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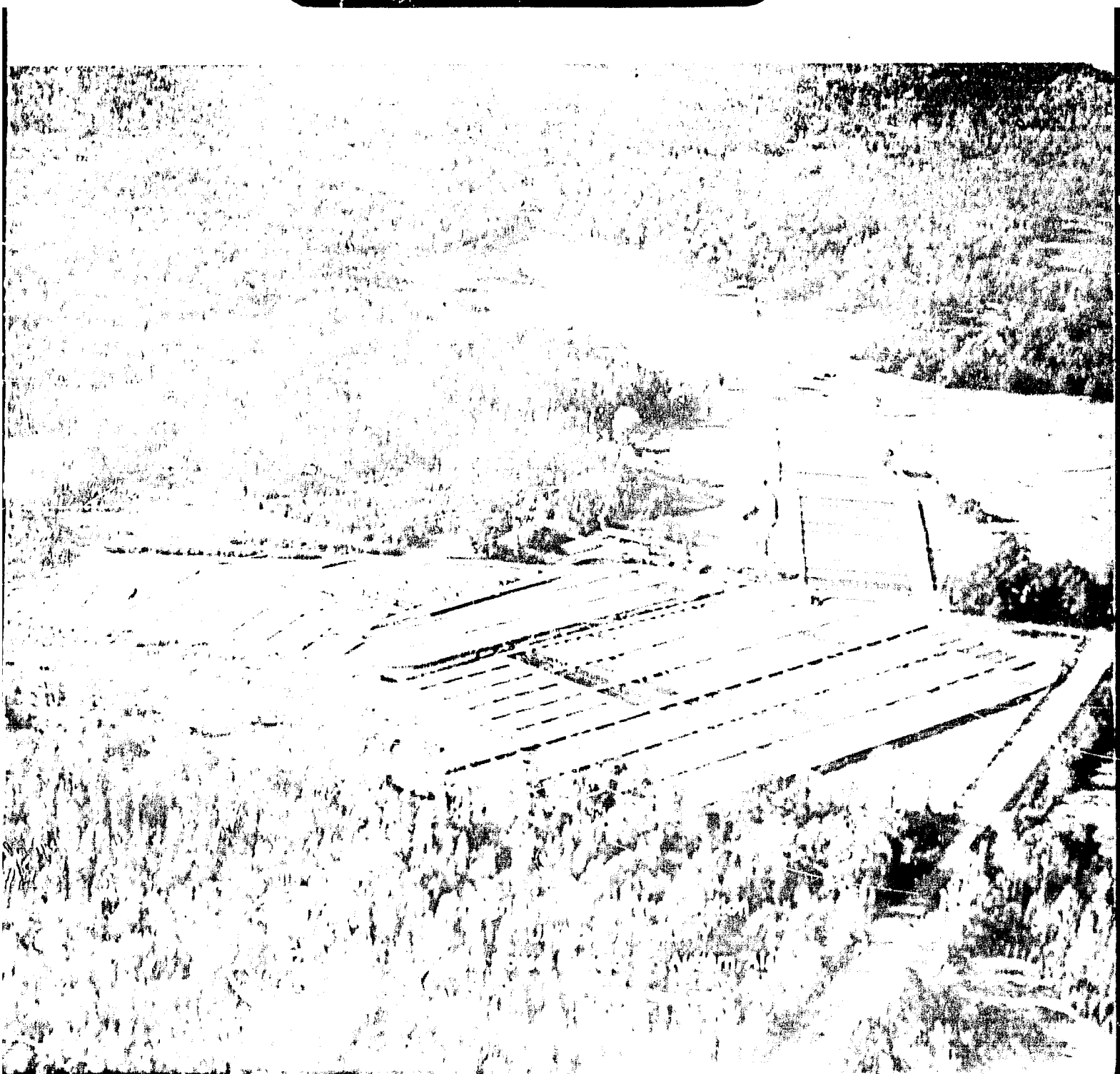

FINAL REPORT

FRESHWATER AQUACULTURE DEVELOPMENT IN COLOMBIA

February 1977 - June 1980

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June 1, 1980

FISHERIES DEVELOPMENT LOAN

AID/LA-C-1176

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I. HISTORY AND PROJECT OBJECTIVES

The International Center for Aquaculture of Auburn University was contracted to provide technical assistance for aquacultural development to INDERENA (Instituto Nacional de los Recursos Naturales Renovables y del Ambiente) through USAID Loan No. AID-DLC/P-2086. This loan supported a multifaceted program for the development of aquaculture and artisanal fisheries. It provided funds to assist in the development of research facilities, to train professional staff of those facilities and to provide technical assistance. Auburn University through its two resident advisors and its on-campus academic program was involved in each of these aspects.

Colombia, as other Latin American countries, does not have a tradition in aquaculture, but there is much interest in its development throughout the country. The Government of Colombia recognized the value of aquaculture and aquaculture is a high priority item in the National Food and Nutritional Plan of 1975.

The USAID loan was implemented to assist INDERENA in upgrading its fishery research capabilities with the objective of developing economically and technically sound aquaculture systems suitable primarily, but not exclusively, for small farmer use.

Colombia is a country of mountains and valleys. The Magdalena River is the principle river in the country, originating in the mountain foothills at an elevation of over 3000 m above sea level and runs a 1600 km course to the Caribbean

Sea. During this project two new aquaculture stations were built to take into account this climatic diversity. The Alto Magdalena Station in Gigante, Huila, is located near the headwaters of the Magdalena River. The moderate climate of the Gigante region is representative of the mountain foothills and the upper valleys of Colombia. The Repelon Station is in the lower Magdalena River floodplain, in a hot climate similar to most of the North Coast and the main Magdalena valley. The results from these two stations could have application to most areas of Colombia where warm water aquaculture is feasible.

Auburn University has been involved in Colombia aquaculture directly or indirectly for several years. It trained its first Colombian student, Mr. Alonso Ramos A., in 1968 and the first in-country visit by a faculty member was in 1970 by Dr. H. S. Swingle. Between that time and the beginning of this project six short-term trips were made to provide technical assistance. Assistance was given in the site selection for the proposed Repelon and Gigante research stations. Preliminary designs of the Repelon station were prepared and on-going construction was reviewed. The capture fishery in the Maganque area was briefly surveyed and suggestions were given for a fishery management program. A proposed shrimp culture project was evaluated. Recommendations were also proposed for research, training and equipment as they relate to aquacultural development. These short-term trips helped to prepare the way for the project as described in this report.

The long-term technical resident assistance began in February of 1977 and concluded in June 1980. The in-country advisors were Dr. Ronald P. Phelps, chief of party and resident advisor for the Repelon aquaculture project; Thomas J. Popma, resident advisor for the Alto Magdalena project; and Richard C. Scully, resident advisor for the Llanos Orientales fisheries biology project.

This report will confine itself to aspects related to aquaculture development, since the fisheries biology project is discussed in a separate report.

II. GENERAL ASPECTS

A. Consultants

Provisions for short-term consultants were included in the project to permit evaluation and additional expertise in specific subject areas. A total of 157 days of short-term consultant time were provided during the course of the project.

The Director, Dr. E. W. Shell, or the Assistant Director, Dr. Donovan D. Moss, of the International Center for Aquaculture at Auburn University, were in-country on three occasions to evaluate project progress and to discuss both administrative and technical aspects with USAID and Colombian government officials.

Early in the project Auburn University macroeconomist Dr. Donald Street was in-country to evaluate the possible implications of aquaculture in the national economy. Dr. E. W. McCoy arrived during the final year of the project to make recommendations on the appropriate experimental design to evaluate specific management methods.

During a 2-week visit, Dr. John Ramsey provided special expertise in fish taxonomy and in the local ornamental fish trade.

Dr. Leonard L. Lovshin was in-country courtesy of USAID Brazil, and held several short seminars with Colombian officials and biologists concerning the status of aquaculture in Brazil and the possible implications in Colombia.

Fishery biologists Drs. William Davies and William Shelton were each in-country to plan and make appropriate modifications of the experimental design for the fishery biology project in the Llanos region (described in a separate publication.) Dr. Shelton also participated in a 1-week seminar on reservoir management and discussed sex manipulation of cichlids with the Auburn University resident staff and their counterparts. The services of Drs. Shelton and

Ramsey were provided courtesy of the U.S. Fish and Wildlife Service, Department of the Interior with only travel expenses being charged to the project.

The instructors who participated in the series of short courses offered in-country by Auburn University (described in greater detail in the training section of this report) also made valuable contributions as consultants in the the areas of their expertise.

B. Construction

One of the significant results during the life of the project has been the construction of two excellent fishculture stations, one in Repelon, Department of Atlantico, and the other in Gigante, Department of Huila. These two stations are equipped to provide the leadership in aquacultural development in Colombia for many years to come.

Auburn University was involved in the site selections and preliminary designs of the stations before the start of the present project. Each location had significant limitations but also recomendable aspects. At Repelon there is a favorable topography, soil texture and water supply, but its isolation is a hardship for its professional staff. In Gigante the sandy soil texture has been a major constraint, but the available water supply and favorable living conditions for its staff were positive factors. The technical advisors worked closely with a local engineering company (Gomez and Cajiao) on the final designs of the Gigante station. Later the advisors participated in the overseeing of construction at both sites.

1. Repelon

The Repelon station is located between the villages of Rotinet and Repelon in the Department of Atlantico on the north coast of Colombia. The station is included in an irrigation district of HIMAT from which it receives its water. The water is pumped into the irrigation system from the Embalse de Guajaro, a

fertile 16,000-ha lake. Water enters from the irrigation canal into a 6,300-m^2 reservoir by gravity, from which it continues to other parts of the station also by gravity.

There is a total water surface area of 9.5 ha divided into 73 earthen ponds: one reservoir, three 2500-m^2 ponds, six 800-m^2 ponds, five irregularly shaped ponds 400 to 1400-m^2, twenty-six 200 m^2 ponds, twenty 1000-m^2 ponds, nine 3000-m^2 ponds and four 5000-m^2 ponds. All ponds have an average depth of 1-m.

There was a total of 2,400-m^2 in buildings constructed divided between laboratories, offices, a shop and storage building, a fish hatchery building, a fish handling building, and living quarters. The main building consists of eleven offices, six laboratories, a library, conference room, cafeteria, kitchen and a living quarters wing containing eight individual rooms along with a dormitory for 30 people. The shop and storage building contains mechanic's and carpenter's workshops, a feed storage and preparation room, a warehouse, and a small laboratory. The fish handling house has eighteen concrete holding tanks, a net storage area, and a small laboratory. The fish hatchery building contains aquaria, metal troughs and related facilities. In addition, there are the residence for the station director, an auxiliary residence, an emergency electrical plant, and a water treatment plant.

Construction began at Repelon with the support of a USAID Agricultural Sector Development Loan which provided funds for 15 earthen ponds that were completed in 1976. Additional pond and service buildings construction began in September 1977 as a part of the Fisheries Development Loan, and was completed in July 1978. A third phase of construction, which includes laboratories and offices, began in February 1979 and will be finished in 1980.

2. Alto Magdalena

The Alto Magdalena station is located at an altitude of 1000 m above sea level in the south of Colombia, 4-km north of the small town of Gigante in the Department of Huila where the water temperature averages 24 to 25°C.

There is a 40-50 l/min water supply available to the station from an open diversion canal that takes the water from a stream 1-km away. The 25-ha station consists of 51 ponds with a total water surface area of 3.4 ha as well as a laboratory-office-building, a fish handling house and a workshop-storage building. The ponds consist of: a 4000-m^2 and a 8000-m^2 reservoir pond having combined capacity of 15,000-m^3; twenty-one 200-m^2 ponds; eighteen 500 m^2 ponds; and ten 1000 m^2 ponds. In the laboratory-office building there are two laboratories, four offices, a library, a classroom, a cafeteria and a kitchen. The fish handling house contains eighteen concrete tanks, 24 aquaria, a small laboratory and a work area. The workshop-storage building consists of a mechanic's and carpenter's shop, warehouse, feed preparation and storage room and a small laboratory.

Pond construction began at the Alto Magdalena Station in April 1978 and was completed in March 1980. The laboratory construction began in May 1978 and was completed in August 1979.

Construction delays were costly both financially and in the technical results that could be produced by the stations. This was particularly true for the Alto Magdalena station where the first ponds at the station became available only in the last 7 months of the project. At Repelon there will have been an approximate 25% cost overrun from the original contracts. The Repelon facilities, when completed, will represent an investment of over $38,000,000 pesos, or approximately $950,000 US dollars. At the Alto Magdalena station there will have been a cost overrun of approximately 45% from the original contracts. The

Alto Magdalena station will represent an investment of over 31,000,000 pesos or approximately $775,000.

These cost overruns coupled with inflation made it necessary to postpone the construction of two fishery biology stations scheduled as a part of the Fisheries Development Loan.

C. Equipment

The USAID Fisheries Loan included approximately $500,000 US for equipment purchases. At the onset of the project Auburn University identified the various types of equipment needed for the aquaculture facilities and fishery biology programs. Later the University was requested to purchase and deliver equipment costing approximately $360,000 US.

A wide range of equipment was purchased includeding such field equipment as vehicles, small tractors, boats, motors, nets, etc. Equipment for the hatchery buildings included various chemicals, aeration equipment and general hatchery equipment.

The workshops are very well equipped for most types of construction and repair work. This will enable the stations to help reduce their maintenance and upkeep costs since most of the work can be done at the stations. The equipment for the workshops include table saws, drill presses, welding equipment, as well as a variety of hand tools.

Both Repelon and Gigante are equipped with feed pelleting equipment that will facilitate a variety of nutritional studies as well as the production of the majority of the feed needed for routine fish maintenance.

The laboratories are equipped to permit studies in water chemistry, nutrition, diseases and general aquatic biology. The equipment chosen was intended to permit the laboratories to respond to a variety of conditions, while trying to reduce future maintenance problems to a minimum.

D. Training

Recognizing the value and long-term benefits of training, this component of the project was given high priority, and constitutes a significant portion of total expenditures of the loan ($412,000 US). Training was divided into three general categories: 1) graduate degree training, 2) Out-of-country non-degree training, and 3) in-country training.

1. Graduate degree training

During the course of the loan, fifteen Colombian biologists were given scholarships to study for a Master of Science degree at Auburn University. Prospective students were encouraged to enroll in various learning institutions other than Auburn University. However, time limitations, stricter language requirements, and higher costs were prohibitive in the cases where transfer or direct enrollment was desired.

Four of the fifteen students concentrated their efforts in the field of fishery biology and management; and one of these four is giving special attention to taxonomy. The remaining eleven students have focused on aquaculture. Although the academic training was organized to give the participants a well-rounded training in general aquaculture, each student received special training and practical experience in specific subject areas, as follows:

reproduction and sex manipulation	(5 students)
fish nutrition	(2 students)
water quality management	(2 students)
parasites and diseases	(1 student)
aquacultural economics	(1 student)

Because of the great emphasis given to degree training, the two new research stations in Repelon and Gigante are staffed by biologists with masters degree training in the specific field of aquaculture and two MS-trained participants

are involved at the administrative and organizational level of the Colombia aquaculture program.

The present number of MS degree trained personnel is considered adequate, based on the present and expected level of funding, but it is suggested that a program of advanced-degree training be continued at a level consistent with a normal attrition rate to private enterprise and other agencies.

2. In-country training

Because of the interest in aquaculture and the number of university-trained biologists actively working in-country, a series of five 1-week short-courses was offered by Auburn University during 1979. Nine general subjects were emphasized, according to the following outline:

Course 1 General principles of aquaculture (Drs. Gary Jensen and Richard Pretto).

Course 2 Fish reproduction and hatchery management (Drs. Leonard Lovshin and Gary Jensen).

Course 3 Water quality and fish nutrition (Drs. Luther Tucker and Leonard Lovshin).

Course 4 Aquacultural economics and extension methods (Dr. John Jensen and Ms. Carol Engle).

Course 5 Fish diseases and pond construction (Drs. Peter Taylor and Gary Jensen).

The instructors were chosen first because of their training and experience in the subject areas, and secondly because of their ability to communicate in Spanish or Portuguese. A detailed study outline and a manual on each subject area was prepared in Spanish and provided to each student. Also, as a future teaching aid, reprints of all photographic slides used in the courses were left with the project coordinator and at the research stations in Repelon and Gigante. All short-courses were attended by approximately 30 biologists of INDERENA and other institutions. Certificates were awarded to those completing the series. The first three courses were offered at Repelon, and the final two in Gigante.

In-country training in the field of fishery biology and reservoir management was offered by Dr. William Shelton, Auburn University, who participated in a 1-week short-course during a visit as special consultant in fishery biology and sex manipulation of fish.

The Auburn advisor at Gigante participated in three short-courses. The first was a 10-day program on the practical aspects of warm-water aquaculture. This course was attended by 15 Colombian biologists actively working in aquacultural projects. Another similar course was offered to personnel employed in aquaculture projects at the technician level. A third short-course (7 days) was offered to 15 third-year students of the University of Choco. The technical staff at Gigante was involved in weekly lectures to high school students at two local agricultural schools where ponds were available for practical as well as theoretical training in the general principles of rural aquaculture. Unfortunately, additional responsibilities at the newly constructed research station and the lack of adequate transportation necessitated the temporary suspension of this program.

4. The third National Aquacu ture Symposium held in Cali in 1979 was partially financed by the Fisheries Development Loan. At this symposium approximately 200 biologists had the opportunity to update their information on the present state of knowledge of Colombian aquaculture.

5. The newly trained Colombian biologists have organized and begun participation in two separate series of short-courses. One series of four or five 1-week courses is being offered to and financed by the regional organization Fondo Piscicola del Tolima, and another aquaculture short-course will be directed to extension agents and technicians employed by Hogares Juveniles Campesinos.

The facilities at the new research stations and the level of training of its staff will permit high quality in-country training at the professional, technical and pond-owner level long after this project is terminated.

3. Out-of-country non-degree training

This category included all non-degree training in countries other than Colombia. This generally consisted of practical short-courses or experience in the US or Latin American countries. The following programs were financed under the loan.

1. Three INDERENA officials were sent to Mexico to participate in the Second Symposium on Latin American Aquaculture.
2. One INDERENA biologist spent 1-month receiving information and practical experience at several Brazilian aquaculture stations.
3. The aquaculture program in Argentina was reviewed by one INDERENA biologist during a 1-week trip.
4. Four biologists spent 1-week in Panama reviewing that country's program of small scale commercial aquaculture and the integration of small-farm aquaculture among the indigenous communities.
5. One INDERENA engineer spent 4 weeks observing small- and large-scale pond and reservoir construction techniques in the US and Panama.
6. Four Colombian officials were involved in a 2-week tour of US aquaculture activities including research facilities, commercial food-fish operations, and organizations involved in the ornamental fish industry.

In summary, the training component is considered as one of the most positive elements in the project. It has greatly unified and fortified aquacultural development in Colombia.

III. TECHNICAL ASPECTS

The following summaries of the technical activities carried out at the Repelon and Gigante aquaculture stations are intended only to highlight the principal technical conclusions arrived at during the course of the project.

A. Technical Summary - Repelon

The technical emphasis of the Repelon program was the evaluation of fish species native to Colombia for their potential in aquaculture and the development of culture systems for the more promising species.

This process began with a screening or preliminary evaluation study to select the more promising species, followed by other studies to evaluate such factors as optimum stocking densities, fertilizer and feeding regimes, fingerling production methods, etc. The ultimate goal was the development of a technically sound extension package.

Several species were selected for study based on their commercial acceptability, morphological characteristics suggesting a potential in aquaculture, and the availability of fingerlings. The species selected for study were bocachico *Prochilodus reticulatus*, barbul *Pimelodus clarias* and *P. grosskopfii*, mojarra amarilla *Petenia kraussii*, mojarra negra *Petenia umbrifera*, dorada *Brycon moorei*, arenca *Triportheus magdalenae*, lisa *Mugil incilis* and *M. brazilenis*, doncella *Ageneiousus caucanus*, bagre pintado *Pseudoplatystoma fasciatum*, blanquillo *Sorubim lima*, sardina *Curimata mivartii*, cuatro ojos *Leporinus muyscorum*, and as predators, agujeta *Ctenolucius hujeta*, moncholo *Hoplias malabaricus* and pacora *Plagioscion surinamensis*.

In addition to these species native to the Magdalena river, *Tilapia rendalli*, *T. nilotica*, cachama *Colossoma macropomum* and *C. bidens*, palomita *Myleossoma* and tucunare *Cichla ocellaris* were also selected for study.

1. Preliminary Evaluation Studies (Table 1)

Since very little was known regarding most of the native species' response to intensive aquaculture, an experiment was designed to measure that response. Each species was tested under three different levels of management: minimum (natural productivity), semi-intensive (the addition of organic fertilizer), and intensive (the addition of organic fertilizer and supplemental feed).

A fish with potential for aquaculture should respond with a higher yield with each intensification in the level of management. The degree of response would be an indication as to what management level might be optimum for the species. The fish density was one per 3-m^2, and the duration of each experiment was 6-months.

It was possible to study the following species in the preliminary evaluation experiment: bocachico Prochilodus reticulatus, barbul Pimelodus clarias, mojarra amarilla Petenia kraussi, mojarra negra Petenia umbrifera, arenca Triportheus Magdalena, dorada Brycon moorei, lisa Mugil, T. rendalli and T. nilotica.

The greatest response to more intensive management was given by three cichlids: T. nilotica, mojarra amarilla and T. rendalli. The net production in organically fertilized ponds (dry chicken litter at a rate of 2500-kg/ha/mm) were as follows: T. nilotica, 948 kg/ha; mojarra amarilla, 616 kg/hja; and T. rendalli, 329 kg/ha. The net productions in fertilized ponds receiving supplemental feed were as follows: T. nilotica, 1,192 kg/ha; mojarra amarilla, 683 kg/ha, and T. rendalli, 372 kg/ha. The production levels indicated uncontrolled reproduction in the ponds. The relatively low production of T. rendalli was due to the lesser amount of fingerlings. Uncontrolled reproduction appeared to be a severe limitation on the growth of T. nilotica, and T. rendalli, and to a lesser extent of mojarra amarilla. Therefore various studies were later initiated to control the reproduction of these species.

Of the remaining species tested, the barbul and bocachico had the greater net productions under intensive management. The net production in fertilized ponds was 214 kg/ha for barbul and 181-kg/ha for bocachico. In response to the addition of feed, the net production of barbul was 266-kg/ha and bocachico 264-kg/ha.

Although the production of barbul was low, the fish demonstrated a near linear growth rate throughout the culture. This, combined with the robust physical condition of the individual fish suggested that an increase in stocking density might yield a higher production without greatly affecting the final size.

Although the net production of barbul and bocachico were similar the barbul had the distinct advantage of reaching an acceptable market size while the bocachico did not.

These results and other available information suggest that bocachico is not suitable as a primary species in intensive aquaculture but may be appropriate for extensive culture or in polyculture when stocked at low densities.

Dorada did not give a high net production under the three conditions tested but the addition of feed to a fertilized pond produced a 135% increase in production. It was observed to be a vigorous feeder and in the process caused part of the feed to be lost, resulting in a poor feed conversion. This suggested that a pelleted feed might improve the production and conversion efficiency.

The low production of lisa and arenca was partly caused by high mortality. The high mortality of lisa (77% overall) did have a positive effect by reducing the density to a point where adequate growth could occur. This was not true for arenca since growth was slow in all levels of management although mortality reduced the final density to one fish per 14.7 m^2 (80% mortality).

The mojarra negra gave the poorest growth and production of any species tested. Its growth rate in fertilized ponds was only 0.17 g/day and where feed

was added, 0.22 g/day. Net production in response to fertilizer was 60 kg/ha and to feeding was 60 kg/ha.

The preliminary evaluation of the species tested provided the basic information needed to orient subsequent investigation. Based on these results further studies were conducted with mojarra amarilla, barbul and dorada.

2. Studies with mojarra amarilla

In the preliminary evaluation of mojarra amarilla the net production was relatively high but consisted in large part of fingerlings produced by the initial stock. What effect this reproduction had on the growth rate of the initial stock was not clear. Several studies were made including control of the mojarra reproduction and determining the effect of the fingerlings on the production of adults.

Mojarra amarilla fry were fed methyl testosterone at rates of 30 and 60 mg/kg of feed for periods of up to 60 days to produce all male populations, but there was no significant change in the sex ratio.

Attempts were made to hybridize mojarra amarilla and mojarra negra in ponds but no reproduction was observed.

Male mojarra were hand sexed and cultured in fertilized ponds for 6 months. The net production was 119-kg/ha. This was similar to the production of only the adults of the mojarra amarilla in the preliminary evaluation (137- kg/ha) without the additional 469-kg/ha of fingerlings that were also produced. It appears that in a 6-month culture the presence of fingerlings had little effect on the overall production of adults.

3. Predator-prey studies with mojarra amarilla

By using a predator-prey combination for the culture of cichlids, it may be possible to develop a balanced system that will stay productive over a long time interval. There are many situations in Colombia where such a system would

be the preferred fish culture technique since it eliminates the need of continuous restocking and permits application by partial harvesting. This will be especially important where ponds cannot be drained frequently or where fingerling distribution channels are not well established. It was with this in mind that various native species were studied as prey or predator species.

The first prey species studied was mojarra amarilla. Six predators were studied individually as a control of mojarra reproduction: pacora, moncholo, agujeta, mojarra negra and tucunare. The predator was stocked at 1 fish/15m^2 and the mojarra amarilla at 1/3m^2. The fish were stocked at same time in ponds fertilized with chicken litter at a rate equal to 2,500 kg/ha/mon and harvested after 6 months.

No predator studied gave adequate control of mojarra amarilla reproduction but the amount of reproduction was reduced where moncholo were present and to a lesser extent where agujeta were the predator. Moncholo and agujeta did reproduce in the ponds during the experiment.

Predator-prey studies are continuing in order to determine predators and stocking densities for T. rendalli and T. nilotica. It appears to be necessary to find an alternative predator for tucunare due to its c ntinued poor survival at Repelon. These now being studied are moncholo, agujeta and mojarra negra.

-. Optimum stocking density for barbul

In the preliminary evaluation of barbul the results indicated it might be possible to culture this fish at a higher density without significantly reducing the final average weights. Barbul were cultured at four stocking densities: 2 fish/m^2, 1/m^2, 1/2m^2 and 1/3m^2. The fish were not fed, but the ponds were fertilized weekly at a rate equivalent to 2,500 kg/ha/mon of chicken litter.

After a 6-month culture the greatest total production was 601-kg/ha at densities of 1 fish/m^2, and the final average weight was 69-gr. At this density

fish production was more than doubled and the individual fish still reached a marketable size duiring the culture period.

It would appear therefore, that the optimum stocking density for barbul culture in organically manured ponds is 1 fish/m^2.

5. Culture of dorada using pelleted chicken feed

Dorada appears to be the most promising commercial species tested from the Magdalena system. It was cultured for 6 months at a density of 1 fish/m^2 using a pelleted chicken feed. Dorada accepted a pelleted feed very well and net production was equivalent to 1,596-kg/ha in 195 days with a feed conversion of 3.2 to 1.

Although dorada shows potential, considerable effort must be given to the production of fingerlings and to the development of an optimum feed before commercial production of this species is practical.

6. Extensive culture of lisa under natural conditions

Lisa fingerlings are abundant along the Caribbean Coast in certain seasons of the year. Studies were made to establish what production might be expected when lisa are cultured extensively. The fish were tested at densities of 1 fish/5-m^2 and 1/10-m^2 in unfertilized ponds for 6 months.

The results were discouraging. At the initial density of 1 fish/5m^2 the final average weight was 103-g, the net production was only 76-kg/ha, and the final fish density 1/14-m^2. This was similar to that seen in the preliminary evaluation where the final fish density was 1/9-m^2 with average weights of 97-g and net production was 108-kg/ha. An extremely high mortality (40%) was encountered in the pond with an initial density of 1 fish/10m^2. At this reduced final density of 1 fish/143m^2, the growth rate was greatly increased. Fish attained the final average weight of 201-g.

It appears that poor survival and density related factors are extremely important in the extensive culture of lisa. Stocking rates of 1 fish/3-5-m^2 will be required to give final densities of approximately 1/10-m^2 and a fish of 100 g. Although such a method would produce a fish of 100 g, the total production obtained would be very low (80-120-kg/ha in 6 months). Other types of extensive cultures should be emphasized.

7. Reproduction studies

One of the primary limitations in the technical program was the inadequate supply of fingerlings for the majority of the species being studied.

The cichlid species spawned in the ponds. Pacora, moncholo and agujeta also spawned in the ponds. Characids such as bocachico, sardina, cuatro ojos, dorada and arenca matured in the ponds but did not spawn. Cuatro ojos were induced to spawn using HCG and carp pituitary. Eggs from dorada were also obtained using the same methods. No catfish such as barbul, blanquillo or bagre pintado matured in the ponds during the years of the project.

8. Monosex culture of tilapias

One method to control cichlid reproduction is the culture of only one sex. This was done with *T. nilotica* and *T. rendalli* separating the sexes by hand. Male *T. nilotica* and *T. rendalli* and female *T. rendalli* were stocked at 1fish/3-m^2 and cultured for 6 months in ponds fertilized with chicken litter at a rate of 2,500 kg/ha/mon.

The male *T. nilotica* gave the greatest net production of 421-kg/ha in 6-months and had an average weight of 222-g. The pond with male *T. rendalli* was contaminated with females resulting in reproduction. Net production of adults in the pond with males was less than that of the pond with females. (92 vs 144-kg/ha.)

9. Culture of cachama using a pelleted feed

The greatest net production in any experiment was obtained with the cachama (4,112-kg/ha in 6 months). This species was introduced from the Orinoco River system in September 1979. It was cultured at a density of 1 fish/m^2, and fed a commercially available pelleted chicken feed. After 6 months the average weight was 443-g and the food conversion was 1.45:1.

This species shows great promise for intensive aquaculture especially after methods can be developed to produce an adequate fingerling supply and culture procedures are refined.

10. Culture of palometa using a pelleted feed

This species is also native to the Orinoco system and is reported to be herbivorous. Because of the limited number of fish available they were fed a pelleted feed with the hopes of bringing them to a sexually mature size rapidly.

They accepted a pelleted feed well but the growth was slow, resulting in a net production of only 450-kg/ha in 6 months. They did show signs of being able to control aquatic weeds.

11. Economic studies

A variety of economic studies were conducted during the project including a socio-economic review of the area, farm surveys, a market monitoring study, and fish marketing studies. Most of the region is devoted to cattle farming. The principle row crops are cotton, rice and sorgum. The farms are large, generally around 100 ha and have an average of 2.7 ponds that generally are not yet used for fish culture. Fish are an important part of the diet among low-income families in towns such as Repelon where fish are 50% of the daily per capita meat consumption.

Fish produced at the station have been offered for sale to determine their commercial acceptability. Small fish of 50-150-g have sold satisfactorily. The

retail prices for mojarra amarilla were $38.60 pesos/kg, barbul $47.60/kg, arenca $65.60/kg and lisa $26.00/kg.

The fish markets in Barranquilla and Cartagena were monitored over a year's period (Table 3). The most valuable freshwater fish were bocachico ($92.20 pesos/kg wholesale and $118.77/kg retail) and bagre pintado ($61.42/kg wholesale and $119.17/kg retail). The least expensive fish was mojarra amarill ($17.87/kg wholesale and $35.30/kg retail).

12. On-going studies

Studies have begun at the Repelon station to evaluate 1) the environmental effect of T. nilotica on various native species; 2) the use of various feed stuffs as feed for monosex cultures of T. nilotica; 3) a preliminary evaluation of sardina as a culture fish and the relative values of inorganic and organic fertilizers for T. nilotica production. In addition, studies with native predators to control cichlid reproduction are continuing.

During the project it was possible to evaluate a number of native species under uniform conditions and to select those species that merit additional study Additional work is needed before recommendations should be used in an extension program.

The most promising species were T. nilotica and cachama. T. nilotica have the potential to be used for a variety of culture methods ranging from an extensive predator prey system to a highly intensive monosex system. Cachama are one of the most promising commercial species for tropical climates in the world. Their excellent response to supplemental feeding and resistance to poor water quality favor the use of cachama in intensive aquaculture.

3. Technical Summary - Gigante

The principal responsibility of the Gigante station was the development and immediate application of technological packages in privately owned rural ponds.

The immediate objectives, therefore, centered around the herbivorous cichlid T. rendalli as the primary culture species.

Previous in-country studies had demonstrated that high production of T. rendalli can be obtained through supplementary feeding with fresh leaves of bore (Alocasia macrorhiza). The biological control of excessive T. rendalli reproduction had also been previously substantiated with a native cichlid tucunare.

Although these basic points had been established, factors that complicated the immediate wide-scale implementation of this system were: 1) the number of sites suitable for the growth of bore are limited due to the sandy soil texture and the general aridness of the region; 2) information on the labor and land requirements for bore leaf production was lacking; and 3) the scarcity of fingerlings of C. ocellaris necesitated the evaluation of an alternative and more abundant predator species.

Conscious of the importance of extending only technically and economically proven methods, the initial emphasis was on the prompt solution of these problems. During the first 2.5 years of the project all activities were carried out in privately owned ponds. The labor and financial inputs were largely supplied by the project to minimize possible negative reactions to an unproven technique.

1. Predator studies

The mojarra negra, a native cichlid common in the Upper Magdalena drainage system, was chosen as the most plausible substitute for the tucunare for the biological control of excessive tilapia reproduction. Early observations have indicated that mojarra negra effectively controlled T. mossambica in unmanaged and under-exploited farm ponds.

Subsequent experiments conducted at controlled predator densities equivalent to 1,250, 2,000, and 3,110 mojarra/ha demonstrated the marginal efficiency of this species as a predator in the warmer elevations in the region. Stocking

densities of 3,300 mojarra negra/ha were required to limit T. rendalli reproduction to acceptable levels and, even at this density, the biological control was not always consistent. Further investigation revealed that mojarra negra in combination with tucunare was a very effective control of tilapia reproduction. This was possible when the combination of 357 tucunare and 1071 mojarra negra/ha was used.

In the cooler coffee growing region it was easier to control tilapia reproduction. At average ambient temperatures of 20-21°C the reproductive potential of T. rendalli was apparently depressed to the extent that mojarra negra alone,- at densities of 2,000 per ha, were effective in the control of tilapia reproduction.

Although the above results could not be considered definitive, it was decided that the information accumulated provided reasonable assurance that population control of T. rendalli was practical in ponds throughout the region. Therefore, further efforts were concentrated in other problem areas.

2. Effect of temperature on T. rendalli production

A significant portion of the farm ponds was located in the local coffee growing zone, but all previous literature on the value of bore leaves as a feed for T. rendalli was based on studies conducted in the warm-temperature zone of the country (24-25°C). Therefore field experiments were conducted during a 10-month culture period in the coffee zone where average ambient air temperatur was 20-21°C. Results indicated that 120-g tilapia could be produced, using fresh bore leaves as supplemental feed, and that even with modest feeding rates, net production of 2,000-kg/ha/yr was possible. In comparison with other studies conducted at warmer temperatures, it appeared that at cooler temperatures appetite was depressed but the conversion efficiency was not significantly altered.

Although maximum production potential was not determined, it was concluded that acceptable production levels were feasible in the cooler temperature zone.

3. Production of bore.

Although it had been shown that high fish production could be obtained when bore leaves were used as supplemental feed, the experience of the first year showed that few farmers would produce the quantities of forrage needed. In many cases this was because of the very limited information available on the labor and land requirements to produce bore. Therefore, three separate studies under distinctly different physical conditions were conducted to determine the affects of soil moisture, fertilizer regimes, shade intensity, plant density and cropping technique on bore production. Although additional research is needed to optimize production methods, sufficient information was accumulated to confidently advise prospective farmers on the expected land and labor requirements of the planting, maintenance and cropping of bore under a variety of conditions. In general the tilapia-bore technological package is appropriate at subsistence and small-scale commercial levels. Because it is labor intensive, the promotion of this technique could have socio-economic benefit in more isolated regions suffering from high unemployment.

4. Use of other supplemental feeds.

Although supplemental feeding of T. rendalli with bore leaves was confirmed as technically advisable, the climate and soil conditions were not favorable for bore production at the majority of the [illegible]d sites. Therefore, a preliminary evaluation of more traditional feeds and feed ingredients was conducted. T. rendalli at densities of 20,000 fish/ha were fed one of three experimental feeds (rice millings, a commercial chicken concentrate or a mixture of cottonseed meal and the chicken concentrate) for 200 days.

Growth was generally slow (0.30-0.35 g/day) and feed conversions deteriorated after fish reached average weights of 65 g. Nevertheless, these final weights are acceptable. A total of 1,260 kg of fish/ha were obtained in 100 and 150 days for chicken concentrate and rice millings diets, respectively. An economic evaluation suggested that chicken concentrate and rice milling diets would be marginally acceptable in small existing ponds at the subsistence level since the total production costs (fingerlings, feed, equipment, and labor) were competitive with the retail price of beef. On a commercial scale where a pond was constructed specifically for fish culture, the production costs were greater than the wholesale price of beef.

Although the above-mentioned results were not very encouraging, the management method could be adopted by the government as part of a short-term program to improve conditions for the rural poor. However, to assure an attractive economic return, a government subsidy in the form of larger fingerlings was considered appropriate. At the Gigante research station it was shown that adequate numbers (at least 300,000-350,000/ha/yr) of T. rendalli fingerlings could be produced with supplementary feeding with a commercial chicken concentrate, at a feed cost of less than $0.50 pesos/20-g fingerling.

5. Less intensive management systems.

The majority of existing ponds in the region were constructed for cattle watering or irrigation. Because there was no tradition of fish culture among the people, only the most innovative land owners were willing to invest scarce resources in an intensive management system. Therefore, for most pond owners, the development of less intensive techniques of aquaculture was necessary.

In five ponds stocked at a density of approximately 5,000 T. rendalli/ha and chemically fertilized every 3 weeks with 10-30-10 at a rate of 30 kg/ha, net fish production was 246-kg/ha in 4 months. Seventeen percent of the production

consisted of uncontrolled reproduction (these ponds were simultaneously used to determine optimum predator densities). The slow growth rate of only 9.5-g/mo indicated the stocking density was near the maximum recommendable for this management practice. At present the costs of this rather modest fertilization regime represents an investment of approximately $3,000 pesos for fertilizer for the production of 246-kg of fish. Stomach analyses indicated that T. rendalli did not feed directly on plankton resulting from fertilization. In another study more intensive fertilization (50-kg/ha/wk) increased T. rendalli production only 33% therefore, it was decided that until further experimentation indicated the contrary it was advisable to suspend the use of chemical fertilization in ponds located in pastures or receiving runoff from fertilized crops.

Two studies indicated that dried chicken manure administered two or three times weekly at a total rate of 1,500-1,500 kg/ha/mon increased T. rendalli production by 40 to 42%. Although production was only 410 kg/ha in 160 days, organic fertilizers, where available, are an alternative for low intensity culture of this species.

6. Studies with other species

With the exception of the limited number of sites where soil conditions and land use preferences of the pond owner would permit adequate production of bore leaves, the culture of T. rendalli seemed to be economically justified only in low-input management practices where pond construction costs were not attributable to fish culture alone. These results increased justification for the introduction of T. nilotica and cachama that arrived at the Alto Magdalena Station in September 1979. Studies were imediately begun to compare the relative value of the two tilapias.

A polyculture of T. rendalli and T. nilotica each stocked at 2000 fish/ha, confirmed that fertilizers stimulate the growth of T. rendalli to a much lesser

extent than for T. nilotica. Chemical and organic fertilization increased the production of T. rendalli by only 33 and 40%, while the production response of T. nilotica was an increase of 79 and 66%, respectively, after 100 days. T. rendalli attained average weights of only 37-40 g in the fertilized ponds, while T. nilotica, under identical conditions, reached final average weights of 107-1 118 g. An analysis of the stomach content showed that T. rendalli, in contrast to T. nilotica, consumed little phytoplankton but relatively larger amounts of fibrous vascular plants. The principle food competition between the two species was for filamentous algae but differences in their general feeding selectivity were distinct enough to suggest possible advantages in the polyculture of the two species. The stomach contents of both tilapias indicated that, in association with insectivorous native fishes (Petenia umbrifera and Pimelodus), the tilapias consumed few insects.

Another preliminary comparison between the two species demonstrated that T. nilotica also accepted fresh bore leaves as a supplementary feed. In this trial both species were offered the forrage ad libitum. T. rendalli daily consumed up to 27% of its body weight and T. nilotica ingested a maximum of 26% daily. The production levels (8-9-kg/ha/day) and conversion efficiencies for T. nilotica and T. rendalli in this experiment justify subsequent detailed studies on the feeding of T. nilotica with fresh bore leaves.

Although T. nilotica is significantly less susceptible to capture than T. rendalli, other qualities, including its larger size at sexual maturity, emphasize the importance of a rapid and effective evaluation of T. nilotica's possible ecological impact on the native capture fisheries.

A strong indication that T. nilotica would not have significant negative ecological impact in the Upper Magdalena area was obtained during the first month of the project. An evaluation of the fish community structure in little

exploited farm ponds in the Gigante area demonstrated the native mojarra negra effectively controls the recruitment of T. mossambica, and in the long run, virtually displaces this tilapia as well as another introduced species, Cyprinus carpio.

7. Economic data

Efforts were focused on the evaluation of T. rendalli as the primary species in a rural aquacultural program. Certain economic aspects governing fish culture potential on a limited commercial scale were also considered.

The sale of fish and red meat was monitored in the local market from April 1978 to August 1979. Although fish constituted less than 2% of total sales volume, the relative price stability, in spite of great seasonal fluctuations in abundance, suggests that the market is not saturated. During at least 10 months of the year fish can be sold at prices slightly below (5-10%) the retail price of beef. Tilapia are presently being grown at the research station for marketing studies to evaluate the impact of price and size on the local market saturation.

During the last months of the project, a native catfish, Rhamdia was successfully reproduced by low dosage injections of HCG. Colossoma and other native species are being collected for future research on fingerling production and their value in a fish-culture system.

Although the lack of an established tradition in aquaculture is a cultural factor that will affect the rate of aquacultural development in this region, the excellent research facilities, the professional level of training of its staff, and the proven potential of the newly introduced fish species are promising elements in the future of fish culture. However, for fish culture to reach its potential the government needs to continue to furnish the physical and financial support needed until aquaculture becomes culturally accepted as a profitable agricultural activity.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. Recommendations on Administrative and Organization Aspects

Auburn University was contracted to provide technical assistance in the development of Colombian aquaculture. Therefore our principal recommendations are of a technical nature. Nevertheless the technical success of a program is dependent on the organizational infrastructure and general administrative support available. Therefore, the following specific observations and recommendations are offered.

1. Financial support for research stations

One of the major problems that has plagued the project has been insufficient funds available in the field. The budgets generally have been adequate but various administrative delays have greatly restricted the cash flow to the stations. Several changes in the administrative procedures were attempted but none adequately solved the problem.

Excellent facilities have been developed as a part of this project but have been underutilized because of financial problems. These problems will become more severe as the need to expand the programs at the station increases. Several promising species for aquaculture have been identified, but cannot be brought to their potential unless adequate funding is available to support necessary research. Further financial constrictions will also occur as the need to increase extension efforts increases. One possible solution is to give the stations more administrative freedom, thus helping to reduce the steps in the administrative process of supporting the stations. This possibility has been discussed with the Director of INDERENA, and the first steps toward the greater administrative independence of the stations have been taken.

2. Training

As mentioned in the earlier discussion on training, continued training at all levels is needed. It is very important for those who have been trained to

receive adequate incentive to remain in the field. This means not only adequate salaries, but also the necessary logistical support to conduct work programs.

Efforts should be made to coordinate training of new personnel in accord with the growth of aquaculture and the governmental capacity to provide logistical support needed for any additional biologists.

3. Construction

Construction must be completed at the two research stations in order that each component of the facilities be utilized to its maximum. This is particularly true at the Repelon Station where the main laboratory-office-living quarters complex was not completed at the end of this project. If this building is not completed and suitable living and working conditions insured, the station will be so under-utilized that previous investments will have been unjustified.

No additional construction at these sites is recommended until it has been clearly demonstrated that the economic and logistic support of the existing stations will be provided. However, it is suggested that INDERENA acquire adjoining land at the Repelon Station to permit possible future expansion.

Although additional aquaculture facilities at other sites will be desirable from a technical point of view, the greatest concern at present is the financial support of these facilities. Therefore, no new construction is recommended for the near future. Existing financial resources should be channelled into the maximum utilization of the existing facilities in the country.

B. General Technical Conclusions and Recommendations

1. Minimum management systems

One of the research areas that should receive higher priority in the immediate future is the development of minimum management systems based on simple predator-prey combinations of species that spawn naturally in ponds.

Such a system would help to meet the short-term demands for an extension package while introducing the pond owner to the basic concepts of aquaculture. The simplicity of the method would allow it to be incorporated by a greater number of pond owners who, for lack of confidence or present pond use, do not now accept more intensive management practices. Because it is a minimum-input system, the agencies involved in extension could better provide the logistical support needed.

In a predator-prey system the basic idea is to stock as prey, a highly productive species that reproduces in the pond. A predator is added to prevent overpopulation and stunting of the prey species. To establish such a system studies are needed on the selection of both predator and prey species, the calculation of correct stocking ratios and inital weights, and on the rates and techniques of exploitation required to effectively crop the population without adversely affecting the population structure. In addition, it is important to establish the time period the system would remain productive and balanced.

After the pond owner's initial introduction to fish culture through a minimum input predator-prey system, many farmers will be interested in greater yields. This may be possible by the addition of fertilizers or feeds, or by the incorporation of other fish species into non-competitive niches. Subsequent studies are therefore needed to evaluate these techniques to intensify the culture once the basic predator-prey system has been successfuly established.

Minimum management systems are recommended because they would put a large number of unexploited ponds into fish production but the benefits will be restricted to rural areas. To increase fish availabilty in urban areas intensive commercial fish culture will be needed.

2. Simultaneous development of small and medium scale commercial aquaculture

In both the United States and Colombia the governments have stressed their commitment toward improving the quality of life in the poorest sectors of the population. Although some programs can be oriented directly toward the target

sector, the development of new agricultural techniques often cannot make significant impact at the subsistence level until they have been accepted at some commercial scale for the following reasons:

(1) The very scarce resources of the poor will normally not be invested in techniques yet unproven at the producer level.

(2) Psychologically, few land owners are willing to make monetary investment in practices that do not give proven monetary returns.

(3) A commercailly successful enterprise is perhaps the strongest incentive to initiate a project on a smaller scale.

These considerations, and the unfortunate fact that the poorest sector does not own any land, justify the recommendation to emphasize the development of aquaculture techniques applicable at the medium-scale commercial level. Once a few successful examples exist in the country, the smaller farmers will be more inclined to accept and invest in similar management techniques. In addition the volume of fish produced by commercial operations will make marketing in the larger cities feasible, thus making fish available to the urban poor. Operators of commercial enterprises are also traditionally more vocal than the owners of subsistance level activities. As a result, they play a very positive role in orienting government support and research toward the solution of the most pressing problems.

3. Market studies

One of the fundamental requirements for a commercial aquaculture system is that it be economically sound. It is thus necessary to have economic data on production costs and market value of the product. Species which are not traditionally found in the market must be experimentally introduced to know their potential supply and demand characteristics and to evaluate their impact on substitute products. In the last year of the project a special consultant (Dr. L.

W. McCoy) suggested an experimental design to obtain the needed economic data on the retail and wholesale value of the cultured species, the acceptability of various sizes of fish, and the relative demand. Also included in his recommendations was the determination of the socio-economic and nutritional impact of farm-raised fish on the townspeople.

If properly conducted this study will furnish essential information needed for the economic evaluation of various technological packages tested at the research stations and will provide some basic information to evaluate the socia implications of aquaculture in Colombia.

It is therefore very important that all efforts be given to facilitate this study so that all the necessary information can be collected in a statistically proper manner. The needed support would not only include financial and staff requirements but also administrative modification of regulations governing sale of fish by INDERENA personnel.

4. Intensification of research in cool temperature aquaculture.

The greatest fraction of the rural population in Colombia is located at or near the cool coffee growing belt between 1400 and 1800 meters msl where average ambient temperatures are generally between 18 and 22°C. Nevertheless, the fish culture practices applied in this region were, or will be, generated in warmer climates characteristic of the lower elevations. Since the cool temperature range is reportedly near the minimum acceptable for good growth of tilapia, a program of controlled investigation in selected private ponds within the coffee belt is recommended to compare the effect of temperature on the production of *T. rendalli*, *T. nilotica*, *Brycon henni* and *Cyprinus carpio*. A description of the suggested experimental design is detailed in a later section of this report.

5. Integration of aquaculture with other farming activities.

Rural aquaculture development should be closely integrated as far as possible with other farm activities. A good example is swine farming where the manure is added directly to the fishpond and the enriched water is used for crop

irrigation. This close integration generally permits a more efficient use of available resources, as well as increases productivity.

Commercial production of tilapia and pigs may be a feasible system in some parts of Colombia. However, in many parts of the country geographic isolation may prevent commercialization of any excess production. Under these conditions, a mixed culture of tilapia without a predator may provide a landowner with all the fish needed for his family and the excess small fish can be used as a feed supplement for the swine. Although the biological and economic aspects of such an integrated system may be highly favorable, it could adversely affect the social acceptability of tilapia for human consumption. This aspect should be evaluated before this package is extended.

Integrated systems imply other problems such as the special care required in the use of disinfectants and pesticides and the possible problems of social acceptability of a fish produced in manured ponds. Nevertheless, the increasing costs of the inputs make the integrated systems economically attractive in the short run and possibly essential in the long run. At present they are most appropriate at subsistance and small scale commercial levels.

6. Increased emphasis on fishery management of reservoirs

Several large reservoirs exist within the country and the construction of others is planned. It is generally accepted that these reservoirs are undermanaged as a fishery resource. Reservoir management programs have been impractical when based on periodic stocking of fish species that are unable to complete their life cycle in the existing conditions of the reservoir. Efforts are normally made to establish a dynamic self-perpetuating fish community whose species composition is based on the physical conditions and natural productivity of that body of water. The intelligent planning for optimum species composition requires careful study of existing conditions, which implies significant financial and

technical support. Although it is generally accepted in Colombia that the reservoirs should be more intensively managed as a fishery resource, the biologists assigned to these projects have not received the support needed to achieve their objectives. It is suggested that international financing be specifically requested to evaluate and manage the fishery potential of existing and planned reservoirs.

7. Watershed Management

One area in which aquaculture can play a part is the restoration of watersheds. In many areas of Colombia there are very distinct rainy and dry seasons. Many small streams cease to flow and small ponds dry up during the dry season. Agricultural practices have denuded much of the land thus contributing further to the water shortage. During the rainy season much of the rainfall is lost because of the absence of adequate vegetative cover to retain it, and accelerated soil erosion.

This water can be stored through the construction of 5-10-ha reservoirs along with smaller water storage ponds higher in the watershed. This should be complemented with a reforestation program. These reservoirs and ponds would help reduce the soil erosion, raise the ground water level as well as provide sites for fish culture. This would be a long range program with long-term benefits for the community as well as the private land owners. By restoring the watersheds it would make water readily available year-round to many small rural towns permiting soil conservation, irrigation projects and improved nutrition through increased fish consumption, as well as to help relieve other problems such as lack of firewood through reforestation. Because of high construction costs it is suggested that private landowners be given an incentive to participate in the program, either in the form of a direct subsidy or low interest loans and technical assistance.

8. Colombian Aquaculture Development Plan.

This project was only one stage in the development of aquaculture in Colombia. To continue its development many aspects must be taken into consideration and a rational development plan must be followed. There are many agencies and institutions involved in aquacultural development. If their resources and effort can be guided as a part of a national development plan, it will greatly speed the development of Colombian aquaculture. Such a plan should include establishing the needs and priorities for investigation, extension, training and identifying the agencies involved and the resources to be made available. As requested by INDERENA, Auburn University prepared and presented document entitled Proposed Plan for Aquaculture Development in Colombia. INDERENA has begun an evaluation of these suggestions and others offered by other agencies within the country. It is recommended that the evaluation be completed and that the Aquaculture Development Plan be formalized.

C. Specific Technical Conclusions and Recommendations

1. Suggested primary species for intensive aquaculture

It is important for rapid development of aquaculture that available resources be concentrated on the study of only a few species. It is too easy to dilute the value of a research program by working with a large number of species which utilize pond space and other resources. Several species have been identified as having potential as a primary culture species in Colombia. Research efforts should be concentrated on these species.

a. Cachama.

The cachama are very promising commercial species giving a net production of 4,112-kg/ha in 6 months when fed a pelleted feed.

The limited number of cachama available for study will be a severe restriction in the rapid development of management procedures for this species. In Bra-

Brazil it was found that it took three or more years for the species to mature in ponds. Future broodstock are presently available at both the Repelon and Gigante Stations, but it is important that cachama fingerlings continue to be available during the next 3 years so that new management procedures can be evaluated and that various age broodstock be available for the future.

One alternative for obtaining fingerlings may be the in-situ reproduction of wild adults as was shown to be feasible in 1979. It is suggested that this procedure be further investigated. Fingerlings can also be purchased from ornamental fish collectors. This alternative also should be pursued to save valuable time while waiting on the 1979 stock to mature.

If sufficient fingerlings are obtained during the next 3 years, several studies are suggested. Priority should be given to (1) environmental effects of the species, (2) optimum diets for its culture and (3) appropriate stocking densities.

Hopefully by the time the broodstock are mature, techniques will be established for larval rearing and fingerling culture of other characids that may be applicable to the cachama.

b. Tilapia nilotica

Results obtained during the last months of the project demonstrate the potential value of this species in Colombian aquaculture development. Its feeding habits, tolerance to low water quality conditions and reproductive behavior make it desirable for simple management systems as well as for intensive aquaculture. An analysis of the history of T. mossambica in the country suggests that T. nilotica would not produce an adverse ecological impact on the catch fisheries. Because of its demonstrated qualitites as a culture species and because of the high probability of no adverse ecological impact, research on intensive management systems and predator-prey relationships should be given high priority, so

concrete technological packages will be available for extension if this species is approved for distribution. The following specific recommendations are given:

i. predator-prey systems

Historically, population control of tilapia has been the greatest single research need with this group of fish. In Colombia predator-prey combinations should be verified or developed. Successful systems would be suitable for extensive and intensive managment and also would provide evidence concerning the probable ecological impact of this introduced species.

Effective predator-prey relationships should be established for various levels of management. Such factors as fish density and pond fertility should be considered. Predator-prey systems should be compared to monosex production systems in terms of production levels and ease of management.

ii. monosex culture

Evaluation of monosex cultures should include comparison of the efficiency and practical applicability of the following techniques: hand sexing, massive rearing of uniform size fry to size where separation of sexes is possible with graders, and massive chemical sex reversal. A long range program of utilizing sex-reversed individuals as broodstock in the production of monosex offspring should be initiated. In 1-year the success of the monosex production programs should be reviewed, and the desirability of the T. hornorum x T. nilotica all-male hybrid should be reevaluated. The monosex individuals obtained in the above mentioned investigations should be utilized in the following production studies.

The relative biological and economic merits of intensive fertilization (chemical as well as organic) in comparison with dry feeds (in pelleted as well as meal form) should receive highest priority in production studies. The need to make other direct comparisons with T. rendalli was previously discussed. The effect of temperature on the growth of T. nilotica should also be considered;

the suggested experimental design is detailed in the section on sabaleta *Brycon henni*.

iii. minimum management systems

T. nilotica has great potential as the primary species in minimum management polyculture systems where intensive culture is impractical or undesirable to the pond owner. Where large experimental ponds are available, studies aimed at determining optimum stocking densities and species composition should be conducted. The choice of species should be based on its ability to complete its life cycle in ponds and to take advantage of unexploited niches. Methods and rates of harvest should be established for harvesting the production without adversely affecting the species interaction.

c. *Tilapia rendalli*

All comparative studies to date indicate that *T. nilotica* may completely displace *T. rendalli* as a principle culture species provided negative ecological impact on native species is not demonstrated. Therefore, investigation efforts with *T. rendalli* should be restricted to those management practices which could be applied immediately to the private sector. The high probability that this species will eventually be replaced by others as a primary culture species makes investigation on the solution of long-range problems impractical. Emphasis is suggested in the following areas:

(1) Determination of whether or not *T. rendalli* requires dry feeds in pelleted form. If economical growth rates and conversion efficiencies are possible with diets in meal form, then other agricultural by-products should be evaluated. If, however, a pelleted feed is required (as is the case with dorada), further feeding studies with dry feeds should be limited to commercially available pelleted feeds.

(2) Studies on the culture of T. rendalli, using fresh bore leaves as a supplementary feed, have shown that this practice is biologically and economically sound where climatic conditions permit high production levels of the plant. However, because of soil conditions and low rainfall in many parts of Colombia, the tilapia-bore combination has limited application. The economic evaluation of other forrage crops as a supplemental feed should be continued. Plant species which grow under less humid conditions than bore should be emphasized.

(3) The advantages of a polyculture of both tilapia species should be evaluated, and comparative studies under fertilizer and feeding practices should be emphasized. This is important so that, if T. nilotica is approved for distribution, the information will be available to decide whether T. rendalli should be included in extension packages.

(4) Monosex culture of T. rendalli should be investigated to determine its value as a primary culture species and also as a secondary species for weed control in the intensive culture of other fish species. Initial efforts should be placed on hand sexing and the evaluation of high density rearing of uniform size fry to a size where mechanical separation of sexes with graders is practical.

Available literature suggests chemical sex reversal of T. rendalli would be difficult. However, since this study would utilize little of the research facilities, it should be evaluated on a small-scale experimental level.

Because of the slow growth rate and the possibility of reproduction due to less than 100% monosex stocking and wild-fish contamination, all extension programs of T. rendalli "monosex" culture should include an effective predator.

(5) The culture of T. rendalli in the cool coffee belt is based on research information produced at warmer elevations. An in-depth study of the effect of temperature on the production of T. rendalli is required. The evaluation should

also include other fish species. The suggested experimental design is described under specific recommendations for the sabaleta (Brycon henni).

d. Dorada

The excellent response by dorada to a pelletized feed justifies further research with this species. Although cachama gave twice the production of dorada under similar conditions, dorada may have several advantages over cachama that need to be investigated: cachama is not native to the Magdalena river system and its environmental hazard is not known, while dorada is native to the Magdalena; secondly, although the methods for reproduction of cachama or dorada are not yet established in Colombia, dorada may have some advantages such as it matures at a smaller size, thus facilitating the handling of the broodstock. Another benefit is that because of certain similarities between the two species, technology developed for dorada may be directly applicable to cachama.

First priority with dorada should be reproduction of the species, including spawning procedures and larval culture methods. When fingerlings are available, studies to determine optimum diets and appropriate stocking densities will be needed.

e. Barbul

This species may have possibilities as a primary culture species under conditions where fingerlings and organic fertilizer are available at minimum costs. It may be possible to increase production through the use of a pelleted feed but the economic practicality is not proven.

A major limitation may be the reproduction of this species, as mature fish from ponds have not been observed. If fingerling production problems are solved, but it is not economically practical to use a pelleted feed, consideration should be given to using barbul as a secondary species in a polyculture with any of the earlier mentioned species.

2. Suggested secondary species for polyculture systems

Several species were studied during the project, but many were unsuitable as primary culture species due to their slow growth or other native characteristics. Although not acceptable as primary species some of them may be useful as secondary species to utilize the diverse niches in an aquaculture system.

a. Predators

An essential factor in an effective predator-prey system is a predator that effectively controls the reproduction of the prey without seriously competing with the prey for food. It is believed that predator-prey systems with tilapia will be an important method in Colombia especially during the early fases of aquacultural development.

i. Tucunare.

This species has been shown to be an effective predator for T. rendalli and in other countries has been successfully used to control T. nilotica. Priority should be given to development of methods to mass produce fingerlings, since the shortage of predator fingerlings is often a major constraint in the foment of a predator-prey fish culture system. The lack of sufficient tucunare fingerlings was a chronic problem at Gigante throughout the project.

Tucunare exist on the North Coast and has been introduced on several occasions to the Repelon Station but a gradual mortality of the stocks has prevented it from being evaluated. The cause of this mortality should be established.

As this species will be used in minimum mangement systems, research efforts should be aimed at establishing minimum stocking rates required to control the excess reproduction of the primary species. Optimum effective densities should also be determined when tucunare is stocked in combination with other less efficient but more productive predators.

ii. Mojarra negra

The slow growth of this species eliminated it as a promising primary fish for culture but efforts should be continued to define its usefulness as a predator. Research at Gigante has shown that in warm climates (24-25°C) mojarra negra alone was not highly effective in the control of T. rendalli reproduction, but that at cooler climates (20-21°C) it was effective. If the culture period was over 6 months in the warmer climates, the mojarra population became stunted. When used in combination with of tucunare at low density (<400-ha), there was reproduction control of both the tilapia and the mojarra.

Studies should be conducted to determine the minimum stocking density of mojarra negra, alone or in combination with tucunare needed to control T. nilotica. Optimum stocking rates should be established for different temperature regimes and various intensities of management.

iii. Mojarra amarilla

Although the mojarra amarilla was the most productive of the native species tested in the preliminary evaluation, its slow growth and tendency to reproduce at small size eliminated it as a highly promising primary species. It may have some value as a predator if its reproduction can be controlled by another predator or by use of monosex populations.

The ability of mojarra amarilla to tolerate very low oxygen conditions makes it desirable in for use in association with T. nilotica that are also very tolerant to low oxygen. Therefore, the practicality of monosex mojarra amarilla for control of tilapia reproduction in intensive production systems should be evaluated. Experience has shown separation of the sexes based on external morphological differences is relatively easy. Studies determining minimum effective stocking rates, natural mortality rates and the maximum allowable culture period should be emphasized.

Mojarra amarilla may be most useful in combination with another predator to control tilapia in intensive and minimum management systems. Although mojarra amarilla may be a productive secondary species and an effective control over tilapia, another predator would have to be used to control mojarra production.

iv. Moncholo

This species has been studied as a predator in this project and in others with inconclusive results. During the project moncholo showed some control of mojarra amarilla and T. rendalli but was not completely effective. Additional studies are needed to determine moncholo's suitability as a predator.

v. Agujeta

Little work has been done with this species to establish its effectiveness as a predator. Preliminary studies indicated that it achieved partial control over mojarra amarilla reproduction. This fish does not reach a commercially acceptable size; this factor may reduce the problem of excessive harvest of the predator species which commonly allows the uncontrolled reproduction of the prey species.

b. Low trophic level secondary species

Several species were studied during the project whose food habits are low in the food chain. They were found unsuitable for intensive aquaculture because of their poor response to intensive management but they may serve as secondary species in a polyculture. These species should be given a low priority and studies begun only after the culture procedures for the principal species are established.

i. Bocachico

Density is a severe limiting factor in bocachico culture. Although growth at high denisities was slow, at low densities the growth rate was rapid. It is relatively resistant to handling and low oxygen and has high market acceptability.

This species should be given first priority over other native species that might be included as a secondary species in a polyculture.

Bocachico can be induced to spawn using several methods but additional work is needed in fry and fingerling production. Studies will be needed to determine stocking rates for its use as a secondary species.

ii. Lisa

This species is not suitable for intensive culture due to its slow growth at high densities and its susceptability to handling and low oxygen. Although the growth rate is acceptable at densities of 1 fish/10 m^2, its low resistance to handling and reduced oxygen levels make it of questionable value even as a secondary species in highly intensified management. It may be used in less intensified systems where bocachico fingerlings are not available.

iii. Arenca

The lack of response by arenca to more intensive management practices combined with poor resistance to handling make it of questionable value even as a secondary species in polyculture.

3. Other species not evaluated

Due to lack of experimental facilities or insufficient number of fingerlings, several species previously considered as potential candidates in the development of Colombia aquaculture were not evaluated during this project. Although observations were made on some of these species, the possible role in aquaculture has yet to be defined. The following recommendations are offered or this group.

a. Sabaleta *Bryconhenni*

This characid is normally found in cool waters and has long been suggested as a fish for aquaculture in the cool coffee zone of Colombia. Another fish of the same genus *B. moorei* has culture potential when offered a supplemental feed.

Although sabaleta apparently do not normally reproduce in ponds, mature wild fish have been artificially spawned, and during this project several adults responded to synthetic hormone injections.

A limited number of broodfish are available at the Alto Magdalena Research Station; it is recommended that this number be increased to a minimum of 100. Until these fish reach sexual maturity it is suggested that personnel be trained to spawn these fish and that artificial reproduction be attempted at the DRI San Carlos Station and/or the new DRI Station in the Department of Cauca.

When the fingerlings are available it is strongly recommended that they be utilized to determine the effect of temperature on production levels, and these results be compared to those obtained with Cyprinus carpio, Tilapia rendalli and T. nilotica. The basic objective is to determine the most appropriate species fo. the cool coffee growing region.

The following experimental design is suggested: total number of ponds, 12 (4 at an elevation of 900-1,000 m, 4 at 1,400-1,500 m and 4 at 1,600-1,700 m); fish density 5,000/ha; organic fertilization at 700 kg/ha every 2-weeks; duration of experiment 4 months. To reduce the effects of between-pond variation, each pond should eventually receive all four treatments (fish species). It will be necessary to use privately owned ponds and great care should be taken in the selection of these ponds. This study should be carried out in the Gigante area, and the ponds should be actively managed by the station personnel.

A subsequent study using supplemental pelleted feed should be conducted at the research station with the four species since daily feeding at the private ponds is logistically impractical.

b. Mirror carp

This introduced species has long been present in Colombia and is widely distributed in private ponds. Observations on its possible ecological impact range from synergistic to competitive with native fish, but overall evidence is not conclusive. In-depth ecological studies probably will be delayed until

production studies have demonstrated it is the most appropriate culture species under certain conditions. It is possible that carp are desirable in the upper coffee zones where the average temperatures are below the optimum temperatures for tilapias. A comparative study under various temperature regimes was suggested for carp, sabaleta, T. rendalli and T. nilotica to determine which of these species is most appropriate in the coffee zone. It was recommended that this study be conducted in Gigante since the carp is already distributed in the area and since mojarra negra has been shown to effectively control carp recruitment. The suggested experimental design was described in detail under the previous section on sabaleta.

If results indicate carp is the most appropriate species for the cool coffee zone, the ecological studies should be emphasized to determine if this technological package is recommendable for other similar zones in the country.

c. Cuatro ojos

Production experiments were not conducted during the project with this species. However it was observed that its growth at low densities was rapid and it readily accepted a pelleted feed under aquarium conditions. Induced spawning of this species has been possible using hormones. This species should be evaluated as a potential culture species when an adequate supply of fingerlings is available.

d. Guabina, or bagre baboso

This species, like many catfish, is highly accepted because of the absence of intramuscular bones. Previous experiments had been conducted in Colombia both under conditions of fertilization and of feeding. The results were not highly promising but this fish may have potential as a secondary species in a polyculture system. The guabina was successfully reproduced with low dosage injections of artificial hormones, but fry-rearing techniques need to be perfected.

Because of limited research facilities it is recommended that experimental production studies be postponed until productive and economically acceptable technological packages have been developed for the more promising species.

e. Doncella

This catfish has a favorable body conformation and reportedly may reproduce in ponds. Although it has good flavor and texture qualities, it receives a relatively low retail price in the markets of the North Coast. The most serious disadvantage of this species is its extremely low tolerance to transport and handling. Limited research facilities should be used to determine if it will accept a pelleted feed and if it will reproduce naturally in ponds. Since doncella completes its life cycle in Prado Reservoir in the Department of Tolima, it may have potential in reservoir management and in minimum management systems.

f. Pacora

This species has good consumer acceptance because of its delicate flavor, and it reproduces naturally in ponds. A preliminary evaluation of this species was not possible because of its extreme intolerance to handling, but production studies carried out in Brazil were discouraging. Studies at Repelon have shown that it was not an effective predator for mojarra amarilla. This fish may have some potential in reservoir management or in minimum management systems but for the immediate future very little research should be conducted on this species.

g. Bagre

Both of these bagres receive a high market price. Under natural conditions these species are carnivorous but the acceptibility of a pelleted feed by these animals under culture conditions is unknown. Large numbers of fingerlings are generally not available from the wild nor have adults matured in ponds. If sufficient number of fingerlings become available the acceptability of pelleted feeds should be evaluated.

h. Ornamental and food fish of the Llanos

Research efforts should be concentrated on the most promising food fish presently available at the research stations. However because of the diversity of the fish fauna of the Llanos it is recommended that the fishery biologists assigned to that region make observations on the feeding habits and reproduction behavior of potential culture species.

Undoubtedly many valuable ornamental species can be profitably cultured under pond conditions. It is recommended that the development of the appropriate technology be carried out with financial and technological support from private enterprise.

i. Macrobrachium rosenbergii

This species has recently been introduced into Colombia. Although to date its culture has not been economically feasible in many parts of the world, great worldwide efforts are being made to develop appropriate technology. Because of the limited research facilities in Colombia and the urgency to develop culture techniques for non-luxury species, it is recommended that only limited research be dedicated to the evaluation of production methods for this species. However, stocks need to be developed and maintained so that when economically sound culture methods are developed in other parts of the world, these proven techniques can be evaluated for their commercial feasibility under Colombian conditions.

Table 1. Preliminary evaluation of various species of fish under three different conditions: natural conditions (T_1); addition of organic fertilizer (T_2) and; addition of fertilizer and feed (T_3).

		Net Production (kg/ha/6 mon)	Average Weight (g)	% Mortality
Bocachico	T_1	155*	48	3.1
	T_2	181	58	6.5
	T_3	264	68	19.5
Barbul	T_1	118	45	3.0
	T_2	214	82	8.0
	T_3	266	99	8.6
Mojarra amarilla	T_1	301**	45	25.0
	T_2	616**	54	15.7
	T_3	683**	80	16.2
Mojarra negra	T_1	32	29	31.4
	T_2	60	32	38.8
	T_3	60	51	43.3
Arenca	T_1	39	58	88.7
	T_2	23	65	88.9
	T_3	70	57	61.4
Dorada	T_1	59	48	28.6
	T_2	64	72	39.5
	T_3	149	98	32.8
Lisa	T_1	103	100	67.6
	T_2	114	177	80.0
	T_3	70	133	83.2
Tilapia rendalli	T_1	104**	74	59.9
	T_2	327**	122	56.5
	T_3	372**	135	64.4
Tilapia nilotica	T_1	439**	52	51.0
	T_2	948**	76	52.7
	T_3	1,192**	73	43.1

* 7 month culture
** adults and fingerlings

Table 2. Culture of Mojarra amarilla (*Petenia kraussii*) at densities of 1 fish/3 m^2 in ponds fertilized with chicken litter at a rate of 2500 kg/ha/mon.

mojarra amarilla	both sexes	both sexes	both sexes	both sexes	both sexes	all male
Predator	pacora	monchalo	agujeta	mojarra negra	none	none
Final predator density	1/22 m^2	1/16 m^2	1/18.2 m^2	1/36.36 m^2	---	---
Average gain/adult mojarra amarilla	59. g	56 g	35 g	35 g	50 g	48 g
% survival adult mojarra amarilla	51	43	73	70	83	77
No. mojarra amarilla fingerlings/m^2 at harvest	12.9/m^2	3.3/m^2	4.14/m^2	10.41	13.7/m^2	0
Average weight of fingerlings harvested	2.6 g	3.0 g	2.3 g	5.5	3.4 g	0
Net production of mojarra amarilla (kg/ha)	100.85	99.5	86.92	55.84	136.45	118.9
Fingerlings	647.16	188.62	106.33	478.26	469.05	0
TOTAL	748.10	288.12	193.25	534.15	605.50	118.9

Table 3. Production of barbul *Pimelodus clarias* at four different densities in organically fertilized ponds.

	D_1 2 fish/m^2	D_2 1 fish/m^2	D_3 1 fish/$2m^2$	D_4 1 fish/$3m^2$	Preliminary evaluation 1 fish/$3m^2$
Initial mean weight (gr)	11	11	11	11	12
Final mean weight (gr)	32	69	77	67	82
Total production (kg/ha/6 mos)	449	601	353	113	234
Net production (kg/ha/6 mos)	224	491	298	76	214
Mortality (%)	39	13	8	49	8

Table 4. Average prices (pesos/kg) in the markets of Barranquilla and Cartagena 1979.

	Wholesale			Retail			
	Barranquilla	Cartagena	mean	Barranquilla	Cartagena	Mean	% markup
Bocachico	85.27	95.74	90.51	112.87	124.87	118.77	31
Arenca	26.00	26.69	26.35	36.17	47.63	41.90	59
Bagre pintado	66.03	56.80	61.42	110.91	127.43	119.17	94
Lisa fresh	43.89	25.80	34.84	55.50	55.07	55.28	59
Lisa salted	33.20	---	33.20	47.10	---	47.10	42
Pacora	46.93	43.10	45.02	85.02	66.74	75.97	69
Cuatrojos	---	79.08	79.08	---	108.70	108.70	37
Mojarra amarilla	---	17.87	17.87	---	35.30	35.30	98
Doncella	46.50	39.93	43.04	73.00	60.93	66.97	56
Barbul	---	27.50	27.50	---	82.50	82.50	200
Blanquillo	61.33	64.17	62.75	101.66	101.66	101.66	62
Sardina	---	37.50	37.50	---	62.50	62.50	67
means	53.70	50.32	46.59	77.80	73.04	73.85	67