Progress Report on Fisheries Development in Northeast Brazil

INTERNATIONAL CENTER FOR AQUACULTURE
AGRICULTURAL EXPERIMENT STATION AUBURN UNIVERSITY
R. DENNIS ROUSE, DIRECTOR AUBURN, ALABAMA
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COVER PHOTO. Harvesting all-male tilapia hybrid fingerlings at the Valdemar C. de Franca fish hatchery in Maranguape, Brazil, for stocking intensive fish culture ponds.

Progress Report on Fisheries Development in Northeast Brazil

LEONARD L. LOVSHIN[1]

AUBURN UNIVERSITY, under contract by USAID (U.S. Agency for International Development), has been involved in improving the freshwater fishery resources in Northeast Brazil since 1966 when several staff members participated in short-term work programs in that country. From 1969 to the present, the University has provided technical assistance in the form of resident advisors to the Brazilian federal agency, DNOCS[2], in fish culture, reservoir management, and fish culture extension. The author was the resident fish culture advisor from June 1972 until his return to Auburn in January 1979. The fisheries technical assistance contract to the Brazilian government was terminated on February 28, 1979. Principal duties involved assisting Brazilian biologists in conducting and analyzing fish culture research and aiding DNOCS in planning and implementing semi-annual fishery short courses for Brazilian and other Latin American fishery workers.

This report summarizes the pertinent activities related to fishery and fish culture research and training within the DNOCS fishery organization during the period January 1, 1977 - December 31, 1978. Previous progress reports describe fisheries development in Northeast Brazil (*3, 7, 8, 9, 10, 11*).

TRAINING AND TECHNICAL ASSISTANCE

The *Centro de Pesquisas Ictiologicas* is recognized as one of the outstanding tropical freshwater fishery research and training organizations in Latin America. Staff of the research center are frequently invited to present research and position papers at national and international fishery conferences. The number of requests for technical assistance in fisheries and aquatic biology from Brazilian and other South American agencies is growing yearly. DNOCS biologists have assisted Brazilian state and federal agencies and academic institutions in planning and carrying out a wide range of fishery activities to develop Brazil's fishery resources and trained manpower.

One of the biologists from the *Centro de Pesquisas Ictiologicas* teaches advanced aquaculture and directs undergraduate thesis candidates at the local Federal University of Ceara. He also acts as a coordinator for the fish culture section of "*Projecto Sertanejo*," and a cooperative rice-fish culture research and development project with CODEVASF[3]. The "*Projecto Sartanejo*" is a large federal project that finances construction of small earthen reservoirs throughout Northeast Brazil. The impoundments will be used to establish integrated farming activities, including fish culture. CODEVASF is one of the Brazilian governmental agencies responsible for the development of the Sao Francisco River valley. CODEVASF has large irrigated areas in rice cultivation and is interested in integrating operation of these areas with fish culture. Brazilian extension agents and researchers connected with both DNOCS and CODEVASF are being trained at DNOCS fishery installations.

A formal agreement between Brazilian and Peruvian governments to exchange technical expertise has involved the research center. A DNOCS fish culture specialist traveled to Peru to help Peruvians establish and improve their own freshwater fishery programs based on the Brazilian experience in the Northeast. Peruvian fishery scientists receive training at the *Centro de Pesquisas Ictiologicas* in areas of aquatic resource management that will enhance the Peruvian program. In 1978, three biologists from the Peruvian Ministry of Fisheries spent 9 weeks at the research center.

The *Centro de Pesquisas Ictiologicas* continues to offer short-term training programs in the aquatic sciences to interested Latin American biologists. Increased demand for training has resulted in the *Centro de Pesquisas Ictiologicas* offering two formal training courses a year. Training programs lasting 2 months are offered, March-April and September-October, for up to 15 students. These short courses contain classroom lectures and practical exercises in the subjects of intensive and extensive fish culture, reservoir management, collection of commercial fishery statistics, hatchery management, and reservoir limnology. Short-term training was offered to 6 Hondurans, 7 Colombians, 1 Panamanian, 1 Venezuelan, and 41 Brazilians in 1977 and 1978.

These Honduran biologists participated in a 2-month fishery training program at the Rodolpho von Ihering fish culture center in Pentecoste, Brazil. The training program is offered twice a year to Latin American biologists.

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[1]Associate Professor, Department of Fisheries and Allied Aquacultures.

[2]Departamento Nacional de Obras Contra as Secas.

[3]*Companhia de Desenvolvimento do Vale do Sao Francisco.*

Officials of the Brazilian government are aware of the contribution that the DNOCS fishery programs are having on animal protein production in the northeast of Brazil. DNOCS is considered the leader in freshwater fishery research and commercial fish production within Brazil. DNOCS's efforts to train Brazilian and other Latin American biologists at the *Centro de Pesquisas Ictiologicas* have also been well received. Realizing that the *Centro de Pesquisas Ictiologicas* requires strengthening to continue its leadership role in Brazil, the federal government, through the *Conselho Nacional des Pesquisas*, has granted the research center Cr. $9 million (U.S. $400,000) for 1979. These additional funds will allow the research center to hire and train new biologists to aid the present staff in meeting the numerous requests for technical assistance, training, and expanded research activities.

INSTALLATIONS AND FACILITIES

New headquarters of the *Centro de Pesquisas Ictiologicas* is scheduled to be inaugurated in 1979. The center is shifting to Pentecoste, Ceara, 100 kilometers by paved road from the state capital of Fortaleza. The new installations contain a 1,200-square meter laboratory and teaching complex, administration building, warehouse, garage-machine shop, fish technology building, and net fabrication and repair house. The building complex is surrounded by pond facilities on 120 hectares of land located below the 5,000-hectare Pereira de Miranda Reservoir at Pentecoste. Housing facilities for station biologists, visiting scientists, and students are near completion. Presently, the *Centro de Pesquisas Ictiologicas* has 162 earthen ponds and 36 concrete tanks ranging in size from 100 to 10,000 square meters and 36 to 75 square meters, respectively. A wet-laboratory containing forty 20-liter aquaria and twenty 500-liter cement fiber tanks plus eight concrete tanks for holding fish is available. Total water area is 11.0 hectares.

When pond installations are completed in 1980, the *Centro de Pesquisas Ictiologicas* will contain over 200 earthen ponds comprising more than 20 hectares of water. The research center's facilities are among the finest in the tropical world for research and training in freshwater fish culture, reservoir management, reservoir limnology, and related aquatic sciences.

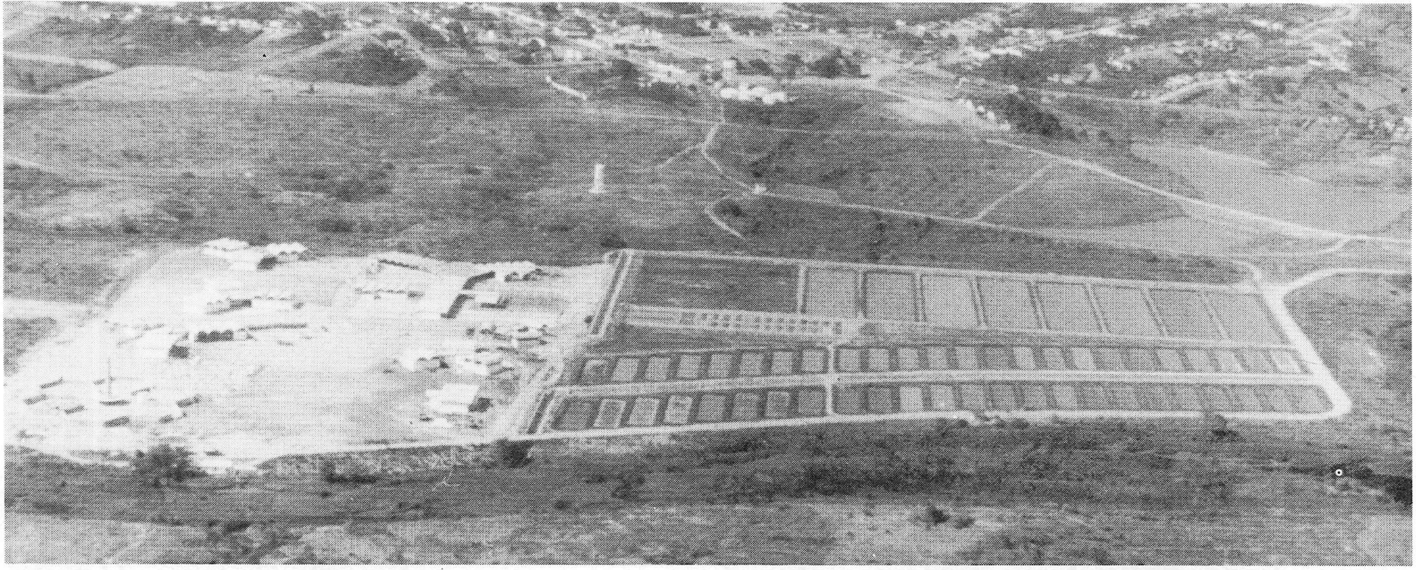
FISH CULTURE RESEARCH PROGRAM

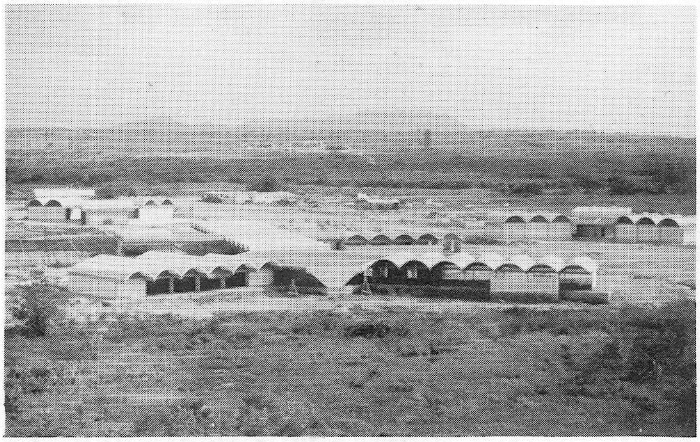
Aquacultural research has been in progress since 1970, directed towards evaluating Brazilian fishes for culture potential and developing culture systems for use in DNOCS irrigation projects and by private farmers. Exotic species with known extensive and intensive culture potential are being investigated. This section summarizes pertinent research performed over the past 2 years. Evaluations of the most promising culture species based on 7 years of research are included.

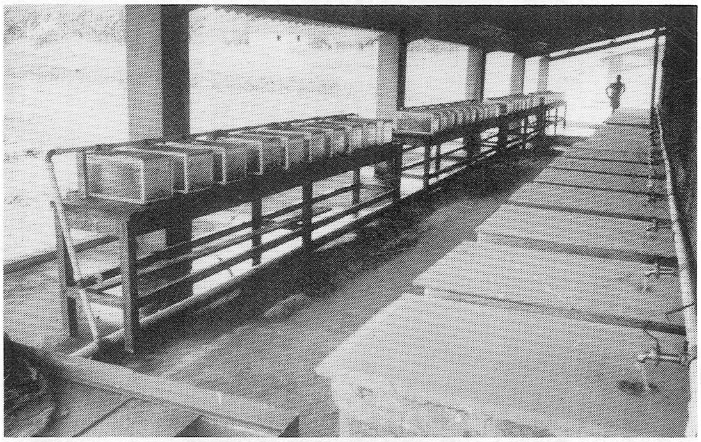
Tilapia Production Experiments

At present, tilapia offer the greatest potential for immediate culture in ponds in Northeast Brazil. Past research results can be

Phase I of Rodolpho von Ihering fish culture research center in Pentecoste, Brazil, provides pond facilities for fish culture training and research. Note pig sties constructed over the ponds in lower left corner of photograph.







Phase II of the Rodolpho von Ihering fish culture center is scheduled for completion in 1980. The complex will include teaching, research, administrative, storage, repair, and dormitory facilities. An aerial view of the center is at top, with building detail shown bottom left and wet laboratory research installations shown bottom right.

reviewed in publications by Lovshin, Da Silva, and Fernandes (13), Lovshin *(10, 11)*, and Lovshin and Da Silva *(14)*. The majority of research on tilapias is presently concentrated on the all-male tilapia hybrid produced by crossing female *Tilapia nilotica* with male *Tilapia hornorum*.

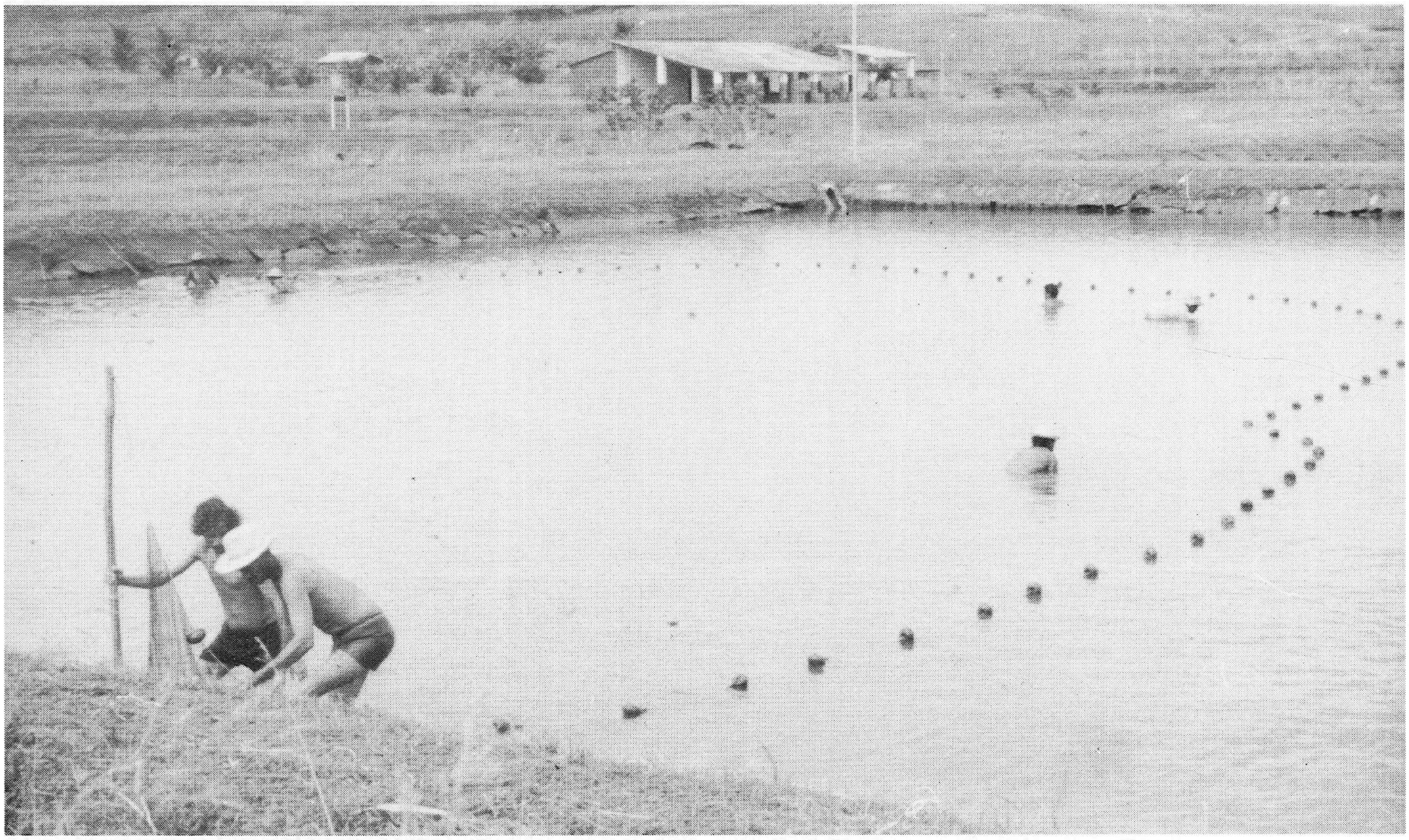
Tilapia hybrids give excellent results when intensively cultured utilizing low-cost agricultural by-products or organic manures as feeds and fertilizers. Past research demonstrated that tilapia hybrids stocked at 10,000 per hectare and fed agricultural by-products reached an average weight of 200-300 grams in 6 months, resulting in 2,000 to 3,000 kilograms per hectare. Maximum production of over 10,000 kilograms per hectare per year of 400-gram fish was obtained by stocking up to 31,000 male tilapia hybrids per hectare and feeding cottonseed and palm nut cake.

Piava, Carneiro-Sobrinho, and F. Melo (unpublished data) tested the growth of the all-male tilapia hybrid fed three types of locally available agricultural by-products. A completely random design was used with three treatments replicated three times. Nine 355-square meter earthen ponds were stocked with 400 tilapia hybrids (11,250 per hectare). Castor bean meal (30 percent protein), *babacu* cake (a palm nut with 21 percent protein), and cottonseed cake (21.5 percent protein) were fed at 3 percent of the average biomass of fish in each treatment once a day, 6 days a week. Every month at least 10 percent of all fish were seined from each pond, weighed, and measured. Feeding rates were recalculated monthly based on the seine samples. After 238 days all ponds were harvested. Results of this experiment can be found in table 1. Differences in total fish production between treatments were significant at the 0.05

TABLE 1. SUMMARY OF RESULTS COMPARING THREE TYPES OF FEEDS ON THE GROWTH OF ALL-MALE TILAPIA HYBRIDS (FEMALE *T. NILOTICA* x MALE *T. HORNORUM*)

Performance measure	Result, by type of feed[1]		
	Castor bean meal	Palm nut cake	Cottonseed cake
Av. initial wt., g	15	14	15
Av. final wt., g	323	266	239
Av. production per pond, kg	123	93	88
Av. production per ha, kg	3,444	2,325	2,200
Survival, pct.	95	95	93
Av. conversion rate			
6 months	1.8:1	1.8:1	2.0:1
7 months	2.0:1	2.4:1	2.3:1
8 months	2.4:1	2.6:1	2.7:1
Growth of fish per day, g	1.3	1.1	0.9

[1]Average of three replicates.



TOP: Monthly seine samples are taken to follow the growth of experimental pond cultures at the Rodolpho von Ihering fish culture center. LEFT: Fish taken from the experimental ponds are weighed and measured by DNOCS biologists to evaluate production practices.

level. Fish fed castor bean meal gained significantly more weight than fish fed *babacu* or cottonseed cake. No significant difference in fish production was found between fish fed *babacu* cake or cottonseed cake. Castor bean meal ($0.10 per kilogram) proved to be the most profitable feed although *babacu* cake ($0.11 per kilogram) and cottonseed cake ($0.15 per kilogram) produced fish economically. Feed conversions (kilograms of feed per kilogram of fish growth) for castor bean meal, *babacu* cake, and cottonseed cake were 2.4, 2.6, and 2.7, respectively.

Augusto and H. Melo (unpublished data) tested effects of ammonium sulfate (20 percent N), triple superphosphate (46 percent P_2O_5), ammonium sulfate plus triple superphosphate, and no fertilizer (control) on the growth of the all-male tilapia hybrid in 355-square meter earthen ponds. Treatments receiving ammonium sulfate and triple superphosphate were replicated three times while treatments receiving both fertilizers and the control were replicated twice. Ponds in the ammonium sulfate and triple superphosphate treatments were fertilized with equal amounts of nitrogen and phosphate (280 grams per application). Ponds in the ammonium sulfate plus triple superphosphate treatment were fertilized with half the amount of nitrogen (140 grams per application) and phosphate (140 grams per application) so that the total amount of nitrogen plus phosphate applied was equivalant to 280 grams. Ponds were fertilized every 15 days by placing the fertilizer on a platform located 20 centimeters below the water surface. Ponds fertilized with ammonium sulfate and triple superphosphate received 1.42 kilograms per pond per application (40 kilograms per hectare) and 0.61 kilogram per pond per application (17 kilograms per hectare), respectively. Ponds receiving both fertilizers had 0.76 kilogram per pond application of triple superphosphate (20 kilograms per hectare) and 0.31 kilogram per pond application of triple superphosphate (8.7 kilograms per hectare) added. All fertilized ponds received an initial application of fertilizer 15 days before fish were stocked.

Ponds were stocked with the equivalent of 10,000 all-male tilapia hybrids per hectare. All ponds were sampled once a month. Ten percent of the fish in each pond were captured with a seine, weighed, and measured. Three fish from each pond were sacrificed monthly and stomach contents analyzed. After 192 days, the experiment was terminated and all ponds were harvested.

Results of this research are summarized in table 2. The use of chemical fertilizers increased the total production of tilapia hybrids two to three times that of the control. Triple superphos-

TABLE 2. SUMMARY OF RESULTS OF THREE TYPES OF CHEMICAL FERTILIZERS AND A CONTROL ON THE PRODUCTION OF ALL-MALE TILAPIA HYBRIDS (FEMALE *TILAPIA NILOTICA* x MALE *TILAPIA HORNORUM*)

Performance measure	Result, by fertilizer treatment[1]			
	Control	Ammonium sulfate	Triple superphosphate	Ammonium sulfate plus triple superphosphate
Av. initial wt., g	20	19	19	20
Av. final wt., g	43	118	101	122
Av. production per pond,[2] kg	12.5	36.3	29.7	34.9
Av. production per hectare, kg	350	1,016	832	977
Survival, pct.[3]	81	87	82	81
Fertilizer per pond, kg	0	22.7	9.8	16.3
Fertilizer per hectare, kg	0	636	274	456

[1]The control and ammonium sulfate + triple superphosphate treatment results are the average of two replicates. The remaining two treatments are the results of three replicates.
[2]Weight of fish at final harvest; sacrificed fish not included.
[3]Survival of fish at final harvest; sacrificed fish not included.

phate alone was not as effective as ammonium sulfate alone or the two fertilizers together. Apparently, a source of nitrogen is needed to increase fish production even in older earthen ponds.

Stomach analyses demonstrated that the all-male tilapia hybrid fed almost exclusively on planktonic and attached algae and bottom muds. Although ponds were rich with zooplankton, benthic organisms, and aquatic insects, few of these items were encountered in stomachs of the hybrids.

Production of All-male Tilapia Hybrid Fingerlings

Several researchers have reported producing all-male offspring when female *Tilapia nilotica* are crossed with male *Tilapia hornorum*. Lovshin, Da Silva, Carneiro-Sobrinho, and F. Melo (unpublished data) performed a series of experiments to determine a system for producing maximum numbers of all-male hybrid fingerlings. Tests were performed to determine the optimum ratio of female *T. nilotica* to male *T. hornorum*, number of female *T. nilotica* per area of spawning pond, and length of time broodstock can be used before replacement is necessary. A total of 142 crosses was made over a 6-year period. Original stocks of *T. hornorum* and *T. nilotica* were obtained from Ivory Coast, West Africa, and the offspring of these stocks were used as broodstock for the experiments. Mature female *T. nilotica* and male *T. hornorum* were stocked into the hybrid spawning ponds in varying numbers per surface area and at different ratios. The broodstock were fed agricultural by-products at 5 to 10 percent of their body weight, 6 days a week. After 70 to 92 days, the ponds were drained and all fingerlings recovered were counted. The broodstock were counted and weighed individually and immediately transferred to a newly prepared spawning pond where a new hybridization study was initiated.

Table 3 has the results of fingerling production when 25, 50, 75, and 100 female *T. nilotica* were stocked in ponds of 350 square meters. The ratio of female *T. nilotica* stocked with the male *T. hornorum* was 5 to 1 in most trials. Best results were obtained with 50 females, or 1 female per 7 square meters of spawning pond. An average of 2,763 hybrid fingerlings was produced per 2.5-month spawning period per pond.

TABLE 3. SUMMARY OF THE RESULTS OF INCREASING THE NUMBER PER AREA OF FEMALE *TILAPIA NILOTICA* AND MALE *TILAPIA HORNORUM* ON THE PRODUCTION OF ALL-MALE TILAPIA HYBRID FINGERLINGS

Performance measure	Result, by male:female numbers			
	5:25	10:50	15:75	20:100
No. of replications	15	61	17	9
Av. No. of fingerlings	1,179	2,763	2,167	1,502
Range of av. No. of fingerlings	0-3,309	0-8,443	473-5,295	607-2,526
Av. No. of fingerlings/ female	52	57	30	15

Data in table 4 show how varying the ratio of female *T. nilotica* to male *T. hornorum* affected tilapia hybrid fingerling production in 350-square meter earthen ponds. The commonly used female to male ratio of 5 to 1 was tested against ratios of 1 female to 1 male and 1 female to 2 males. Increasing the number of male *T. hornorum* to female *T. nilotica* increased the number of hybrid fingerlings produced. Best results were obtained when two *T. hornorum* males were stocked for every *T. nilotica* female.

TABLE 4. SUMMARY OF THE RESULTS OF INCREASING THE RATIO OF FEMALE *TILAPIA NILOTICA* TO MALE *TILAPIA HORNORUM* ON ALL-MALE TILAPIA HYBRID FINGERLING PRODUCTION

Performance measure	Result, by male:female ratio[1]		
	5:25	25:25	50:25
Av. initial wt., g (males)	103	144	101
Av. initial wt., g (females)	103	105	101
Av. No. of fingerlings	699	1,532	2,159
Av. No. of fingerlings/female[2]	30	64	88
Av. No. of days in period	80	82	80

[1]Average of six replicates.
[2]In some cases, less than 25 females were found at draining.

Table 5 gives results of the effects of repeated use of the same group of broodstock (10 *T. hornorum* males and 50 *T. nilotica* females) on fingerling production. Groups of broodstock were repeatedly transferred to freshly prepared 350-square meter spawning ponds until fingerling production declined, at which point the broodstock were removed. This procedure gave an indication of the length of time the brooders could be used before replacement with new broodstock. After the third spawning period, the production of hybrid fingerlings declined. Therefore, after approximately 8 months or 3 spawning periods,

TABLE 5. SUMMARY OF RESULTS OF REPEATED USE OF BROODSTOCK GROUPS, 50 FEMALE *TILAPIA NILOTICA* x 10 MALE *TILAPIA HORNORUM*, ON ALL-MALE TILAPIA HYBRID FINGERLING PRODUCTION

Performance measure	Result, by spawning period			
	1	2	3	4
No. of replicates	12	12	12	6
Av. No. of fingerlings	2,969	2,405	2,569	1,465
Range of av. No. of fingerlings	620-6,000	412-4,679	0-8,443	0-2,976
Av. No. of fingerlings /female	57	50	53	33
Range of av. No. of fingerlings/female	12-120	8-61	0-192	0-69

TOP: The Valdemar C. de Franca fish hatchery, one of five hatcheries operated by DNOCS in the Northeast of Brazil, produces fingerlings for stocking into public and private reservoirs. RIGHT: Fingerlings being harvested.

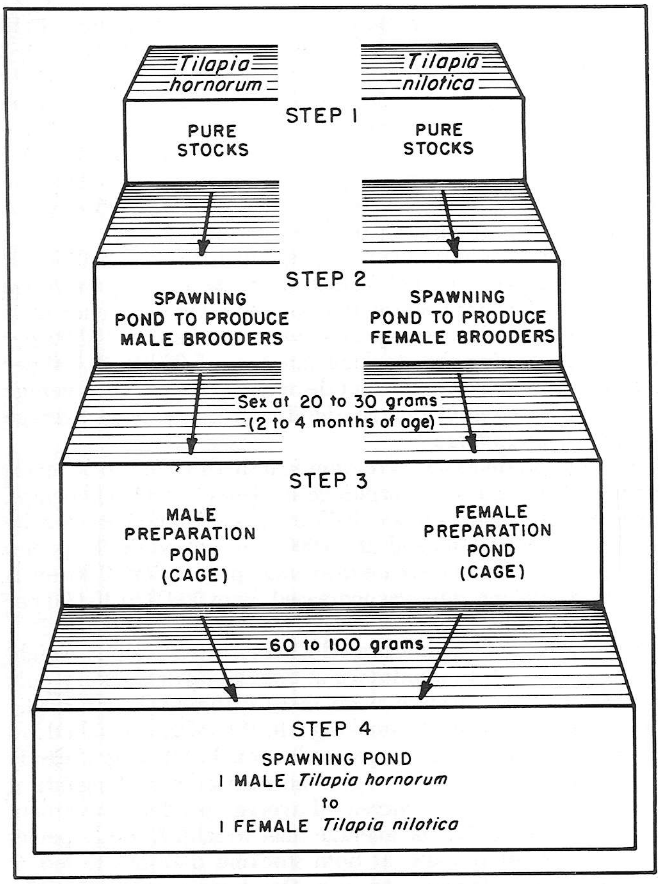
the broodstock would be removed and new broodstock introduced. At the time of replacement, broodstock are about 13 to 14 months old assuming they were stocked when sexually mature at 5 to 6 months (60 to 100 grams).

The drawing illustrates the procedure now used by DNOCS to produce all-male tilapia hybrid fingerlings. Pure stocks of *T. hornorum* and *T. nilotica* are held in covered 36-square meter concrete tanks with a filtered water supply. Pure broodstock of both species are released into 350-square meter ponds separated by at least 50 meters to prevent contamination. These earthen ponds are used to produce the number of *T. nilotica* and *T. hornorum* broodstock required for mass producing all-male hybrids. When the immature, pure stock fingerlings reach a size at which they can be readily sexed (20 to 30 grams), female *T. nilotica* and male *T. hornorum* are placed in separate ponds to allow them to grow to maturity isolated from their opposite sex. If pond facilities are limited, fish can be stocked into cages and fed a complete ration. Immature female *T. nilotica* and male *T. hornorum* should reach sexual maturity in 2 months, 60 to 100 grams, when stocked two to three per square meter and fed 5 percent of their body weight daily. Mature male *T. hornorum* and female *T. nilotica* with swollen genital papillae are placed in the hybridization pond at the ratio of one male to one female, stocking one female per 7 square meters of pond surface area. Water depth of spawning ponds should be slightly less than 1 meter. After 2.5 months, hybrid fingerlings should be removed from the spawning pond to avoid possible backcrossing with the parents. Hybrid fingerlings should be separated from hybrid fry to reduce cannibalism.

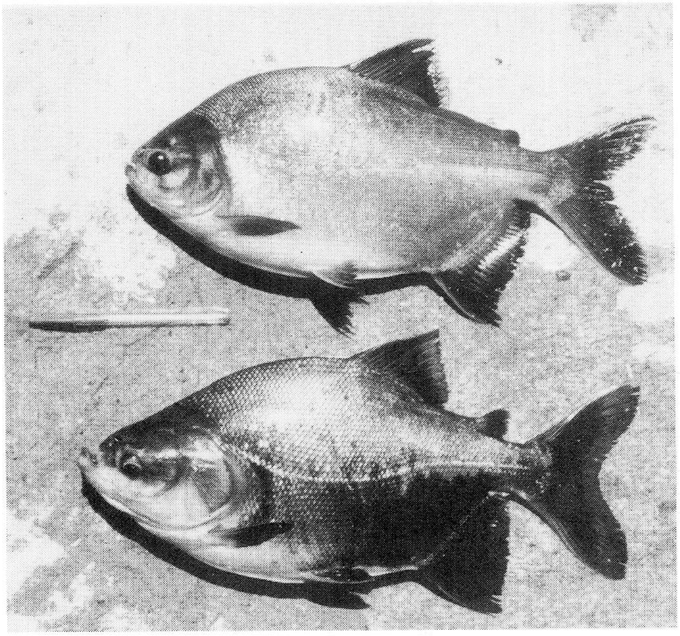
Fingerling production remains the primary constraint to raising all-male tilapia hybrids on a commercial scale. Fingerling production per square meter of spawning pond is low. Reasons for low hybrid fingerling productivity are not thoroughly understood. Apparently, the percentage of female *T. nilotica* that will spawn with male *T. hornorum* is low. This appears to be caused by differences in spawning behavior between the two species. Females that do spawn produce normal numbers of hybrid fry. At present, a large pond hatchery facility would be required to produce the number of all-male hybrid fingerlings necessary for a large grow-out operation.

Evaluation of Tilapias in Intensive Fish Culture

Use of tilapias in intensive fish culture has been highly promising when some method of reproduction control is



System for producing all-male Tilapia hybrid fingerlings (female *Tilapia nilotica* x male *Tilapia hornorum*).



***Pirapitinga (Colossoma bidens)*, top, and *tambaqui (Colossoma macropomun)*, bottom, two fruit eaters native to the Amazon River basin, have demonstrated excellent culture potential in experimental ponds at the Rodolpho von Ihering fish culture center in Pentecoste, Brazil.**

practiced. Reproduction control with a predator *(11)* and culture of selected males *(13, 14)* or all-male tilapia hybrids *(10, 11, 14)* have all successfully reduced or eliminated excessive reproduction in Brazil. Research has been concentrated on the culture of all-male hybrids. The all-male tilapia hybrid has proven to be an exceptional culture fish, able to withstand handling, diseases, and low levels of dissolved oxygen in culture ponds. Farmers in demonstration trials have harvested 4,000-8,000 kilograms per hectare per year of marketable fish using manures and agricultural by-products as feeds. Such yields are highly profitable, yet the commercial production of all-male hybrids has been slow to be adopted and provide the desired impact on fish production in the Northeast. Expansion of tilapia hybrid culture has been restricted by the lack of hybrid fingerlings. This is because of several reasons:

1. Lack of government and private fingerling production facilities.
2. Low numbers of all-male hybrid fingerlings produced when compared with pure species fingerling production.
3. Relatively high level of technology needed to produce all-male hybrid fingerlings when compared with producing tilapia fingerlings of one species.

The average farmer in the Northeast does not have the technical capability to produce tilapia hybrid fingerlings. Extreme care is needed to maintain pure lines of broodstock so that all-male hybrids can be produced with regularity. Fingerling production is limited to government facilities that are unable to produce large quantities of fingerlings at this time. Private production of hybrid fingerlings will be limited, in most cases, to large farmers with money to build proper hatchery facilities and hire a full-time trained technician to run the hatchery. However, wealthy farmers have not demonstrated an interest in investing in large-scale hybrid tilapia fingerling production.

While the all-male tilapia hybrid is an excellent culture fish and should prove valuable in certain culture situations, it is the author's opinion that the hybrid is not the fish to be raised by lower and middle class farmers on an expanded scale throughout the Northeast. The best alternatives for expanding intensive fish culture in the Northeast are the culture of pure *T. nilotica* with partial harvesting, an easily reproduced predator, or monosex males. The average farmer can produce his own fingerlings for the culture of *T. nilotica,* since the technology is not complicated. Thus, fish farmers would not have to depend on the government to produce their fingerlings.

Experiments with *Tambaqui (Colossoma macropomum)* and *Pirapitinga (Colossoma bidens)*

Numerous Brazilian fishes have been tested for intensive culture potential *(10, 11)*. However, only two have demonstrated characteristics of good culture fishes.

Tambaqui (Colossoma macropomum) and *pirapitinga (Colossoma bidens)* are native to the Amazon River basin. Both feed principally on fruits and seeds. In seasons when fruits and seeds are not available, *tambaqui* is known to feed on zooplankton filtered from the water. Both fishes grow rapidly and are highly prized as food fish. These species spawn in the Amazon River and its tributaries in response to rising waters during the rainy season.

Lovshin, Da Silva, Fernandes, and Carneiro-Sobrinho *(12)* demonstrated in preliminary pond tests with fingerlings captured and transported from the Amazon River that both species possess excellent culture characteristics. However, neither species spawned naturally in standing water ponds. Lack of initial success spawning *tambaqui* and *pirapitinga* under hatchery conditions limited experimentation due to a lack of fingerlings. In March 1976, *pirapitinga* was artificially spawned for the first time. In February 1977, both *tambaqui* and *pirapi-*

Over 8,000 kilograms per hectare per year of *pirapitinga (Colossoma bidens)*, averaging 900 grams, have been harvested from experimental ponds.

tinga were artificially spawned and *tambaqui* was spawned again in February 1978. Da Silva, Carneiro-Sobrinho, and F. Melo *(1)* and Lovshin *(11)* described this spawning procedure. Both species were spawned using intramuscular injections of pituitaries taken from mature *curimata comum, Prochilodus cearensis.* It was found that *pirapitinga* spawn naturally after pituitary administration when the males and females are placed together in a spawning tank. However, *tambaqui* must be stripped of their sex products to obtain viable eggs. *Pirapitinga* males and females reach sexual maturity at 2 and 3 years of age, respectively. It appears that *tambaqui* males and females reach maturity at 3 and 4 years of age, respectively. Preparation of broodstock of both species is of utmost importance for spawning to be successful. Broodstock should be well fed and stocked at about 200 to 300 per hectare. Two to 4 weeks before spawning is anticipated, it is important to stimulate both sexes of broodstock to maximum preparation. This is best accomplished in areas of low rainfall by moving the broodstock to a pond that receives a large amount of rain run-off. This pond should be kept half-full so that the first good rainfall will fill it. Increase in sexual preparedness due to the rainwater is immediate if the fish are close to their spawning season. A second method involves moving the broodstock to a freshly filled pond. It appears important that the freshly filled pond first be dried for several weeks, thereby allowing grasses to grow in the pond bottom before it is filled.

Further research should be conducted on broodstock management, spawning techniques, and fry raising. However, annual spawning of both *tambaqui* and *pirapitinga* now appears feasible.

Fingerlings of both species from the 1977 spawning season were tested in production experiments by Da Silva, Carneiro-Sobrinho, F. Melo, and Lovshin *(2)*. A 2 x 2 factorial design was used to test *tambaqui* and *pirapitinga* at two stocking densities. Each species was stocked at 5,000 and 10,000 per hectare, each stocking level being replicated three times. Twelve, 355-square meter earthen ponds with independent water inlets and drains were used. All fish were fed a pelleted chicken ration (17 percent protein) at 3 percent of the average standing crop of fish in each treatment. Fish were fed in the afternoon, 6 days a week. Between the tenth and eleventh months of the experiment, feeding was suspended in all ponds due to low dissolved oxygen levels. When feeding was resumed, fish were fed at 1.5 percent of the average body weight of fish in each treatment until termination of the experiment. Feeding rates were recalculated monthly based on samples of fish taken with a seine. Monthly sampling consisted of weighing and measuring 20 percent of the fish in each pond. Water was added to the ponds only to replace evaporation and seepage losses, except when low dissolved oxygen in the tenth month required water renewal to decrease fertility levels. The experiment terminated after 365 days. A summary of the results can be found in table 6.

Statistical analysis showed a significant difference (0.05 level) between the average final weight of *tambaqui* and *pirapitinga* stocked at 5,000 per hectare, but no significant difference (0.05 level) between the two species when stocked at 10,000 per hectare. Increasing the stocking rate from 5,000 to 10,000 per hectare resulted in a significant decrease (0.05 level) in average weight for *tambaqui* but no significant decrease in average weight for *pirapitinga.*

Average productions were significantly different (0.05 level) between *tambaqui* and *pirapitinga* stocked at 5,000 per hectare, but no significant difference (0.05 level) was found between the two species when stocked at 10,000 per hectare. Both species showed a significant increase in average production (0.05 level) when the stocking rate was increased from 5,000 to 10,000 per hectare.

While *tambaqui* demonstrated a higher final average weight and production than *pirapitinga* at both levels of stocking, only at 5,000 fish per hectare were these differences statistically detectable. Increasing the stocking rate of *tambaqui* resulted in a significant increase in average production, but this significantly reduced the final average weight. Increasing the stocking rate of *pirapitinga* significantly increased average production without significantly reducing the average final weight. As both species reached harvestable size at both stocking densities tested, it appeared advantageous to use the higher stocking rate. Maximum average production for both *tambaqui* and *pirapitinga* when stocked at 10,000 fingerlings per hectare was 9,391 and 8,319 kilograms per hectare per year, respectively.

Both species reached marketable size in 6 months, table 6. Food conversion rates at 6 months were excellent, considering the low level of dietary protein used. The 12-month food conversions were good, but these had increased because poor water quality and high standing crops had lowered ration utilization efficiency.

Both species were able to withstand dissolved oxygen levels below 0.5 milligram per liter for 8 to 10 hours without mortality. After 2 weeks of extremely low nighttime dissolved oxygen levels, slight mortality was encountered in two *pirapitinga*

TABLE 6. SUMMARY OF THE RESULTS OF TWO LEVELS OF STOCKING ON THE GROWTH AND PRODUCTION OF *TAMBAQUI (COLOSSOMA MACROPOMUM)* AND *PIRAPITINGA* (COLOSSOMA BIDENS)

Performance measure	Result, by stocking densities per ha			
	Tambaqui		*Pirapitinga*	
	5,000	10,000	5,000	10,000
Av. initial wt., g	25	23	30	28
Results at 6 months				
Av. wt., g	619	424	521	415
Av. production/ha, kg	3,054	4,245	2,571	4,154
Feed conversion	1.6:1	1.6:1	1.8:1	1.6:1
Final results[1]				
Av. final wt., g	1,496	1,052	1,064	896
Av. production/pond, kg	237	333	150	295
Av. production/ha, kg	6,683	9,391	4,230	8,319
Feed conversion	2.8:1	2.8:1	3.7:1	3.0:1
Survival, pct.	91	87	80	94
Growth, g/day	4.0	2.8	2.8	2.4

[1]All results are the average of three replicates except *tambaqui* and *pirapitinga* at 5,000 per hectare which are the average of two replicates due to low survival in one pond in each treatment.

TABLE 7. SUMMARY OF THE RESULTS OF *TAMBAQUI* (*COLOSSOMA MACROPOMUM*) AND *PIRAPITINGA* (*COLOSSOMA BIDENS*) IN POLYCULTURE WITH THE ALL-MALE TILAPIA HYBRID (FEMALE *TILAPIA NILOTICA* x MALE *TILAPIA HORNORUM*)

Performance measure	Result, by stocking densities					
	Tambaqui + all-male hybrid			*Pirapitinga* + all-male hybrid		
	5,000/ha		5,000/ha	5,000/ha		5,000/ha
Av. initial wt., g	25		18	33		20
Results at 6 months						
Av. wt., g	485		245	383		261
Av. production/ha, kg	2,393		1,209	1,890		1,288
Feed conversion	1.7:1		1.2:1[1]	1.8:1		1.0:1[1]
Final results[2]						
Av. final wt., g	1,189		748	1,045		681
Av. production/pond, kg	200		117	170		128
Av. production/ha, kg	5,640	(8,939)	3,299	4,794	(8,404)	3,610
Feed conversion	2.8:1		1.8:1[1]	2.7:1		1.8:1[1]
Survival, pct.	95		89	93		99
Growth, g/day	3.2		2.0	2.8		1.8

[1]Feed conversion is calculated using the total weight of *Colossoma* and tilapia hybrids.
[2]Results are the average of three replicates.

ponds. No mortality due to dissolved oxygen was encountered in ponds with *tambaqui*. The poor water quality slowed the growth of both species, and only after dissolved oxygen levels were corrected did normal growth resume.

A second experiment involving the polyculture of *tambaqui* and *pirapitinga* with all-male tilapia hybrids was run concurrently with the preceding experiment. A completely random design was used with two treatments replicated three times each. *Tambaqui* and *pirapitinga* were stocked in 355-square meter earthen ponds at 5,000 per hectare along with 5,000 all-male tilapia hybrids per hectare (combined stocking rate of 10,000 fish per hectare). Fish were fed 3 percent of the average body weight of *tambaqui* and *pirapitinga* only. Fish received a pelleted chicken ration (17 percent protein) in the afternoon, 6 days a week. Between the tenth and eleventh months of the experiment, feeding was suspended in all ponds due to low dissolved oxygen levels. When feeding was resumed, fish were fed at the rate of 1.5 percent of the average body weight of *tambaqui* and *pirapitinga* until termination of the experiment. Feeding rates were recalculated monthly based on seine samples. Monthly sampling consisted of individually weighing and measuring 20 percent of the fish populations in each pond. After 365 days, ponds were harvested. A summary of the results can be found in table 7.

Analysis of variance (0.5 level) demonstrated no significant difference in the final average weights of *tambaqui* and *pirapitinga*. However, there was a significant difference (0.05 level) in the final average productions. Again, *tambaqui* had a higher production, 5,640 kilograms per hectare, than *pirapitinga,* 4,794 kilograms per hectare. *Tambaqui* and *pirapitinga* grown in polycultures with the all-male tilapia hybrid had total productions approximately equal to production of both *Colossoma* species in monoculture at 10,000 per hectare. The use of tilapia increased the total productions of the polycultures by more than 3,000 kilograms per hectare. The added production of tilapias was realized without an increase in the feed used. Feed conversions demonstrated that both species of *Colossoma* were utilizing the feed efficiently. Conversion efficiency was equal to or better than the monoculture of these species at 5,000 per hectare, tables 6 and 7. Apparently, the tilapia hybrids were produced on planktonic algae and organic wastes generated by the *tambaqui* and *pirapitinga*. Thus, the polycultures are much more efficient and economical than the monocultures, resulting in higher productions with less feed.

Both *tambaqui* and *pirapitinga* have demonstrated outstanding culture characteristics. Both species are resistant to handling, poor water quality, and diseases. They feed on a wide variety of fruits, seeds, agricultural by-products, and formulated rations, and are extremely easy to capture with a seine. Although *tambaqui* and *pirapitinga* have good quality flesh, large intermuscular bones may limit consumer acceptance. Both *Colossoma* species have been artificially reproduced. These two tropical, freshwater species have shown more fish culture potential than any other South American fishes tested to date. The results discussed here support the exciting possibility that these fish can be cultured effectively. Further work with the species should be pursued vigorously.

RESERVOIR FISHERIES

Since 1911, DNOCS has constructed 254 public reservoirs and aided in the construction of thousands of small private reservoirs in the Northeast. These reservoirs collect and retain run-off water during the short rainy season, providing water for irrigation, livestock, and human needs during the dry season. To better utilize these waters, the Department of Fisheries and Fish Culture within DNOCS began a fish research and stocking program in 1932 and 1942, respectively, to increase natural fish production in these reservoirs.

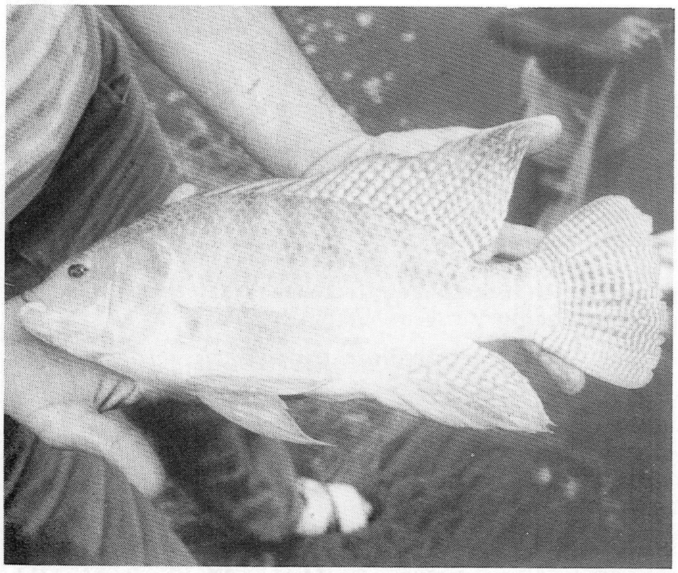
It soon became evident that the limited fish fauna of the semi-arid Northeast was not sufficient in species diversity to significantly increase reservoir production. Thus, DNOCS biologists began testing and stocking species of fish from river basins outside the Northeast and exotic to Brazil. Fish were selected for their economic value, ability to reproduce in reservoirs during periods of low rainfall, and ability to fill an underutilized ecological niche. Two species of fish were introduced from the Sao Francisco River, one species from the Parnaiba River, five species from the Amazon River, and *Tilapia rendalli* and *nilotica* from Africa.

DNOCS controls the commercial fishery in 103 reservoirs *(6)*. In 1977, a total of 14,788 metric tons of fish and shrimp was captured from these reservoirs. Of this total, 85 percent was composed of seven species, of which five were introduced to the Northeast, table 8. The 1978 catch totaled 19,478 metric tons of fish and shrimp. The same seven species composed 90 percent of the total fish and shrimp catch, table 8.

Tilapias have proven to be an excellent addition to DNOCS reservoirs. From 1970 through 1978, total production of *T. rendalli* and *T. nilotica* from DNOCS controlled reservoirs was 5,859 and 7,332 metric tons, respectively. This represented 13 percent of the 101,520 metric tons of fish captured over the 9-year period. Introduced to the Northeast in 1960, the herbivorous *Tilapia rendalli* was the dominant tilapia species captured in DNOCS reservoirs until 1977. In 1977, however, *T. nilotica* surpassed *T. rendalli* in kilograms captured even though *T. nilotica,* introduced to the Northeast in 1971, is found in fewer reservoirs than *T. rendalli*. *Tilapia nilotica* first entered

Table 8. Principal Native and Exotic Fish and Shrimp Species Comprising the Commercial Fishery in 103 DNOCS Controlled Reservoirs

Common name	Scientific name	Source	Production 1977 Tons	Pct.	Rank	1978 Tons	Pct.	Rank
Pescada do Piaui	*Plagioscion squamosissimus*	exotic	3,012	20	1	3,943	20.2	2
Canela shrimp	*Macrobrachium amazonicum*	exotic	2,680	18	2	2,939	15.1	3
Peacock bass	*Cichla ocellaris*	exotic	1,871	13	3	2,154	11.1	4
Traira	*Hoplias malabaricus*	native	1,636	11	4	1,830	9.4	5
Nile tilapia	*Tilapia nilotica*	exotic	1,533	10	5	4,842	24.9	1
Curimata comun	*Prochilodus cearensis*	native	980	7	6	934	4.8	6
Congo tilapia	*Tilapia rendalli*	exotic	925	6	7	881	4.5	7
Others			2,151	15		1,955	10.0	
Total			14,788	100		19,478	100	



***Tilapia nilotica*, widely cultured in ponds and reservoirs throughout Northeast Brazil, is a highly regarded food fish. Over 4,800 metric tons of this species were captured in DNOCS controlled reservoirs in 1978.**

the capture statistics in 1974 when 16.1 metric tons were caught. In 1978, ten reservoirs produced 4,842 metric tons of *T. nilotica*, making this species the principal fish captured in DNOCS reservoirs just 5 years after its introduction. It is expected that the production of *T. nilotica* will continue to increase as it becomes more widely stocked.

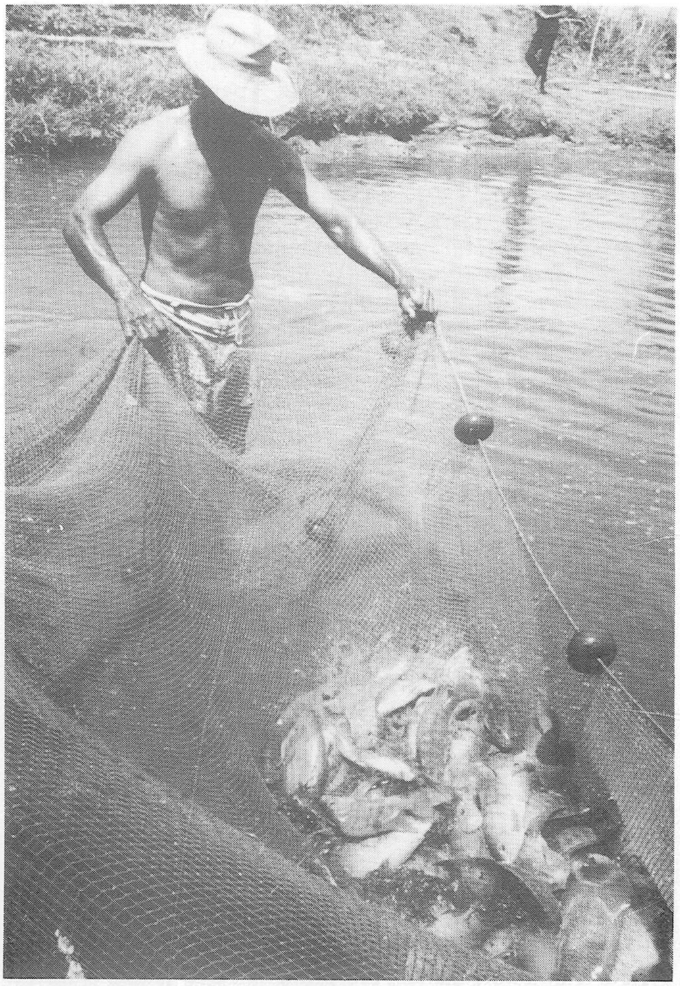
Lovshin, Peixoto, and de Vasconcelos *(15)* demonstrated the economic and fish production benefits of stocking tilapias into reservoirs in the Northeast. Tilapias adapt well to most reservoirs, reproduce independent of the rainy season, are easily captured with cast nets and gill nets, and are readily accepted by consumers at a good price. Stunting of tilapia populations in the reservoirs has not been a problem.

Stocking of fish species not native to Northeast Brazil into the many public and private reservoirs located in this region has proven highly successful. Fish captured from these interior waters are almost entirely consumed in rural areas where reservoir fish are priced lower than other meats. Over 10,000 licensed fishermen gain at least a part of their yearly income fishing in DNOCS controlled reservoirs. The Brazilian experience in reservoir construction, fingerling fish production, stocking, research, and regulated capture should serve as a model for the whole tropical world.

FISH CULTURE EXTENSION

There are 20 private farmers and four DNOCS irrigation projects producing tilapias intensively in the Northeast, most located in the state of Ceara. The total pond area in water is about 8 hectares. There is strong farmer interest in raising tilapia hybrids, but the demand for fingerlings is greater than supply. Culturists raising tilapia hybrids are producing large crops of fish, resulting in high economic returns.

De Carvalho, Fernandes, and de Oliveira *(4, 5)* made economic studies of one private farm and two DNOCS irrigation projects raising all-male tilapia hybrids. A cattle



Over 10,000 kilograms per hectare per year of marketable all-male Tilapia hybrids have been harvested using agricultural by-products as feeds.

TABLE 9. COST-BENEFIT ANALYSIS OF THE INTENSIVE CULTURE OF TILAPIA HYBRIDS IN A 0.35-HECTARE POND

Item	Amount	
1. Costs		
Fixed costs		
Pond construction[1]	Cr.$3,510.00[2]	
Pond maintenance	Cr.$ 100.00	
Total fixed costs		Cr.$3,610.00
Variable costs		
Fingerlings (Cr.$0.12/unit)	Cr.$ 480.00	
Total variable costs		Cr.$ 480.00
TOTAL COST		Cr.$4,090.00
2. Revenues		
Gross income (1,392 kg at Cr.$12.00)		Cr.$16,704.00
Net income		Cr.$12.614.00 (U.S. $1,051.17)

[1]Pond construction was paid with profits from the first culture period.
[2]$1.00 U.S. = Cr.$12.00.

farmer built a 3,500-square meter farm pond in a natural depression below pens holding 120 young calves. The pond was stocked with 4,000 tilapia hybrids averaging 48 grams each. The wastes from the calves were washed into the pond daily, and no other fertilizer was used. After 130 days, the pond was harvested and 1,392 kilograms (3,977 kilograms per hectare) of fish with an average weight of 400 grams were harvested. Profit for the 130-day culture period was Cr. $12,514.00 ($1,051), table 9.

Two earthen ponds of 2,300 square meters each were built in the DNOCS Morada Nova irrigation project located in the state of Ceara. These ponds were dug in saline soils that were unfit for traditional agricultural crops and received water by gravity flow from an irrigation canal. Each pond received 2,400 all-male tilapia hybrids with an average weight of 15 grams, provided by DNOCS hatcheries free of charge. Fish were fed rice bran daily at 3 percent of their body weight in each pond. Ponds were fertilized with 154 kilograms per week (670 kilograms per hectare) of fresh cattle manure. Rice bran and cattle manure were by-products produced in the irrigation project. After 180 days, both ponds were harvested. Pond one yielded 671 kilograms of fish (2,917 kilograms per hectare) with an average weight of 235 grams and a food conversion of 4.0 to 1. Pond two yielded 917 kilograms of tilapia hybrids (3,983 kilograms per hectare) with an average weight of 384 grams and a food conversion of 2.9 to 1. Profit for both ponds over the 180-day culture period was Cr. $3,502.25 ($250), table 10.

Tilapia raised in DNOCS irrigation projects are being sold in supermarkets in Fortaleza, Brazil.

Two earthen ponds of 5,000 square meters each were built in the DNOCS Pentecoste irrigation project. The ponds were located on saline land unfit for irrigated crops. Pond one received 5,000 tilapia hybrid fingerlings with an average weight of 11 grams. Pond two received 5,600 tilapia hybrid fingerlings averaging 18 grams. Fingerlings were provided by the Pentecoste fish culture research station free of charge. Fish were fed wheat bran at 3 percent of their body weight daily. Each pond was fertilized with 1,000 kilograms of cattle manure 2 weeks before stocking and received 500 kilograms per week of fresh cattle manure after stocking. The cattle manure was a by-product of a dairy operation located in the irrigation project. After 253 days, pond one was harvested by the farmers in the irrigation cooperative resulting in a harvest of 1,957 kilograms (3,914 kilograms per hectare) of fish with an average weight of 402 grams. Food conversion was 2.5 to 1. The second pond, harvested by draining after 229 days, yielded 2,249 kilograms (4,498 kilograms per hectare) of tilapia hybrids averaging 430 grams. The rate of food conversion was 2.3 to 1. Fish from both ponds were sold on the pond bank to a supermarket chain in Fortaleza for Cr. $13.50 ($0.85) per kilogram. Profit for both ponds was Cr. $20,522.75 ($1,283), table 11.

TABLE 10. COMBINED COST-BENEFIT RATIO OF THE INTENSIVE CULTURE OF TILAPIA HYBRIDS IN TWO, 0.23-HECTARE PONDS ON THE MORADA NOVA IRRIGATION PROJECT

Item	Amount	
1. Costs		
Fixed costs		
Guard service	Cr.$164.00[1]	
Amortization of ponds (10 years)	Cr.$7,079.00	
Harvest equipment (net) .	Cr.$ 600.00	
Total fixed costs		Cr.$7,843.00
Variable costs		
Rice bran (5,388 kg at Cr.$0.80/kg)	Cr.$4,310.00	
Cattle manure (8,000 kg) .	Cr.$1,200.00	
Harvest labor	Cr.$ 205.00	
Total variable costs		Cr.$ 5,715.00
TOTAL COST		Cr.$13,558.00
2. Revenues		
Gross income (1,587 kg at Cr.$10.75)		Cr.$17,060.25
Net income		Cr.$ 3,502.25 (U.S. $250.00)

[1]$1.00 U.S. = Cr.$14.00.

TABLE 11. COMBINED COST-BENEFIT RATIO OF THE INTENSIVE CULTURE OF TILAPIA HYBRIDS IN TWO, 0.5-HECTARE PONDS ON THE PENTECOSTE IRRIGATION PROJECT

Item	Amount	
1. Costs		
Fixed costs		
Guard service	Cr.$ 1,615.00[1]	
Amortization of ponds (10 years)	Cr.$15,461.00	
Harvest equipment (net) .	Cr.$ 800.00	
Total fixed costs		Cr.$17,876.00
Variable costs		
Wheat bran (9,755 kg at Cr.$0.98/kg)	Cr.$9,532.25	
Cattle manure (36,500 kg)	Cr.$8,850.00	
Total variable costs		Cr.$ 18,382.25
TOTAL COST		Cr.$ 36,258.25
2. Revenues		
Gross income (4,206 kg at Cr.$13.50)		Cr.$ 56,781.00
Net income		Cr.$ 20,522.75 (U.S. $1,282.67)

[1]$1.00 U.S. = Cr.$16.00.

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For more information communicate directly with the Director of the Department of Fisheries and Fish Culture at the following address:

Director
Departmento Nacional de Obras Contra os Secas (DNOCS)
Av. Duque de Caixias, 1700
Caixa Postal 650
60.000-Fortaleza, Ceara, Brazil