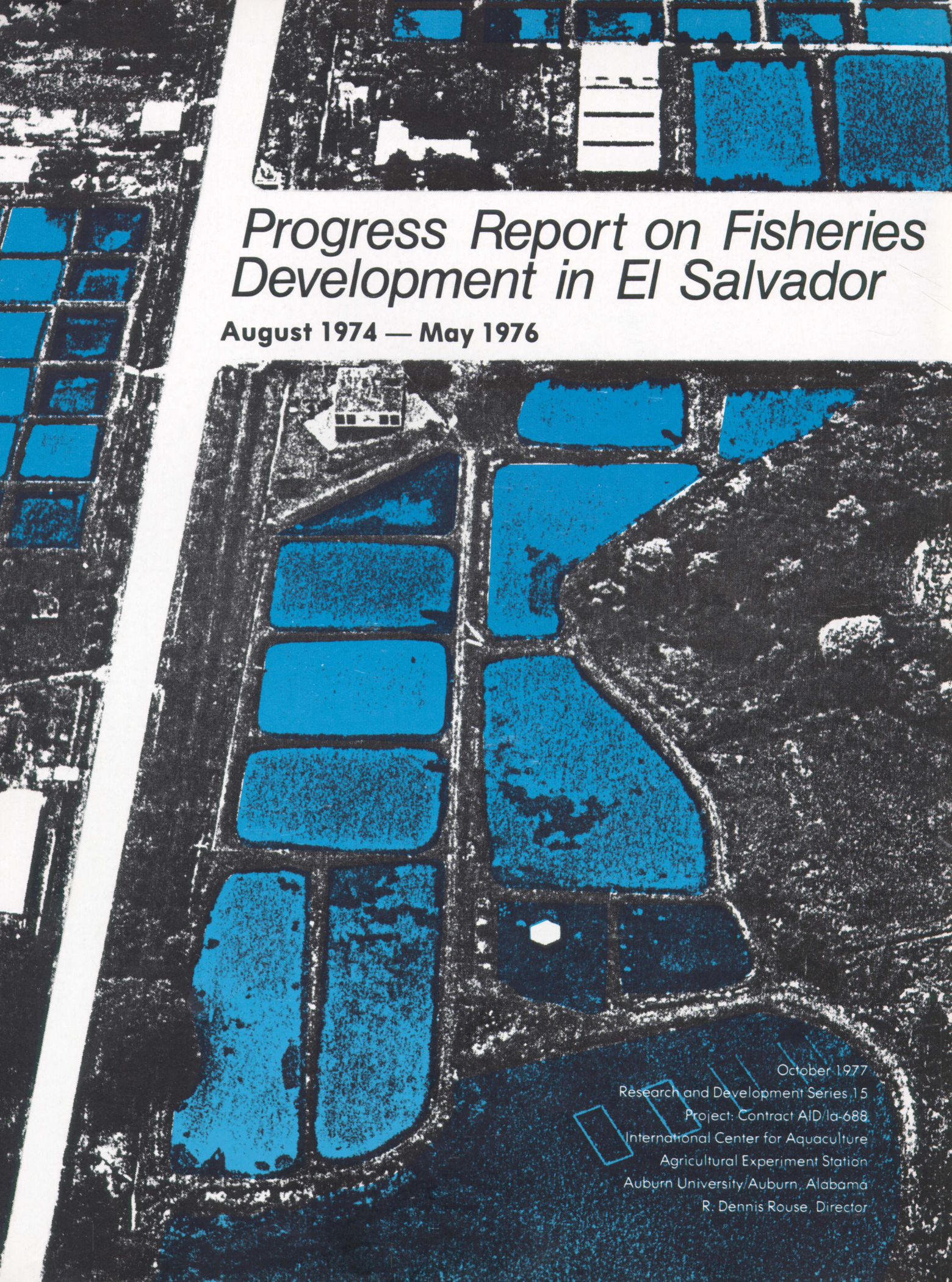

Progress Report on Fisheries Development in El Salvador

August 1974 — May 1976

October 1977
Research and Development Series 15
Project: Contract AID/la-688
International Center for Aquaculture
Agricultural Experiment Station
Auburn University/Auburn, Alabama
R. Dennis Rouse, Director

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PUBLISHED 10/77 - 1M

PROGRESS REPORT ON FISHERIES DEVELOPMENT IN EL SALVADOR[1]

August 1974 — May 1976

David G. Hughes[2]

INTRODUCTION

THE EL SALVADOR Fishery Resources Service of the General Directorate of Natural Renewable Resources (DGRNR), Ministry of Agriculture and Livestock (MAG), received technical assistance in aquaculture research and extension and inland fisheries development from 1972 to 1976 through a contract between the Agency for International Development and Auburn University's International Center for Aquaculture. Contract AID/la-688 provided technical assistance funds from January 1, 1972, to December 31, 1973, for Dr. David R. Bayne, Assistant Professor, Department of Fisheries and Allied Aquacultures, as full-time resident fisheries advisor. His work focused on the following areas, as outlined in detail in his 1974 report[3]:

1. Renovation and expansion of research and supporting facilities at the Santa Cruz Porrillo Fisheries Station.
2. Aquacultural research with emphasis on increased fish production.
3. Aquacultural extension to disseminate improved technology to farmers and other user groups.
4. Investigations of the fishery resources of major lakes and other natural waters of El Salvador.

The work was carried out in conjunction with host-country technical personnel, U. S. Peace Corps Volunteers, and short-term technical fisheries staff from Auburn University.

By the end of Bayne's 2-year tour, substantial progress had been achieved, including the following:

1. Near completion of the renovation and expansion of research and supporting facilities at the Santa Cruz Porrillo Fisheries Station.
2. Initiation of a country-wide project to survey lakes and rivers for fisheries statistics, limnology, and fishery biology data, and the testing and evaluation of fish gear and capture techniques.
3. Establishment of an active aquacultural extension program.
4. Establishment of an active program of practical aquacultural research designed to increase production and profit for the fish farm operator.
5. Initiation of academic training in aquaculture and fisheries for two host-country staff.

Just prior to Bayne's departure in 1973 an economic evaluation of the freshwater fisheries of El Salvador was made by Dr. E. W. McCoy, of Auburn University, at the request of USAID/El Salvador. In a 1974 report[4], McCoy described the emerging state of fish culture in El Salvador and stressed the necessity for continuing applied research to reach the highest possible level of production and the subsequent melding of research and extension for a successful field program. He analyzed the macro- and micro-impact of increased fish production, and the need for providing both short- and long-run capital for production and processing.

For the period of January 1 to September 9, 1974, the Fisheries Department had no resident fisheries advisor. Until March 1974, Sr. Jose E. Cabrero was head of the Fisheries Service and managed the Fisheries Project. In late March he enrolled in the Graduate School of Auburn University in a Ph.D. degree program in the Department of Fisheries and Allied Aquacultures. From March 1974 until the arrival of the author in September 1974, the Fisheries Project was coordinated by Sr. Enrique Castro Butter, a graduate in biology from the University of El Salvador. Sr. Butter continued to serve as Acting Fisheries Chief until the return of Dr. Cabrero in early 1976.

The author was employed as the resident fisheries advisor of the Fisheries Project, contract No. AID/la-688, beginning September 9, 1974. Efforts while in-country were focused principally with the aquacultural research and extension programs, and to a limited extent in assisting the Fisheries Service with marine and freshwater fisheries biology, fish capture programs, and general fisheries administration. This report limits its discussion to the progress made during the author's tour of duty.

ADMINISTRATION AND FINANCIAL INPUTS

Upon initiation of the Fisheries Project in 1972, the Ministry of Agriculture (MAG) changed the status of the Fisheries Section to that of a full department. A total staff of eight (six technicians and two supporting) with an operating budget of ¢110,000[5] characterized the Fisheries Section at that time. Since then the Fisheries Service (now called Fishery Resources Service) has experienced substantial growth, particularly in aquacultural programs, professional and supporting staff, and financial support by MAG, table 1. Aquaculture in 1976 comprised 66.7 percent of the total Fishery Resources Service budget of ¢1,678,952. Amount budgeted for aquaculture in 1976 was over 900 percent

[1]The fisheries development program was financially supported by the Government of El Salvador and the U. S. Agency for International Development.

[2]Research Associate, Department of Fisheries and Allied Aquacultures.

[3]BAYNE, DAVID R. 1974. Progress Report on Fisheries Development in El Salvador. Res. and Dev. Ser. 7. Auburn Univ. (Ala.) Agr. Exp. Sta. Int. Center for Aquaculture.

[4]MCCOY, E. W. 1974. Economic Analysis of the Inland Fisheries Project in El Salvador. Res. and Dev. Ser. 6. Auburn Univ. (Ala.) Agr. Exp. Sta. Int. Center for Aquaculture.

[5]U. S. $1.00 = 2.50 colones (¢).

TABLE 1. FISHERY PERSONNEL AND BUDGETS DEVOTED TO AQUACULTURE BY THE FISHERY RESOURCE SERVICES, 1972-76

Year	Total staff	Total colones[1]
1972	6	124,000
1973	7	250,250
1974	9	352,700
1975	17	450,000
1976	39	1,119,032

[1]U.S. $1.00 = 2.50 colones (¢).

greater than the budget in 1972, and 250 percent greater than in 1975.

Reorganization of the fish culture program in 1976 brought together fish culture research and hatchery production of fingerlings with fish culture extension. The new division (Fish Culture Section) is headed by Sr. Cesar Abrego Funes, a returned graduate in fisheries from Auburn University. His wide experience in Salvadorean fish culture research, extension, and fisheries administration and his recent participation in an academic program should permit improved planning and implementation of interrelated activities in the rapidly expanding field of aquaculture in El Salvador. Two areas of aquaculture still remain outside the dominion of the Fish Culture Section — cage culture of fish in lakes, which remains under the Inland Waters Section, and marine shrimp and oyster culture and brackishwater fish culture, part of the Marine Fisheries Section. The organization of the Fisheries Resources Service is outlined in figure 1, with detail on only the Fish Culture Section.

The major portion of aquacultural program money was allocated to the community pond program. To the traditional pond construction-fish management team (engineers, a biologist, and agronomists), four social workers and one social worker supervisor were added in 1975. Plans called for doubling the number of social workers for 1976, the majority to assist the community pond program and the others to work with communities of artisanal fishermen and cooperatives. An additional engineer-topographer-draftsman team was added in 1976, resulting in two complete pond design-construction engineer teams. A professional geologist joined the biologist on the site-selection team to evaluate topographical, soil, water, and geographical characteristics of proposed community pond sites.

Using USAID funds, Auburn University provided $3,000 (U.S.) worth of equipment for the aquacultural extension program and for operation of the new fingerling production station at Izalco, Sonsonate, and $1,000 (U.S.) worth of publications in the fields of aquaculture, fisheries science, and aquatic ecology. Over 300 items of scientific literature relating to aquaculture and fisheries in general were also contributed by the Peace Corps and Auburn University during the second phase of technical assistance to the project.

The Peace Corps continues to provide key technical input to the Fishery Resources Service in the training of counterparts and in the joint development of specific technical projects. Since 1974 Peace Corps Volunteers have worked with their national counterparts in a variety of fishery projects: one fishery biologist team completed a number of limnological and fishery studies in the major lakes of the country; another team studied physical, chemical, and biological aspects relating to pollution of the country's major rivers; and another worked in fish culture extension and training and completed a country-wide fish marketing survey. Investigations are continuing in the following: feeding,

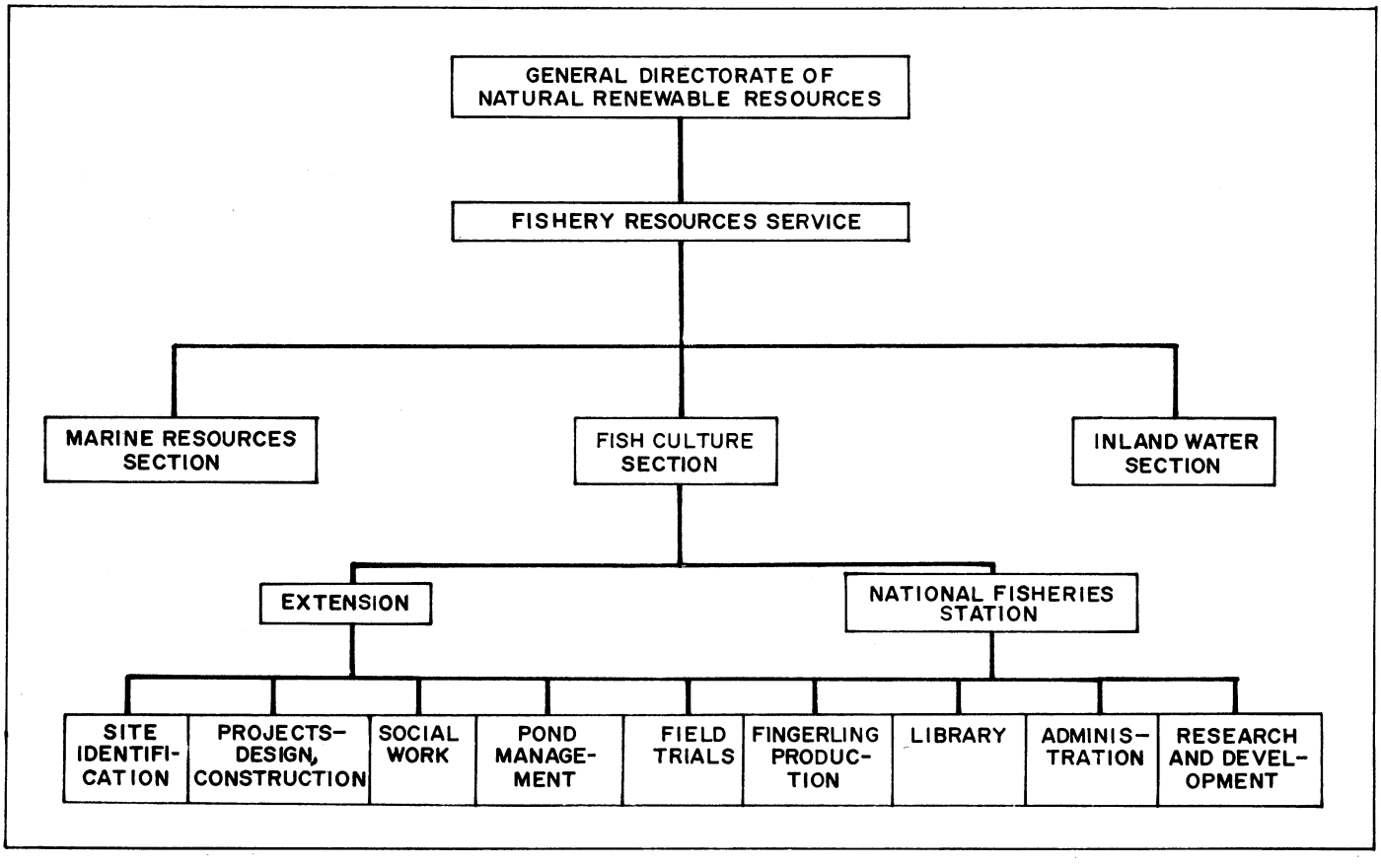


FIG. 1. Organizational chart of the Fishery Resources Service, showing detail of only the Fish Culture Section.

fertilizing, and stocking densities of tilapia[6] in pond culture; pond ecology in dry and wet seasons; ration development for tilapia utilizing agricultural by-products; fishing gear and methods development and demonstration; shrimp and juvenile fish distribution in estuaries; larval oyster biology and the development of oyster culture technology; and fish marketing by coastal artisanal fishermen cooperatives.

RENOVATION AND NEW CONSTRUCTION AT FISHERIES STATIONS

National Fisheries Station, Santa Cruz Porrillo

This station, located in the Department of La Paz, was renovated starting in 1971. A pond expansion program was completed in January 1975. Thirty-two 0.05-hectare earthen and thirty 20-square meter concrete ponds were constructed. The newly constructed and renovated ponds were fully utilized in yield trials or fingerling production in 1975 and 1976. Total pond area of the station was 6.10 hectares, of which 4.03 was used for fingerling production, figure 2. An 0.4-hectare community pond was constructed for the benefit of the station workers, most of whom were skilled in the techniques of pond culture. This pond will form part of an integrated farm model of fish-horticulture-small animal production, to serve as a demonstration for area farmers and cooperative groups.

Plans have been made to construct 0.5 hectare of additional ponds for fingerling production and to convert a large, 1.57-hectare pond into three fingerling ponds. Water supply and drain lines were redesigned for more effective operation of the ponds. The conference room was renovated to function as a combined conference room, study area, and fisheries library, and this facility was air-conditioned. The complete regional library of the UN/FAO-CCDP (Central American Regional Fisheries Development Project) was transferred from San Salvador to the station after the project terminated in 1975. A new dormitory and a dining hall were completed in 1976. Additional feed and fertilizer storage space was also constructed.

Fingerling Production Station, Izalco

To meet the rapidly increasing demand for fingerlings and as a first step to decentralize government production of

[6]The tilapia species reported herein, although commonly called tilapia, have been reclassified, *Sarotherodon* sp.

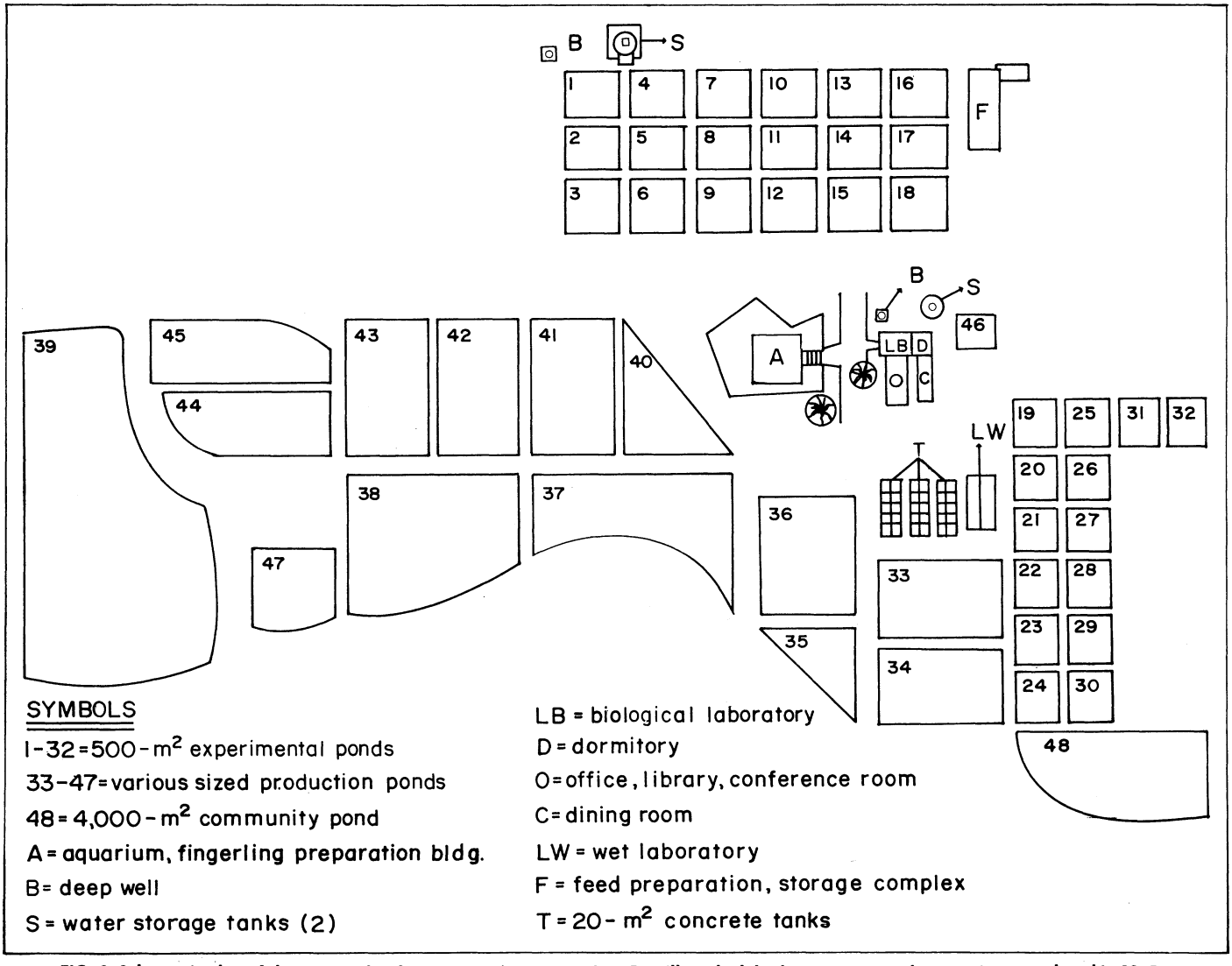


FIG. 2. Schematic plan of the National Fisheries Station at Santa Cruz Porrillo, which had renovation and expansion completed in 1975.

Aerial view of the National Fisheries Station, Santa Cruz Porrillo, after new construction was completed in early 1975. The station now has 30 concrete tanks and 32 earthen ponds for experimentation plus 15 earthen ponds for fingerling production. Total water area is 6.1 hectares.

fingerlings, a new station was designed to serve the western half of the country, at the Centro de Menores, Izalco, Department of Sonsonate. This station, scheduled for completion in late 1976, will have fifteen 400- to 600-square meter ponds for fingerling production, and two 360-square meter and two 50-square meter ponds for broodstock isolation. In addition, a wet laboratory, storage facilities, office, and dormitory will be constructed, figure 3. Principal emphasis will be on the production of the all-male tilapia hybrid, although the station will have the capability of functioning as a multi-species nursery and for experiments in fingerling production. An existing community pond of about 2,000 square meters, located adjacent to the fingerling ponds, will be utilized for demonstration of fish farming techniques to area farmers and cooperative groups as well as continue to provide fish for residents of the Centro.

FISH CULTURE RESEARCH

Tilapia has continued to be the main culture species in El Salvador, principally *Sarotherodon aurea*, since 1973 when it was determined to be superior in production to *S. mossambica*. Until recently *S. aurea* has been experimented with and extended to the farmer in monospecies culture or in polyculture with the predator guapote tigre *(Cichlasoma managuense)*. Principal emphasis in research has been directed to increasing production of tilapia or tilapia and guapote tigre in earthen ponds through management inputs. Variations in fertilizer and fertilization rates, feeding of agricultural by-products, fingerling stocking rates, polyculture species ratios, partial vs. complete harvesting, and recruitment control by seining have been studied. In addition, diet testing with *S. aurea* and the all-male hybrid tilapia, production trials of the all-male hybrid in earthen ponds, and production trials of *S. aurea* in salt-producing ponds and cages have been important activities of aquacultural research in the past 2 years in El Salvador.

Introduction of New Fish Species

As a part of its efforts to increase the efficiency and quality of fish culture systems, the Fisheries Project in 1974 introduced stocks of *Sarotherodon hornorum* and *S. nilotica* from the DNOCS (National Department of Works Against the Drought) Center for Fisheries Research in Pentecoste, Ceara, Brazil. Offspring produced from the crossing of the *S. hornorum* male with the *S. nilotica* female are all-male hybrids with the typically superior growth pattern exhibited by hybrid animals. The result is the elimination of one of the most troublesome problems encountered in tilapia culture, that of uncontrolled reproduction which results in overcrowded fish populations and stunted fish. All-male tilapia hybrids in yield trials in Brazil consistently produced 8,000 to 10,000 kilograms per hectare per year with individual fish averaging 400 grams at harvest[7].

To counteract reduced fish productions resulting from heavy growth of noxious aquatic weeds, especially submergent *Hydrilla* sp., now prevalent in ponds at the National Fisheries Station and in a number of private ponds, grass carp *(Ctenopharyngdon idella)* were introduced from Auburn University. Growth has been remarkable, with the fish stocked in weedy ponds increasing in weight from 50 grams to 3.6 kilograms in 705 days. Attempts at producing offspring by induced spawning techniques will be made when the fish mature sexually.

All-male Tilapia Hybrids

Stocks of *S. nilotica* and *S. hornorum* for production of fingerlings arrived in late 1974, and research with the all-male hybrid tilapia began the following year in El Salvador. Research, however, has been severely limited principally because pond facilities at the National Fisheries Station were inadequate to properly maintain parent stocks in pure state and at the same time to produce the number of fingerlings needed for the testing program. This situation will improve

[7]LOVSHIN, L. L. 1977. Progress Report on Fisheries Development in Northeast Brazil, July 1, 1975 - December 31, 1976. Res. and Dev. Ser. 14. Auburn Univ. (Ala.) Agr. Exp. Sta. Int. Center for Aquaculture.

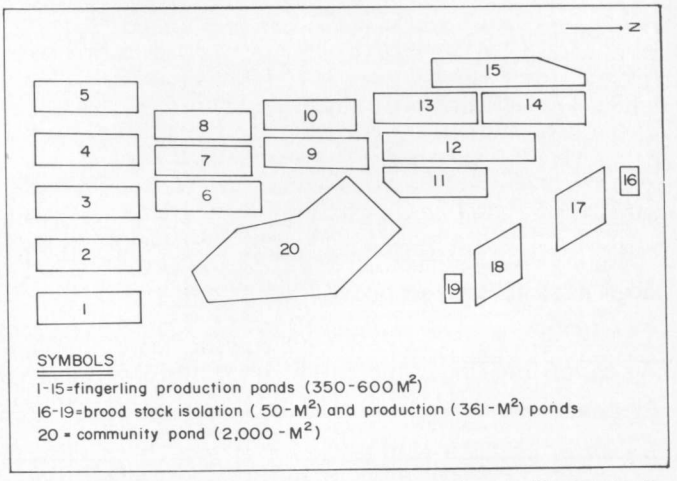
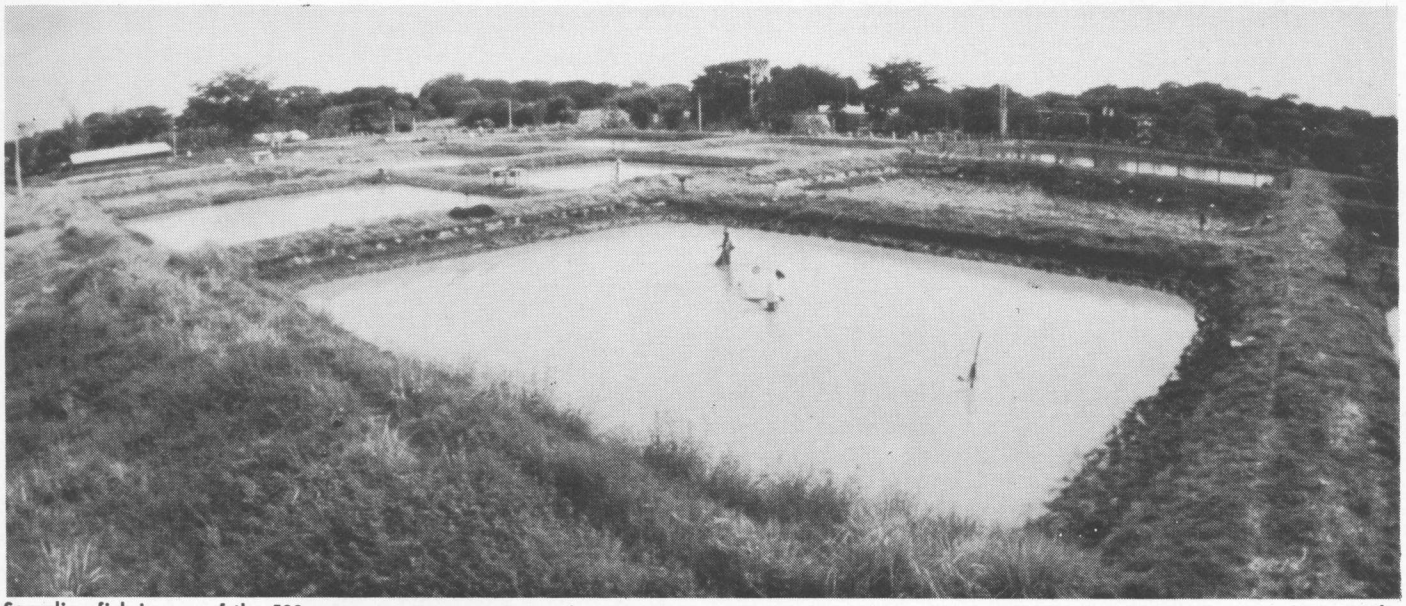


FIG. 3. Schematic plan of the newly constructed Fingerling Production Station at the Centro de Menores, Izalco.



Sampling fish in one of the 500-square meter experimental ponds at the National Fisheries Station, Santa Cruz Porrillo. Primary emphasis in the last several years has been on increasing fish production by fertilizing and feeding.

by late 1977 with completion of the new Izalco fingerling production station, which will be used exclusively for hybrid fingerling production. The Santa Cruz Porrillo Station will continue to produce *S. aurea* fingerlings for yield trials for food fishes.

Production trials with the hybrid tilapia were conducted in 500-square meter earthen ponds at the Santa Cruz Porrillo Station. Two stocking rates and two fertilization rates were tested during a 91- to 98-day growing season in 1975, table 2. There were no statistical differences ($p > 0.25$) in total fish production between treatments. Fish at the lower stocking rate of 10,000 fingerlings per hectare grew at approximately twice the rate (0.9 gram per day) and were about twice the size at harvest (106 grams) as those stocked at the higher rate of 20,000 fingerlings per hectare. Apparently the carrying capacity of these ponds was reached at about 3,000 kilograms per hectare per year and the increased fertilization in treatment 3 failed to increase capacity, table 2. Both treatments at the higher stocking rate failed to produce adequate numbers of harvestable fish.

Observations of all-male hybrid tilapia production in two commercial ponds using organic waste materials as a nutrient supply provided valuable information on yields that might be expected from this fish in El Salvador. One pond (2,400 square meters) stocked at 10,000 fish per hectare and fertilized at 295 kilograms chicken manure per month plus other organic materials for 150 days had a projected annual harvest of 7,400 kilograms per hectare. Another pond (1,728 square meters) fertilized with manure of commercially reared brood sows and partially harvested after the sixth, seventh, and eighth months and completely harvested after the ninth growing month had a total projected yield of 7,100 kilograms per hectare per year.

Nutrition Experiments with Tilapia Using Agricultural By-products

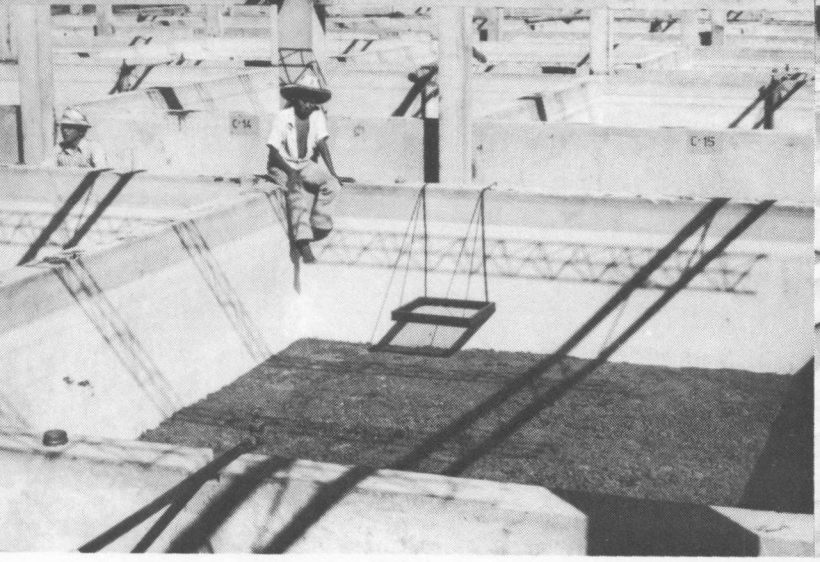
As a means of increasing fish production in farm ponds above that expected from fertilization alone, and to establish guidelines for the economical formulation of rations for tilapia, two experiments were conducted at the National Fisheries Station using mainly agricultural by-products as feed sources. Experiments were carried out in 20-square meter concrete tanks located under a roofed, open-sided structure. Six test diets formulated from locally available agricultural by-products and one complete diet, table 3, were each tested in triplicate. Only enough water was added to replace that lost to evaporation.

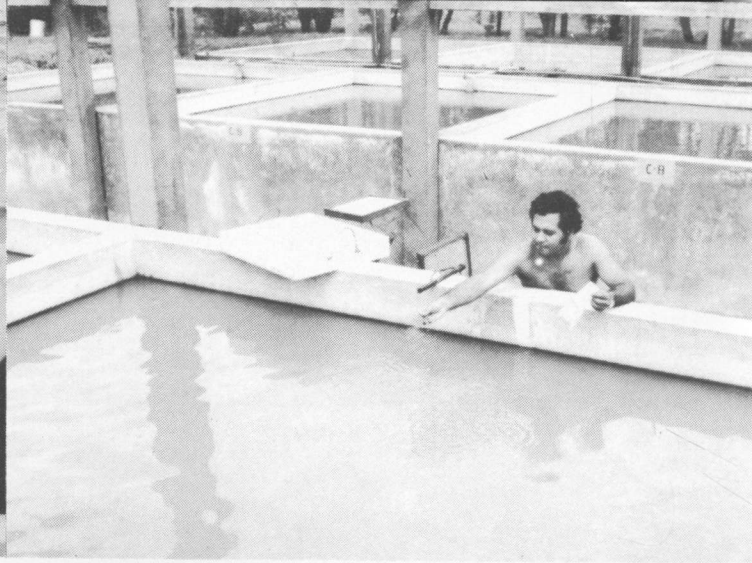
In the first experiment, *S. aurea* fingerlings averaging 21 grams in weight were stocked at the rate of 2 per square meter of water surface. The diets were formulated to represent a range of low protein-low energy to high protein-high energy levels, and contained from 14.1 to 36.6 percent protein and from 2,867 to 3,691 kcals per kilogram gross energy. The diets were in ground meal form. All fish were fed once daily, 6 days each week, at rates of 3 percent total fish weight for the first week, 5 percent for the remainder of the first 2 months, 4 percent for the third and fourth months, and 3 percent for the fifth and sixth months.

All fish were harvested 156 days after stocking. Production and cost data are summarized in table 4. The complete ration, diet 7, produced the highest net gain (5.65 kilograms) and the best feed conversion efficiency (1 kilogram gain per 3.1 kilograms feed consumed). Test diet 5, the high protein-high energy formula, produced the best growth and feed conversion efficiency at the lowest cost. Next was diet 6, which contained shark oil as an energy source. Fish receiving

TABLE 2. RESULTS OF PRODUCTION TRIALS WITH ALL-MALE TILAPIA HYBRID

Treatment	No. of replicates	Stocking rate/ha	Fertilization, kg/ha/month		Projected total fish production, kg/ha/year	Average growth rate, g/day	Percentage marketable fish	Average weight of fish at harvest, g
			Chicken manure	0-20-0				
1	3	10,000	1,000	120	2,997	0.90	96	106
2	3	20,000	1,000	120	3,531	.43	39	53
3	3	20,000	1,250	150	2,886	.43	31	50





Diets formulated from agricultural waste products were tested in these 20-square meter concrete tanks at the National Fisheries Station, Santa Cruz Porrillo. Biologist Huezo is feeding pelleted feed made from agricultural waste in the photo at right. Soil placed in bottom of tanks is visible in photo at left.

diet 1, the low protein-lower energy diet lost weight. Although cost per kilogram of gain was almost the same for diets 5 and 6, diet 5 would be favored because it produced higher weight gain. It was concluded from these preliminary data that when natural food is unavailable, as encountered in the concrete tanks of this experiment, tilapia require dietary protein and energy levels similar to those of other cultural warmwater species for maximum growth rates.

TABLE 3. INGREDIENT COMPOSITION, PROTEIN, AND GROSS ENERGY LEVELS, OF SEVEN TEST DIETS FED TO TILAPIA IN CONCRETE PONDS

Feedstuff	Content by diet						
	1	2	3	4	5	6	7
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Chicken manure	70	30	50	60	40	50	10
Coffee pulp	30	30	10	----	----	10	----
Cottonseed meal	----	10	20	30	45	20	20
Rice polishings	----	20	10	----	10	10	10
Meat meal	----	----	5	10	5	----	20
Corn	----	10	5	----	----	5	10
Fish meal	----	----	----	----	----	----	20
Soybean meal	----	----	----	----	----	----	10
Vitamin premix	----	----	----	----	----	----	[1]
Shark liver oil	----	----	----	----	----	5	----
Protein, pct.	14.1	13.6	19.8	23.1	26.6	16.7	36.6
Energy, kcals	2.96	2.86	3.11	3.30	3.56	2.88	3.69
Cost/100 kg, ¢	2.86	13.64	14.81	16.17	17.78	14.32	55.88

[1]Vitamins per ton: vit. A, 5 million I.U.; Vit. E, 40 g; vit. D, 6 million I.C.U.; riboflavin, 15 g; d - pantothenic acid, 55 g; niacin, 90 g; thiamine HCl, 20 g; pyridoxine HCl, 5 g; folic acid, 1 g; vit. B_{12}, 0.025 g; ascorbic acid, 500 g; and biotin, 0.4 g.

TABLE 4. NET PRODUCTION, FEED CONVERSION AND FEED COST OF TILAPIA PRODUCED IN CONCRETE TANKS FROM SEVEN TEST DIETS

Diet no.	Net gain,[1] kg	Kg feed/ kg gain	Cost/kg gain, ¢
1	-0.03	----	----
2	.77	11.3	1.54
3	.90	8.7	1.29
4	1.16	10.0	1.61
5	2.00	4.7	.84
6	1.29	6.3	.90
7	5.65	3.1	1.72

[1]Net gain per 40 fish.

A subsequent feeding experiment was designed to test the growth and economic response of tilapia to four percentages of protein (20, 25, 30, 35) in isocaloric (1.80 kcal per gram) diets. All-male tilapia produced from the *S. hornorum* male x *S. nilotica* female cross, averaging 14.5 grams, were stocked in the same concrete tanks as used in the previous experiment at the rate of 1.5 fish per square meter of water surface. Four diets were formulated basically from agricultural by-products to contain 20, 25, 30, and 35 percent protein, table 5.

The protein quality of each diet was kept equal by maintaining a constant ratio of the various protein sources in each diet. Ground corn cobs were used as a filler and beef tallow was used to keep the diets isocaloric. The diets were fed in meal form. A fifth treatment, the control, was not given any supplemental feed. Treatments were replicated in four tanks. The roof over the concrete ponds was removed and a 15-centimeter layer of soil was placed on the bottom of each to more closely approximate natural earthen pond conditions and increase the practical applicability of the results. The fish were fed twice daily at a rate of 3 percent of the total fish weight of each tank, 6 days per week.

Fish were harvested 112 days after stocking. No significant difference ($p<0.05$) in growth was measured among the various protein levels fed, although the fish fed the higher protein diets grew slightly more, table 6. Fish in the control ponds, which received only natural pond food, gained 39 to 42 percent as much weight as the fish that were fed, indicating an appreciable food contribution from the pond biota.

A comparison of feed costs per kilogram of weight gain indicates that, under conditions such as those where tilapia received a significant amount of food from the pond, there was no economic advantage in increasing protein levels over 20 percent. It is tentatively recommended that supplemental

TABLE 5. PERCENTAGES OF INGREDIENT COMPOSITION, PROTEIN AND ENERGY LEVELS, AND COSTS OF FOUR ISOCALORIC DIETS OF VARIOUS PROTEIN LEVELS FED TO TILAPIA IN CONCRETE PONDS

Feedstuff	Content, by diet			
	1	2	3	4
Fish meal	5.0	4.3	3.6	2.9
Soybean oil meal	15.3	13.2	11.0	8.8
Rice polishings	32.7	28.1	23.5	18.8
Coffee pulp	7.0	6.0	5.0	4.0
Cottonseed oil meal	40.0	34.4	28.8	23.0
Beef tallow	----	6.2	12.4	18.8
Corn cobs	----	7.8	15.7	23.7
Protein, pct.	35	30	25	20
Energy, kcl/kg	1,800	1,800	1,800	1,800
Cost/100 kg, ¢[1]	34.97	30.09	25.15	20.13

[1]Excludes costs of beef tallow and corn cobs.

TABLE 6. PROTEIN CONTENT, NET PRODUCTION, FISH GROWTH, FEED CONVERSION EFFICIENCIES, AND COST PER KILOGRAM OF FISH PRODUCED, WITH FOUR ISOCALORIC DIETS OF VARIOUS PROTEIN LEVELS

Diet		Net production, kg	Kg feed/ kg gain	Cost/kg gain, ¢
Number	Protein percentage			
1	35	3.20	1.9	0.23
2	30	3.22	1.8	.16
3	25	3.12	1.9	.12
4	20	2.95	2.1	.09
Control	not fed	1.26	----	----

diets (composed of feedstuffs with sufficient nonprotein energy and diversified to provide good protein quality) for feeding to fish in ponds of moderate primary productivity and densities up to about 3.8 kilograms per square meter should contain approximately 20 percent protein for economical growth. For more intensive culture systems, such as raceways and cages, protein requirements would probably be near 30 percent of the diet.

Economic Evaluation of Tilapia Stocked at Four Densities

Economic evaluation was made of *Sarotherodon aurea* with fertilization alone or fertilization with feed production in earthen ponds at four stocking densities. Seven treatments were studied, six replicated four times and one replicated three times. Guapote tigre was stocked with the tilapia at the ratio of 1 guapote to 4 tilapia. Four densities of tilapias were tested, 1, 2, 3, and 4 per square meter. Inorganic (0-20-0) and organic fertilizer (dry chicken manure) were applied at rates of 122 and 1,050 kilograms per hectare per month, respectively. Beginning on day 29 of the experiment, feed equivalent to 3 percent of the calculated tilapia biomass was applied 6 days per week. The formulation used was based on information gained from testing diets with *S. aurea* in concrete tanks in previous experiments at the Santa Cruz Porrillo Fisheries Station, table 7. After 140 days the experiment was terminated due to the beginning of aerial cotton spraying in the area, which in previous years resulted in fish deaths of varying magnitude.

Fish production was relatively low in the fertilized-only treatments, and not significantly different ($p>0.05$) for the three lower stocking rates—956, 1,173, and 1,189 kilograms per hectare. The per square meter stocking did not include an unfertilized treatment, table 8. The factor most likely affecting production was excessive turbidity during the rainy season due to erosion of pond banks. Growth rates of the three unfertilized treatments were 0.42, 0.29, and 0.21 gram per fish per day for the three respective stocking rates.

At all stocking densities in the fed treatments, growth and production were substantially improved over fertilizer alone. Tilapia stocked at 1 per square meter grew 0.68 gram per day, about 0.3 gram per day faster than fish stocked at the same rate with fertilizer only. Growth rates for the fed treatments stocked at 2, 3, and 4 tilapia per square meter were 0.67, 0.48, and 0.41 gram per fish per day, respectively. No significant difference ($p>0.05$) was found among "S" feed conversion values among the fed treatments, the values ranging from 1.42 to 1.70. The highest total fish biomass present at harvest was 2,860 kilograms per hectare for ponds fed and stocked at 4 tilapia per square meter. In the fertilized-only treatments the carrying capacity was approached with 1,200 kilograms per hectare. In the 3 tilapia per square meter treatment this level was reached in 4 months; in the 2 tilapia per square meter treatment it was calculated for about 7 months. There was no indication of declining growth rate in any of the fed treatments during the last part of the experiment.

TABLE 7. INGREDIENT COMPOSITION, PROTEIN, ENERGY, FIBER, AND COST OF SUPPLEMENTARY FEED USED IN THE ECONOMIC EVALUATION OF TILAPIA STOCKED AT FOUR DENSITIES IN 1976

Feed ingredients	Content, pct.
Coffee pulp	5.0
Corn	2.5
Cottonseed meal	32.5
Chicken litter	45.0
Rice polishings	10.0
Meal meal	2.5
Shark liver oil	2.5
Protein, pct.	23
Fiber, pct.	26
Energy, kcals/kg	1166
Cost, ¢/100 kg	
Unpelleted	17.00
Pelleted, delivered to station	26.00

TABLE 8. BIOLOGICAL AND ECONOMICAL RESULTS FOR A 168-DAY GROWING SEASON WITH TILAPIA AT FOUR DIFFERENT DENSITIES IN 1976

Treatment, fish/m²	Growth, g/fish/ day	Feed conversion, 'S'	Total production, kg/ha	Total income, ¢	Total cost, ¢	Net income ¢
1, not fed	0.42	----	1,080	1,198	2,178	-980
1, fed	.68	1.42	1,710	2,463	2,872	-409
2, not fed	.29	----	1,280	1,445	2,372	-925
2, fed	.67	1.55	2,670	3,960	3,575	385
3, not fed	.21	----	1,210	1,316	2,557	-1,241
3, fed	.48	1.53	2,980	4,172	3,839	333
4, fed	.41	1.70	3,600	4,858	4,292	566

An economic analysis, following procedures described by Greenfield[8], was made to determine the point of maximum net returns for each treatment for a 6-month period. A payment schedule was calculated for a total of 168 days (two 14-day periods after the total experiment time of 140 days). None of the fertilized-only treatments had net profits at the end of 140 days or for the projected 168-day growing period. Feeding increased tilapia growth rates and costs. At 1 tilapia per square meter, a loss was calculated for both the 140- and 168-day periods. The next three stocking rates resulted in profits at the 140-day period, ¢265, ¢412, and ¢160 for 2, 3, and 4 tilapia per square meter, respectively. The 2 tilapia per square meter treatment reached maximum profits at 154 days (¢420 net profit), while the 3 tilapia per square meter treatment declined to ¢366 at 154 days and to ¢333 at 168 days. The 4 tilapia per square meter treatment profits continued to increase, reaching ¢524 at 154 days and ¢566 at 168 days.

Although the 4 tilapia per square meter treatment resulted in higher net profits, the 2 tilapia per square meter fed treatment is recommended for field testing. The testing should be with farmers who can maintain reliable records and have a history of successful pond management. Ponds should meet the basic conditions of having no weeds, stable banks, and be harvestable. The 4 tilapia per square meter fed treatment should be tested further under strict experimental conditions, due to the large variation found between fed ponds, before adoption as a field recommendation for qualified farmers.

Tilapia Production in Salt Ponds

The first controlled stocking of *Sarotherodon aurea* in salt-producing ponds was conducted in El Salvador in 1975,

[8]GREENFIELD, J. E. 1974. Economic Evaluation of the Tilapia Hybrid Culture in Northeast Brazil. Paper presented at FAO/CARPAS Symposium on Aquaculture in Latin America. Montevideo, Uruguay. November 26-December 2, 1974.

These private salt-drying ponds near Jiquilisco Bay are used to produce salt only during the dry season. With slight modification, however, the 500-hectare pond complex could substantially increase aquacultural production in El Salvador.

using ponds from a private firm located adjacent to Jiquilisco Bay. Fish were stocked and harvested in the wet season when the ponds are normally inactive in the production of salt. Four ponds, 6,340 to 9,510 square meters in size, were stocked with fingerling tilapia of 5-15 grams weight. Ponds were filled by gravity flow during high tide, with water passing through two metal screen filters, first a coarse grade, then a fine grade screen. In several ponds, however, the screens became clogged and broke, allowing entry of other aquatic organisms, including various predators. All ponds were fertilized with 80 kilograms per hectare of 20-20-0 inorganic fertilizer applied bi-monthly. Two ponds were stocked with 2 fish per square meter and two with 1 fish per square meter. Salinity at the initiation of the experiment was 25‰, increasing to 31‰ by experiment end. Harvesting revealed numerous brackishwater fish and shrimp other than the stocked tilapia. Although production was lower than in freshwater, ranging from 917 to 1,392 kilograms per hectare per year, adequate filtration of intake water can be expected to reduce tilapia predators and competitors to the point that management of the ponds exclusively for fish or tilapia-shrimp polyculture would be economically attractive. The 500 hectares of such ponds along the coast of El Salvador, producing the minimum expected yield of 1,000 kilograms per hectare per 6 months, would produce during the wet season more than 500 metric tons of high quality, high value fishery products.

Culture of Fish in Cages

Enthused by the positive results from preliminary production trials of *Sarotherodon aurea* in cages on Lake Ilopango in 1974, both the Fisheries Service and the private sector embarked on more conclusive tests of its economic feasibility in 1975. Ten large cages, measuring from 20 to 40 square meters in surface area and with a depth of 1.5 meters, were placed in Lake Ilopango by the Fisheries Service and a private individual. Results were mixed. There was good growth during the latter half of the dry season when heavy phytoplankton blooms in the upper several meters of the lake furnished abundant natural food for the fish. Poor growth and feed conversion efficiencies during the rest of the year resulted from inadequately formulated or processed feed, loss of fish due to poaching, wave damage to cages during storms, and harvesting difficulties. Nonetheless, production data were attractive enough to stimulate an expansion of effort by the GOES in cage culture research and development. The GOES's plan for 1976 was to test the interaction of stocking

A private entrepeneur at Lake Ilopango, near San Salvador, uses these floating cages for rearing tilapia. Made of steel framing and covered with netting, the cages measure 4 X 8 X 1 meter.

density, feed type (based on rations containing mainly agricultural by-products), daily feeding rates, and cage shape (square vs. cylindrical) on the production of *S. aurea*. Results of these studies will go far toward determining the economic feasibility of cage culture. A plan was also established to introduce the culture of tilapia in large commercial sized cages (up to 40 cubic meters) as a supplementary and alternative source of income for members of fishermen cooperatives of Lake Ilopango and Laguna Metapan. Encouraged partly by the relatively high sale price of tilapia (¢2.00-2.75 per kilogram liveweight) in markets in nearby San Salvador, at least two new cage culture operations were initiated in 1976.

FISH CULTURE EXTENSION

In early 1974 the entire effort in fish culture extension was carried out by two Salvadorean agronomists and one Peace Corps Volunteer biologist. Due to change in policy within the Ministry of Agriculture, the fish culture extension program was suspended for the major part of 1974. The three extension staff in the meantime worked on other productive tasks, one in the successful eradication of the water hyacinth (*Eichhornia crassipes*) from Laguna de Chalchuapa, the other two in a nationwide survey of fish marketing. In late 1974, shortly after the arrival of this advisor, fish culture extension was formally resumed under the direction of the Fisheries Service. During 1975 two additional biologists were hired and one biologist with past experience in extension was transferred to the extension division, thus increasing the field extension staff to five with each assigned a particular geographical zone.

A full-time supervisor was assigned to manage both the private and community pond activities. Two engineering teams, each consisting of a civil engineer, topographer, and assistants, with a draftsman to serve both teams, designed and supervised construction of new community ponds. Increased demand on trained staff for the expanding community pond program required the reassignment of one extension worker to survey sites for new community pond projects, thus reducing the number of zones to four. Extension staff had the responsibility of providing technical assistance to both private and community ponds. Fish culture supervisors and extension specialists prepared and presented short courses and lectures for students at the National Agricultural School, the Navigation and Fisheries School, area agricultural-vocational high schools, and to extension staff of FOCCO, the Agricultural Development Bank (BFA), and the Agricultural Extension Service (CENTA). They also prepared exhibits on aquaculture activities in El Salvador for display at regional agricultural fairs. In response to the need for seines by private and community pond owners, extension workers assisted traditional net-makers by introducing basic techniques of seine manufacturing. Production of seines now is a regular economic activity for several persons that were previously underemployed.

Private Ponds

A 1971-72 survey revealed that 500 fish ponds existed in the country with a total area of about 53 hectares. The ponds ranged from 20 square meters to more than 1 hectare, with an average size of 0.11 hectare. Production in farm ponds for 1972 was 6.8 metric tons, with an average productivity of 136 kilograms per hectare per year. With technical assistance provided by the Fisheries Service, 22 farmers produced an average of 4,879 kilograms per hectare per year in 1973. Upon reestablishment of pond extension services in late 1974,

Harvestable size river shrimp, *Macrobrachium tenellum*, after several months of growth with tilapia and guapote tigre in a private pond that used irrigation water as its water source.

major effort was begun to increase production in existing ponds. Pond owners were contacted to determine the status of their ponds and to establish the level of interest by the owner. Owners who showed interest in managing ponds for fish production were assisted in renovating their ponds and implementing sound fish production programs. Advice was also given to private individuals on site selection and construction of new ponds. As a result of these extension efforts, 97 ponds with a surface area of 26 hectares, on 48 different farms, were totally rehabilitated by late 1975. Another 85 ponds on 47 farms, with 12.7 hectares of water surface, were in the process of being rehabilitated. As a direct result of the extension efforts in placing new or renovated ponds in production, fingerling distribution reached the record level of 456,925 in 1975, up from 96,033 in 1974 and 30,000 in 1972.

Fish production from private ponds reached 39.8 metric tons by the end of 1975, compared to 6.8 metric tons in 1972. Annual fish production should be at least 3,000 kilograms per hectare under average management and 5,000 kilograms per hectare when ponds are well managed. For the 38.7 hectares of ponds rehabilitated or in the process of rehabilitation in 1975, harvest potential ranged from 116 metric tons under average management inputs to as much as 193 metric tons under well-managed conditions.

For the first time in El Salvador, formal guidelines and specific funds were established to extend loans to prospective fish farmers. This was accomplished through a cooperative effort between the Fisheries Service and the Agricultural Development Bank. Prospective creditors were given assistance by the Fisheries Service in preparation of a cost-benefit analysis for their proposed fish farming plans. The farmers also were advised in the execution of these plans. Several large commercial projects were initiated during 1975 and 1976 through this and other sources of credit. The

largest, located near Acajutla, consisted of 16 newly constructed ponds covering over 5 hectares of water. Ponds stocked with *Sarotherodon aurea* and guapote tigre, as well as juvenile freshwater shrimp, *Macrobrachium* spp., collected from rivers, were fertilized with 20-20-0 fertilizer and chicken manure, or received supplementary rations consisting of agricultural by-products.

Community Ponds

In 1974 the GOES implemented a program for development of community ponds. This program is funded through FOCCO (Communal Development and Cooperation through Self Drive and Mutual Help), a separate governmental institution whose objective is to assist in community development. The community ponds program is aimed at developing within selected communities various resources and management skills to enable numbers of the communities to achieve a better standard of living. Rural cooperatives, agrarian reform settlements, and members of government facilities are typically the participants in this program. Normally land to construct a pond is given to an organized community group by the government, local municipality, agrarian reform settlement, or a private donor. The community provides labor during the land preparation and pond construction phases, and once fish are stocked, community labor maintains the ponds and feeds and harvests the fish. The Fisheries Service, through the FOCCO funds, provided assistance in selection of the pond site, pond design, construction of the pond (tractor and driver), fish to stock the pond, and assistance in pond management. Until 1976 social workers under the direction of FOCCO collaborated in each community pond project. In 1976, with the arrival of several social workers, the Fisheries Service assumed the entire responsibility of the community pond development program and of providing social assistance to the projects. Four teams of one fish culture extension specialist and one social worker, with the back-up assistance of two pond design-construction enginer teams, were formed to provide technical assistance that is more comprehensive and responsive to community needs.

At the end of 1975 there were 57 community ponds functioning, while others were in the process of design or construction. The goal in 1976 was to complete 100 additional ponds comprising about 20 hectares in surface area. Benefit to the community has generally been in the form of fresh fish, usually a percentage of the harvested fish based on a worker's share in total labor provided by the community members. Community ponds in general have not reached the level of production achieved in experimental or private ponds. Nonetheless, some of the best production in rural ponds has been recorded from community ponds, the most salient example being the pond at the Izalco Livestock Experiment Station where over 7,400 kilograms of fish per year were produced.

SHORT TERM TECHNICAL ASSISTANCE

On two occasions Auburn University fishery personnel visited the Inland Fisheries Development Project to provide a general review and evaluation of progress. Dr. Donovan D. Moss, Assistant Director of the International Center for

TOP: Harvesting the uniformly sized all-male hybrid tilapia at the community pond project in the Livestock Center, Izalco. BOTTOM: Members of the Izalco community pond project and social worker agents and fish culture extension agents chart production of the all-male tilapia hybrid, which surpassed 7,000 kilograms per hectare per year with pig manure used.

Aquaculture, visited in January 1975. He reviewed the site and plans for the new fingerling production station at Izalco and the recently completed new construction at the National Fisheries Station, studied the problem of aerial pesticide contamination at the same station, and lectured to the general public and the staff of Natural Renewable Resources on the topic of intensive aquaculture around the world.

Dr. Bryan Duncan, a coordinator of international training programs at the International Center for Aquaculture, visited the Project in March 1976. He concentrated mainly on a review of the organization of the community pond and extension program and fingerling production system. He presented a lecture on the principles of fish culture extension to the fish culture extension division, and discussed milkfish culture in the Philippines before the fish culture research staff.

FISH MARKETING SURVEY

To determine the factors which influence the marketing of fish in El Salvador and their implications in the development of aquaculture, a countrywide survey on fish marketing was conducted by two Fisheries Service staff. The survey covered an entire year, from August 1, 1973, to July 31, 1974, and placed emphasis on marketing in the rural area where incomes are lowest, diets are inadequate, and 60 percent of the nation's population resides. The publications resulting from this study, considered by many to be the most important contribution to fish marketing in Central America, have been in heavy demand (Parkman and Salgado 1975, Parkman and McCoy 1976, 1977). The conclusions reached by the authors included the following:

1. Most of the fish consumed in El Salvador comes from marine sources, although the freshwater artisanal fisheries contribute substantially to the total supply.

2. Fish compared favorably in price with other animal protein products, both on a cost per kilogram and cost per unit edible protein basis. Second-class marine fish, sold at the retail price of ¢1.43 per kilogram and containing 132 grams protein per kilogram fish, costs ¢10.82 per kilogram of protein. Loin beef, on the other hand, costs ¢29.22 per kilogram protein, pork loin ¢20.24, poultry ¢20.28, eggs ¢19.43, and milk ¢12.94 per kilogram of protein.

3. Major cities served as centers of fish distribution for surrounding areas. The per capita consumption of all types of fish was greater in the major cities than in the rural towns, due to the low incomes of most rural inhabitants and the dependency of rural markets on the major cities for fish supplies. In fact, the large cities absorb the majority of already inadequate fish supply reaching the city distribution centers, thus limiting the amount available to the more distant rural towns.

4. Consumers preferred the flavor of freshwater fish over most marine species. Among the freshwater fishes, the cichlids (mojarras, guapotes, and tilapias) brought premium prices while the catfishes, characins, and topwater minnows were sold at prices comparable to those paid for second-class marine fish.

5. As a result of a moderately expanding per capita income and population increases, projected demand for fish will grow in all locations. Domestic production has not increased significantly in recent years. By 1985 the projected urban demand will be 4,354 metric tons and the rural demand will be 1,077 metric tons. To benefit low income consumers, large increases in production of inexpensive fish are needed in all sectors.

6. Pond-raised fish is seen as an important source of future supplies in El Salvador. In addition to being preferred over many other types, pond-raised fish can be economically produced at competitive prices and can be raised near areas of consumption, thus reducing transportation costs and increasing quality. In addition, fish production in ponds will reduce the dependency of rural areas on the cities for already inadequate fish supplies.

INTERNATIONAL TRIPS AND CONFERENCES ATTENDED

The Acting Fisheries Chief, Lic. Enrique Castro Butter, and the advisor attended the first UN-FAO Regional Symposium on Aquaculture in Latin America, at Montevideo, Uruguay, from November 26 to December 2, 1974. The meeting was designed to bring together aquaculture leaders from the region to share their experiences in aquaculture, define the present level of aquaculture technology, and to establish priorities for future research and development in aquaculture. On return to El Salvador from the conference, the author routed through Fortaleza, Ceara, Brazil, to visit the DNOCS/USAID/Auburn University Fish Culture Development Project. The Chief of Party, Dr. Leonard Lovshin, and John Jensen, fish culture extension advisor, both of Auburn University, toured the author through the research facilities at the Center for Ichthyological Research in Fortaleza, the extensive pond research facilities located at two sites in Pentecoste, area DNOCS fingerling production stations, and several private farms employing the all-male tilapia hybrid culture technology. The author carried back to El Salvador stock of the species *S. hornorum* and *S. nilotica* for production of all-male fingerlings.

The Acting Fisheries Advisor, the Marine Resources Unit Head, Lic. Ricardo Hernandez Rivas, and the author attended the Central America Seminar Workshop on Artisanal Fisheries Development and Coastal Aquaculture at San Jose, Costa Rica, January 13-17, 1975. Objectives of this meeting were for the representatives to present the state of development in artisanal fisheries and aquaculture in their countries, to develop a methodology to define problem areas, and to define some of the priority action areas.

The Acting Fisheries Chief attended the UN/WHO-sponsored Inter-American Meeting in Guatemala, April 16-19, 1975, where he presented a paper on the intensive culture of fish for improving human nutrition in the Central American countries. The paper was part of a series given in the section dedicated to the use of small animal species for the production of food in the Americas.

A 3-day trip to Guatemala was made by the heads of the Inland Fisheries Unit and Aquaculture Unit and the author during March 1976 to obtain information on past experiences with fish culture in the higher, cooler altitudes of Guatemala. The information was gathered for application to El Salvador's plan to determine the feasibility of extending pond aquaculture to the highland areas.

The author and two members of the Marine Resources Unit attended a 2-day short course on environmental pollution, sponsored jointly by ICAITI (Central American Institute for Industrial Research and Technology) and ROCAP (AID Regional Offices for Central America and Panama) at San Salvador in early 1976.

Two fish culture extension staff of the Inland Fisheries Unit attended a 2-week course in San Salvador on "Communication and Agricultural Extension," July 1-12, 1975, sponsored by IICA (Inter-American Institute of Agricultural Sciences). One fish culture extension specialist of the Inland Fisheries Unit participated in a 2-month practical training course in intensive aquaculture in various parts of Israel, sponsored by the government of Israel, in late 1976.

FISHERIES PUBLICATIONS

The number of fisheries publications in the field of inland fisheries and aquaculture has dramatically increased since Bayne in 1974 reported publications completed at the end of the first phase of the Inland Fisheries Project. Works not reported at that time and completed, or in press, since then are listed below:

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ACKNOWLEDGMENTS

The author acknowledges the contributions made by the Fisheries Service biologists, extension workers, engineers, and social workers to the fish culture research and extension programs, and other members of the General Directorate of Natural Renewable Resources who were particularly helpful and friendly to me. Appreciation also is expressed to the Peace Corps Volunteers and staff of the USAID Office of Rural Development for their support and cooperation during the Project.