0% feed	-93	494	1,080	-1,480	-893	-307
CL 500/2.0% feed	-350	290	929	-1,737	-1,097	-458
CL 750/no sub.	244	876	1,508	-1,033	-401	231
CL 750/1 mon. sub.	-431	403	1,236	-1,818	-984	-151
CL 750/2 mon. sub.	-469	307	1,084	-1,857	-1,080	-304
CL 750/3 mon. sub.	-95	694	1,483	-1,482	-693	96
10,000/ha + feed/C	-21	836	1,692	-1,299	-442	415
20,000/ha + feed/C	-295	1,024	2,342	-1,572	-254	1,065
30,000/ha + feed/C	302	2,015	3,727	-975	737	2,450
No aeration/sub.	-64	1,146	2,356	-1,452	-241	969
10% sat./sub.	665	2,134	3,604	-809	660	2,130
30% sat./sub.	768	2,286	3,804	-705	812	2,330
C:N control	1,051	2,041	3,030	-227	763	1,753
C8:N1	946	1,918	2,890	-331	641	1,613
C6:N1	1,876	3,171	4,465	599	1,893	3,188
C4:N1	723	1,677	2,631	-554	400	1,353
CL 750/N+P/C	-71	612	1,295	-1,349	-666	17
CL 500/N+P/C	603	1,465	2,328	-675	188	1,050
CL 250/N+P/C	529	1,362	2,196	-749	85	919
N+P/C	-92	562	1,216	-1,369	-715	-61
CL 500/N+P/W	1,760	3,026	4,292	483	1,749	3,014
CL 250/N+P/W	479	1,303	2,126	-799	25	849
N+P/W	177	904	1,631	-1,100	-373	354

Tilapia production inputs evaluated by sensitivity analysis were: commercial fish feed (20 to 25 percent protein), urea, diammonium phosphate (DAP), adult tilapia sales price and variable capital interest rate.

Change in commercial feed price of +/- 20 percent did not reverse the sign for income above variable cost for any enterprise that used feed (Table 40). Reduction of feed price by 20 percent resulted in transition of negative net returns into positive returns for two enterprises (Table 40). Treatments where tilapia were stocked at 10,000/ha were most sensitive to changes in feed price. At stocking rates of 20,000/ha, enterprises were less sensitive to feed price. A stocking rate of 30,000/ha was profitable at all feed prices evaluated. A +/- 20 percent change in feed price resulted in, on average, a 33 percent change in short-term profitability and a 56 percent change in long-term profitability.

All enterprises, except one, that used urea were profitable in the short term in response to a +/- 20 percent change in urea price (Table 41). Urea price variation tested resulted in an average change in short-term profitability of 7 percent and an average change in long-term profitability of 29 percent. A +/- 10 percent change in diammonium phosphate price caused, on average, a 9 percent change in short-term enterprise profitability. Long-term profitability changed 12 percent, on average, in response to price variation. Further, long-term profitability was negative where DAP was used with urea, but was positive when DAP was combined with chicken litter.

Variation in tilapia sales price by +/- 25 percent of the 1992 level resulted in negative short-term profitability (Table 42). Twenty-five treatments had positive income above variable costs at all tilapia sales prices. Twelve treatments had negative income above variable costs at the lowest tilapia sales price. A 25 percent-reduction in tilapia sales price resulted in negative long-term profitability for most treatments (Table 42). Changes in short- and long-term profitability averaged 96 percent and 200 percent, respectively, in response to the +/ - 25 percent change in tilapia sales price.

Variable capital interest rates have been volatile in Honduras in recent years, and have varied by as much as 50 percent. Fifty percent increase or decrease in interest rate was tested by sensitivity analysis (Table 43). All treatments except three showed positive short-term profitability at the three interest rates tested. Long-term profitability was negative for 25 treatments, which indicates that short-term profitability was marginal. Fourteen treatments had positive long-term profitability at all interest rates tested. The +/- 50 percent variation in variable capital interest rate yielded average changes in short- and long-term profitability of 17 percent and 37 percent, respectively.

TABLE 43. EFFECT OF VARYING ANNUAL INTEREST RATE (APR) OF VARIABLE CAPITAL ON SHORT-TERM (INCOME ABOVE VARIABLE COSTS) AND LONG-TERM (NET RETURNS TO LAND AND MANAGEMENT) PROFITABILITY OF AQUACULTURE ENTERPRISES IN HONDURAS. VALUES ARE IN U.S. DOLLARS PER SIX-MONTH PRODUCTION CYCLE

	Variable capital interest rate (APR)					
	Income above variable costs			Net returns to land and management		
Treatment	-50 pct. (11.5 pct.)	1992 rate (23 pct.)	+50 pct. (34.5 pct.)	-50 pct. (11.5 pct.)	1992 rate (23 pct.)	+50 pct. (34.5 pct.)
Chem Fert/Cycle I	-612	-680	-747	-1,890	-1,957	-2,025
Chem Fert/Cycle II	-1	-102	-203	-1,278	-1,379	-1,481
Cow Manure	1,136	1,071	1,007	-141	-206	-271
CL 125	394	325	256	-883	-953	-1,022
CL 250	890	819	747	-387	-459	-531
CL 500	1,248	1,167	1,086	-30	-110	-191
CL 1,000	1,603	1,508	1,413	325	230	136
CL 1,000 @ 2	1,189	1,083	976	-88	-195	-301
2,500/ha + CL	-230	-307	-384	-1,507	-1,584	-1,661
10,000/ha + CL	1,147	1,058	969	-131	-220	-308
20,000/ha + CL	1,778	1,677	1,575	501	399	298
CL 750/no urea	789	704	619	-488	-573	-658
CL 750/urea	891	799	707	-386	-478	-571
CL60/feed	2,989	2,799	2,609	1,602	1,412	1,221
20,000/ha + feed/W	2,477	2,260	2,043	1,199	982	765
CL plus feed	3,047	2,898	2,749	1,659	1,511	1,362
CL 500/no feed	248	169	91	-1,030	-1,108	-1,186
CL 500/0.5% feed	424	338	251	-963	-1,050	-1,136
CL 500/1.0% feed	590	494	398	-797	-893	-990
CL 500/2.0% feed	408	290	172	-980	-1,097	-1,215
CL 750/no sub.	966	876	787	-312	-401	-490
CL 750/1 mon. sub.	558	403	247	-829	-984	-1,140
CL 750/2 mon. sub.	455	307	159	-932	-1,080	-1,228
CL 750/3 mon. sub.	825	694	563	-562	-693	-824
10,000/ha + feed/C	970	836	701	-307	-442	-576
20,000/ha + feed/C	1,244	1,024	803	-33	-254	-474
30,000/ha + feed/C	2,266	2,015	1,763	988	737	486
No aeration/sub.	1,339	1,146	953	-48	-241	-435
10% sat./sub.	2,330	2,134	1,938	856	660	465
30% sat./sub.	2,484	2,286	2,088	1,011	812	614
C:N control	2,141	2,041	1,940	864	763	662
C8:N1	2,021	1,918	1,815	744	641	538
C6:N1	3,277	3,171	3,065	1,999	1,893	1,788
C4:N1	1,789	1,677	1,565	511	400	288
CL 750/N+P/C	722	612	501	-555	-666	-766
CL 500/N+P/C	1,569	1,465	1,361	292	188	84
CL 250/N+P/C	1,465	1,362	1,259	188	85	-18
N+P/C	669	562	455	-608	-715	-822
CL 500/N/P/W	3,133	3,026	2,919	1,855	1,749	1,642
CL 250/N+P/W	1,407	1,303	1,199	129	25	-79
N+P/W	1,009	904	799	-269	-373	-478

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Harvesting fish from reseaarch pnds.

CONCLUSIONS

Economic conclusions from the enterprise budget analysis of 41 nutrient-input regimes has led to the verification of an important agricultural economic concept and to some specific insights regarding Honduras. A principle well known to agricultural economists, the concept of marginal returns, is well demonstrated with the Honduras data. Simply stated, the aquacultural production system with the greatest production is not always the enterprise producing the greatest profit.

The 23 percent interest rate for agricultural loans that prevailed in Honduras may be responsible for making once profitable nutrient input regimes unprofitable now.

Temporal financial conditions have an important impact on the choice of fish production systems; the higher the interest rate the less fish farm operators are likely to borrow money for operating capital or for capital expenditures. Rural resource-limited farmers may never borrow money and instead rely on traditional agricultural patterns to supply nutrients, i. e., manures, and to work the farm, i. e., family labor.

Stocking rates of at least 20,000 fish/ha pond surface area appear to be required for profitable fish culture enterprises in Honduras.

Only one enterprise where tilapia were stocked at 10,000/ha had positive net returns to land, labor and management, although many treatments at this stocking rate showed positive income above variable costs.

Climatic factors also appear to affect profitability of pond management systems; net returns generally were greater during the warm/rainy season.

Honduras PD/A CRSP researchers have presented various production options to Honduran fish farmers and a diverse set of nutrient-input regimes has resulted in profitable aquacultural operations, even at the 23 percent agricultural loan interest rate prevailing in Honduras in 1992. Twelve treatments from four categories of nutrient management resulted in positive net returns. These 12 nutrient management systems provide a range of profitable options to fish farmers in Honduras.

Sensitivity analyes indicated that enterprise profitability was most affected by changes in tilapia sales price. Feed price had the next greatest impact on short- and long-term enterprise profitability, followed by variable capital interest rate. It appeared that interest rate changes did not affect treatment profitability as much as was anticipated initially. Changes in chemical fertilizer prices had the least effect on enterprise profitability.

On the low technology end of this range, use of chicken litter resulted in profitable tilapia production. On the high technology end of this range, use of formulated feed and aeration resulted in profitable tilapia production. In the middle of the technology range, the combinations of chicken litter and chemical fertilization or chicken litter and formulated feed resulted in profitable production systems. Such a range of profitable tilapia production systems allows appropriate input choices in poor areas as well as in conditions favoring capital intensification. A wide choice of profitable production intensities and system alternatives offer efficient resource utilization and leads to a foundation for sustainable aquaculture.

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APPENDIX

Cross-Reference of Studies to PD/A CRSP Work Plans

Study number in this report	PD/A CRSP work plan
Study A1	Work plan 2: site-specific study
Study A2	Work plan 5: Study 3
Study A3	Work plan 5: Study 4
Study A4	Work plan 5: site-specific study
Study B1	Work plan 1
Study B2	Work plan 2
Study B3	Work plan 3
Study B4	AU-USAID/Honduras project
Study B5	Work plan
Study B6	Work plan 5: Study 6
Study B7	Work plan 6: Study 1
Study C1	AU-USAID/Honduras project
Study C2	AU-USAID/Honduras project
Study C3	Work plan 4 (1987-1988)
Study C4	Work plan 5: Study 1
Study D1	Work plan 4 (1988-1989)
Study D2	Work plan 5: Study 2
Study D3	Work plan 5: Study 5
Study D4	Work plan 5
Study E1	Work plan 1: site-specific study
Study E2	Work plan 2: site-specific study
Study E3	Work plan 4 (1988-1989)
Study E4	Work plan 5: Study 5