Commercial Fish Farming Project in Nigeria

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COVER PHOTO. Net of harvestable fish grown in production ponds at Bendel Tiffany Farms being prepared for market.

Commercial Fish Farming Project in Nigeria

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INTRODUCTION

THE MINISTRY OF AGRICULTURE AND NATURAL RESOURCES of Nigeria's Bendel State (formerly Mid-West State) contracted Tiffany Industries Americas Corporation (a subsidiary of Tiffany Industries, Inc., St. Louis, Missouri) to develop and manage a large-scale mechanized row crop farm and a commercial fish farm. Subsequently, the International Center for Aquaculture (ICA) at Auburn University was subcontracted by Tiffany Industries Americas Corporation to develop and manage the commercial fish farm component, which became known as "Aviara Fish Farm" of "Bendel Tiffany Farms." The term of the contract with ICA was April 1, 1974, to December 31, 1979.

Malcolm C. Johnson, ICA Associate Professor of Fisheries, was assigned project leader. He, along with specialists in land development and agriculture, traveled to Nigeria on June 19, 1974, to make preliminary evaluations of potential sites from which the final farm sites would be selected.

The project leader returned to ICA in July 1974 to outline a commercial fish production project plan. This included project design, specifications and sources of commodities, and budget preparation. The planning results are reported in detail in "Development of a Commercial Fish Farm in Mid-Western State, Nigeria", a 1975 publication by Johnson.

Additional complementary information may be found in the following internal ICA reports: "Nigerian Fish Farming Project Report, April 1, 1974, to December 31, 1977," and "Nigerian Fish Farming Project Report, January 1, 1978, to December 31, 1978." The project leader traveled with family to Nigeria to establish residence on June 16, 1975.

SITE SELECTION

Land having potential for a fish farm site was identified between the village of Aviara in Isoko Division and the Ase River in the 1974 survey. However, during June and July 1975, an effort was made to locate a site that was accessible by better roads and nearer to an urban center. The criteria for site selection were (1) relatively impervious soils; (2) smooth, sloping topography; (3) underlying, water-bearing sands; (4) good accessibility; and (5) availability of land that provides adequate area to develop a fish farm.

Soil quality was surveyed in an area of the Niger Delta south of a line extending east from the town of Sapele, figure 1. The Ase River formed the eastern boundary of the area surveyed; the Forcados River, a major Niger River tributary, formed the southern boundary; and the city of Warri was on the western boundary. The site most nearly conforming to the above criteria, with the exception of accessibility, was located 1¾ miles south and east of Aviara Town in Isoko Local Government Area (formerly Isoko Division).

Aviara is 60 miles east of the nearest commercial town and

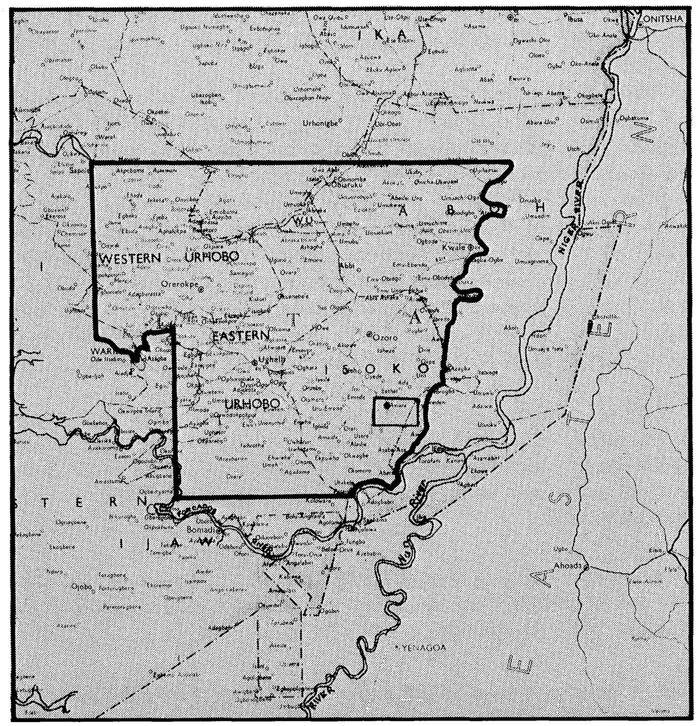

FIG. 1. Map showing location of fish farm site in Isoko Local Government Area.

seaport, Warri, which is reached via a poorly maintained, two-lane highway. Average travel time was 90 minutes, but it varied with the season and road condition. Until suitable housing could be constructed at the site, the project leader resided in Warri and commuted daily.

Aviara is an assemblage of nine villages of one clan in an area of about 10 square miles. Aviara Town is the home of the king and is the center of clan affairs. Land under control of the clan is assigned to families on a progenitorship basis and is subject to removal or redistribution by the council of chiefs and the king. Once the site was identified, the clan was advised and in a public meeting voted to contribute the land to the Bendel State for the development of a commercial fish farm. Compensation for existing crops was to be made to each farmer by the Ministry of Agriculture, and the dispossessed were to further benefit through employment guarantees, increased trade, and other benefits resulting from development of commerce. It was agreed that project jobs would first be offered to qualified clan members, and would only be offered to outsiders when necessary to obtain qualified workers.

On December 31, 1981, there were 38 fish farm employees, approximately 32 of whom were recruited locally. Technical people whose home villages lie outside of Aviara were required to move to

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Aviara. The resulting cash flow in the magnitude of 8,000 naira (N)[1] (U.S. $12,000) per month has had an apparent impact on the village economy. This impact should continue to grow as farm development progresses. Additional skilled and unskilled workers will be required in the future.

The site chosen, figures 2 and 3, was vegetated with tropical rain forest, except for a few small family plots of cassava, yam, bananas, and cola nut trees. The dimensions of the site are 1 mile wide by 1.7 miles in length. The total area is 960 acres, with approximately 500 acres targeted for development into fish ponds.

At the highest elevation the soils are a relatively coarse sand overlain by a thinner layer of sandy loam. The extent of this soil type is approximately 80 acres. Due to favorable topography and well drained soils, this area was readily adaptable as a headquarters site for shops, warehouses, fuel dump, fish holding shed, and housing. It will also accommodate an airstrip for executive type aircraft.

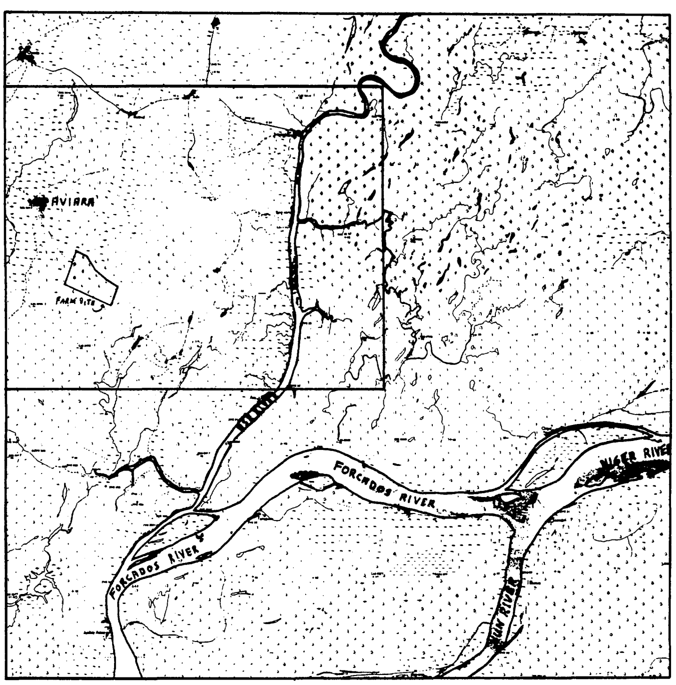
This sandy ridge slopes to the southeast into a low swamp of alluvial clays. The topography is rough, but it is suitable for the construction of commercial fish ponds of the type found in the Mississippi River delta of the United States.

Floodwaters from the Niger River inundate this area during mid-September to mid-November each year. The height of the flood varies from year to year depending on the rainfall in the upper Niger valley which extends hundreds of miles into Niger and Mali. Local rainfall is also a contributing factor. Since 1969, flooding has not been excessive, perhaps due in part to the stabilizing influence of the Kaingi Dam on the Niger River, which was completed in that year.

Official statistics on local floods were not available for past years. Information was obtained by interviews, by examination of old watermarks, and from data for other locations in the same river system made available by Shell Oil Development Company, Nigeria Limited.

[1]Naira: U.S. dollar ratio varied from 1:1.45 to 1:1.88 between June 1974 and December 1981. All costs/prices represent the exchange rate current at the time of the transaction.

FIG. 2. Enlarged area of site showing location of Aviara Town and the site for fish farm.



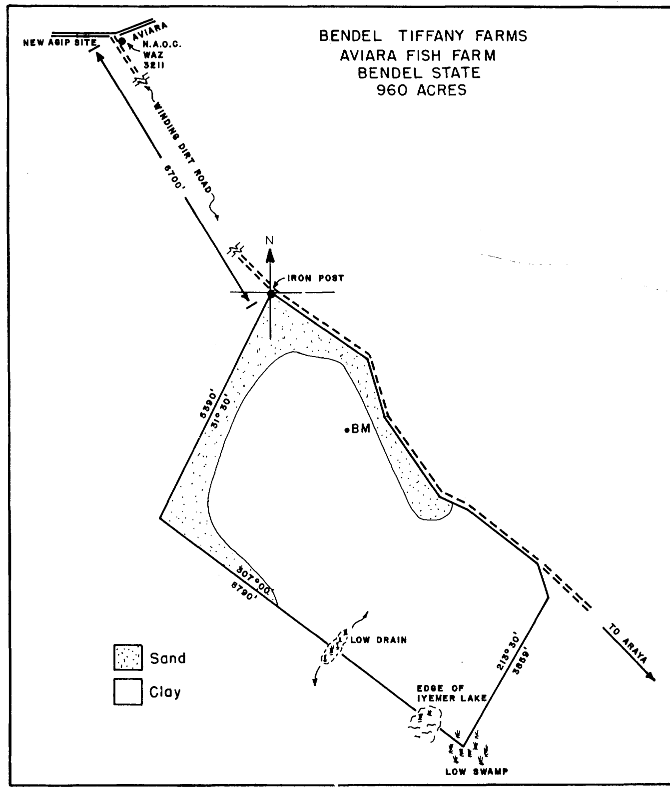


FIG. 3. Sketch of 960-acre site to be developed into commercial fish farm.

SITE DEVELOPMENT

Land clearing was scheduled to begin with the advent of the dry season in January 1976. However, machinery was not available until February 6, 1976, at which time one D-6 Caterpillar tractor began operations. Between February 6 and April 15, 1976 (the beginning of the rainy season), several D-8 caterpillars became available. Trees were felled on 200 acres of land and piled on 60 to 80 acres in the proposed pond area, of which about 30 acres were burned. The headquarters site was cleared, piled, raked, burned, and graded. Land clearing operations were considerably slowed due to intermittent early rains, and by mid-May were completely halted for the duration of the rainy season. By late December, floods had receded and portions of the pond site were dry enough to begin final clearing, grading, and preparation for pond construction.

By May 31, 1977, 850 acres had been cleared of trees, 450 acres burned, 150 acres cleaned of debris, 70 acres prepared and surveyed for pond construction, and 31.6 acres of ponds constructed. By the end of 1981, approximately 100 additional acres had been completely prepared for pond construction and a total of 130 acres of ponds completed and operational.

When the land was acquired, the entire site was covered by forest except for several small plots that had been hand-cleared and planted in local crops. A small percentage of the growth was giant trees with fluted or buttressed bases. These trees had diameters of 8 to 10 feet at ground level and towered well above the canopy of the forest. No effort was made to identify tree species. Tree height was not measured; however, the buttress trees towered to 100 feet or more, and trees of the forest canopy from about 60 to 80 feet, with diameters at breast height of 1 to 3 feet. Many large vines with diameters up to 6 or 8 inches entwined themselves through the tops of trees and through the heavy undercover of brush extending to the ground.

The timbered story immediately below the main canopy was composed of smaller recruits of the same species. The underbrush was composed of a variety of shrubby plants from knee height to 10, 12, or 15 feet. The root system of all trees was near the surface.

Track-type caterpillar tractors with whatever type blade they were equipped were used to fell trees. Dirt blades, root rakes, or Rome K/G tree cutting type blades were raised to the maximum travel of the tractor's C-frame for leverage and the trees pushed over, carrying their shallow roots with them. Buttress trees were cut at ground-level with K/G blades and the stumps dug up with dirt blades. Root rakes and K/B blades were then used to pile the trees into windrows for burning. It is estimated that piling and burning in this manner requires two or three times the number of tractor hours per acre as felling. Work-time studies were not made because of erratic performances of the poorly-maintained machines.

The project leader considers the above described method of felling trees to be more efficient in forests of this type than cutting the trees at ground level and then digging the stumps in a separate operation. The Rome K/G blade appears best suited to windrowing, although root rakes perform this function well. The root rake is indispensible for sweeping the ground of small logs, roots, and stumps, and for repiling the burning windrows.

Any remaining debris was picked up by hand, collected into small piles, and burned. Finally, a heavy ground breaking disc was used to plow the remaining organic material into the soil. It was discovered that more complete burning could be accomplished in a shorter time if the felled trees were left in place until their foliage had dried before windrowing. Following this procedure, not only do the leaves turn to tinder and burn more readily after piling, igniting the coarser materials, but the limbs, boles, and other woody materials dry better and faster. During the dry season, felled green trees could often be burned completely in 2 to 4 weeks.

HEADQUARTERS

The headquarters site is a pleasant sandy ridge area located well above all floods, at least in the memory of the oldest villagers. The short arm of the boomerang-shaped ridge parallels the east-west trans-village road for about 1,500 feet; the longer arm is at right angles to the road and runs more or less east and west a distance of 1 mile. Heavy clay soils suitable for ponds lie at a lower elevation within the angle of the boomerang and continue southward and eastward for 7 to 10 miles beyond the headquarters site.

The headquarters facilities consist of a large (50 x 160 feet) fish-holding and hatchery building, figure 4. The building is enclosed at one end with aluminium siding. This enclosure houses the office, the wet-lab, and storage for small hardware and supplies that require shelter. It also houses four concrete tanks (3 x 3 x 25 feet) that are to be used for indoor breeding and fry-rearing purposes and other specialized hatching and incubation facilities.

The rest of this structure is an open shed in which there are 11 fish holding tanks measuring 4 x 3 x 45 feet. Each tank has an independent water supply and drain, and a walkway along each side to facilitate fish seining, treatment, size grading, and other procedures.

The entire building is supplied water by steel lines embedded in the concrete slab. Water of low hardness is supplied from a borehole or well at a rate of 800 g.p.m. The submersible well pump is powered by a 240-volt generator rated at 162 KVA (129 KW) power output. Water is discharged into a 5,000-gallon elevated surge tank, from where it flows by gravity to the facility. Water level in the tank is controlled by an automatic mercury switch. This system will also furnish water to the housing, shops, and work area.

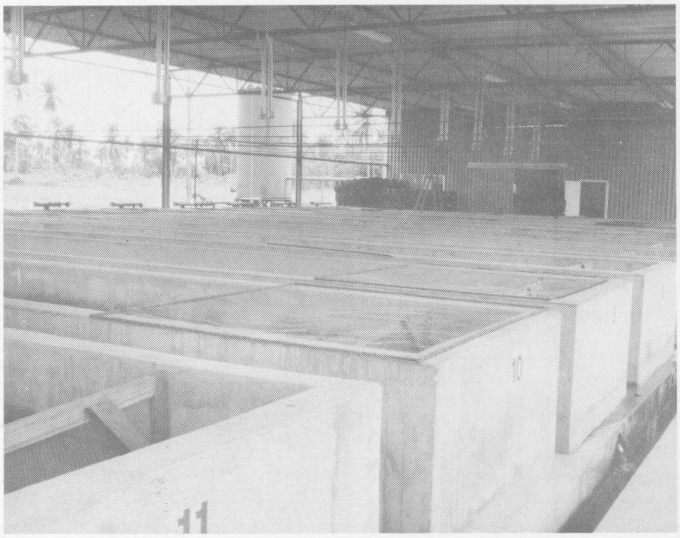


FIG. 4. TOP—fish holding and hatchery building; BOTTOM—close-up showing fish holding tanks in foreground and office in background.

The construction of the fish holding hatchery building is that of conventional pre-fabricated metal buildings, with a 6-inch concrete slab floor. A 6,000-square-foot slab could be poured in one piece in one day by conventional equipment and methods in the United States. With only one 1/4-cubic-yard concrete mixer available at the project site, it was possible to pour only one strip 10 feet wide across the 50-foot dimension of the building per day. This required 15 "cold-joints" in the overall length of the slab. In order to strengthen and enhance the integrity of the slab, the normal procedure of joining individual slabs by smooth butts was modified.

Wood planks measuring 2.5 x 2.5 inches and suspended 4.5 inches above the ground were used for the form for the 7-inch thick slab, rather than 1 x 6 inch planks resting edgewise upon the ground. The 6 x 6-inch mesh wire used to strengthen the concrete slab was extended under and 10 inches beyond the 2.5-inch form. Reinforcing bars (3/8-inch) were cut into 2-foot lengths and inserted at intervals of 3 feet, 1 foot into the freshly poured concrete; the other foot of reinforcing bar extended into the area to be poured the following day. The freshly poured concrete was then allowed to flow under and about 6 inches beyond the 2.5 x 2.5-inch wooden form resulting in a sloped leading edge. When the wooden form was removed, the result was a lock-joint type interfacing of the set concrete with concrete poured on the following day. The slab interfaces were held tightly together by the reinforcing mesh and bars embedded in each slab.

Concrete holding tanks were constructed on the finished slab. Holes 5/8 inch in diameter were drilled into the slab at the center-line of the tank walls at 18-inch intervals. Steel reinforcing bars long enough to reach just short of the 3-foot high walls were inserted vertically into the holes and cemented in place. The tank walls were formed with prefabricated steel forms into which concrete was poured.

In addition to the main building, there is a tool shed and work area for heavy equipment repairs, a fuel depot, a pipe yard, a 60-ton-capacity feed storage silo, and a modern four-bedroom, air-conditioned house.

POND CONSTRUCTION

In 1977, trees were felled on the larger part of the farm site. One area of approximately 70 acres at the highest level of suitable pond soils was selected as the site for constructing the first ponds. This acreage was then cleared, swept, burned, and thoroughly cleared of debris as described earlier. When all woody material had been reduced to ash, tractors equipped with dirt-blades leveled the land roughly.

A permanent bench-mark was established to provide vertical and horizontal control for site development. This bench-mark was tied in to a marker positioned by the Nigerian Agip Oil Co. (N.A.O.C.) in Aviara Town to provide geographical coordinates for future cartographical purposes.

The principal soil type in the pond area is alluvial clay streaked with fine laterite. It lies beneath a sandy loam topsoil that varies from about 1 to 18 inches in depth. The clay remains slightly moist and plastic beneath the top-soil mulch, but when exposed to the sun and air, dries to a dense hard crust. The clay is homogenous to a depth of about 3 feet. At that depth the laterite becomes gravelly and more pervious. During construction, efforts were made to minimize penetration into the gravelly clay. However, where the gravel was accidentally exposed the seepage rate was not great enough to be a problem.

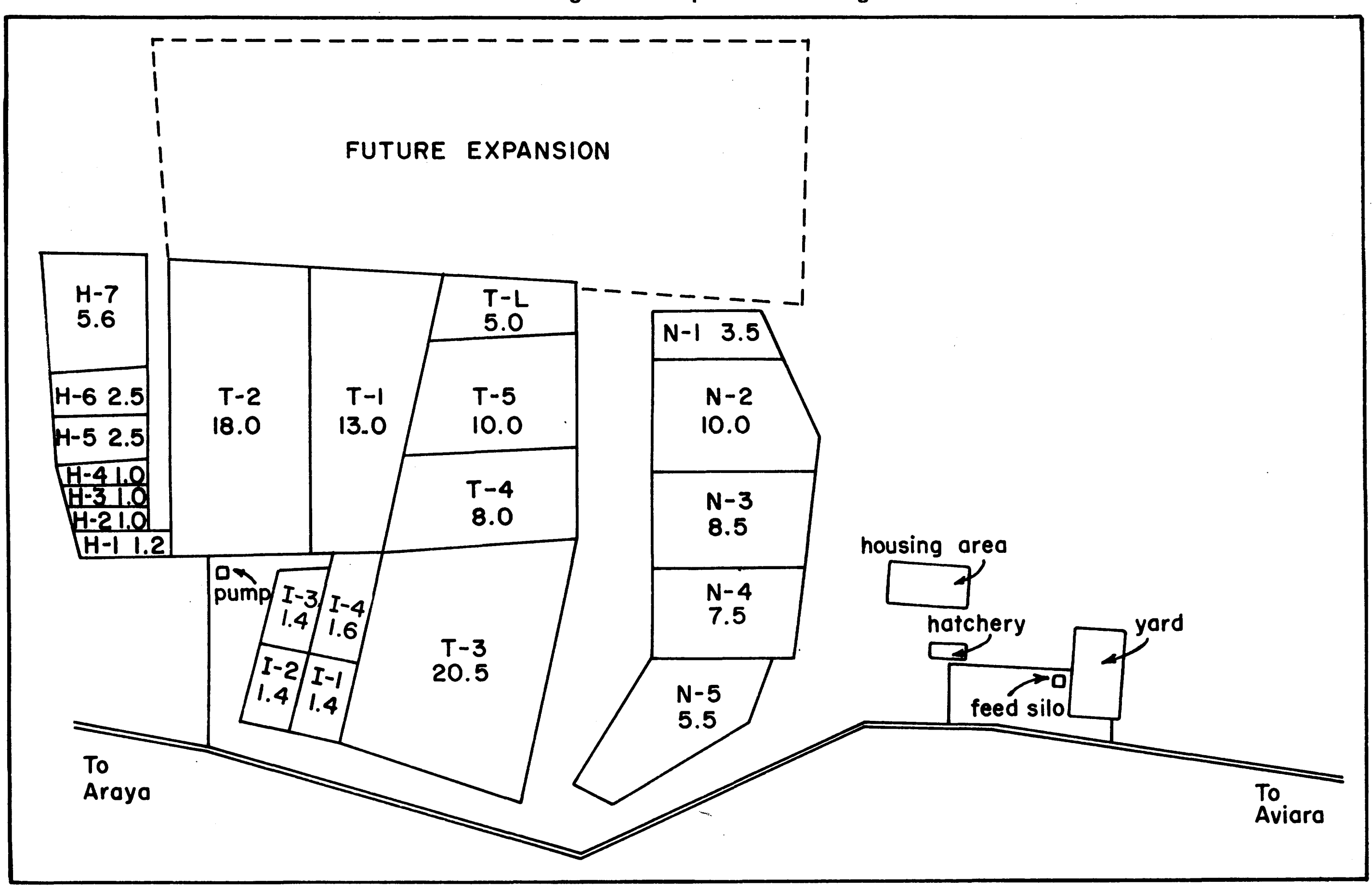
An arbitrary baseline 1,600 feet in length was established at the upper elevation of the clay soil area. From this baseline a grid was established with deviations determined for 100-foot intervals. From these data, levees and ponds were positioned and designed on the basis of economy and ease of construction.

Levee height was designed to provide 2 feet of freeboard when the highest point in each pond was flooded with 30 inches of water. It was thought that this height was also adequate to keep out seasonal Niger River flood water for about a 15-year expectancy. The side slopes of earthen dams were designed at 3:1 and the top-width 12 feet. Allowance was made for an estimated 20 percent shrinkage.

All levees were built by Caterpillar tractors equipped with dirt blades. The soil was excavated as near to the levee base-line as possible and pushed into place. To avoid excessive borrow-pit depth and to maintain good interior drainage, the width of the borrow areas varied with the amount of fill required at each station of the levee under construction.

Levee construction proceeded as follows: an estimate was made of the width of the interior borrow-pit that would be necessary to yield enough soil to build the levee to the desired height and width at a given point. The topsoil from this area was then pushed onto one toe of the levee base, leaving the clay substrate of the borrow-

FIG. 5. Aviara fish farm showing individual ponds and acreages with related facilities.



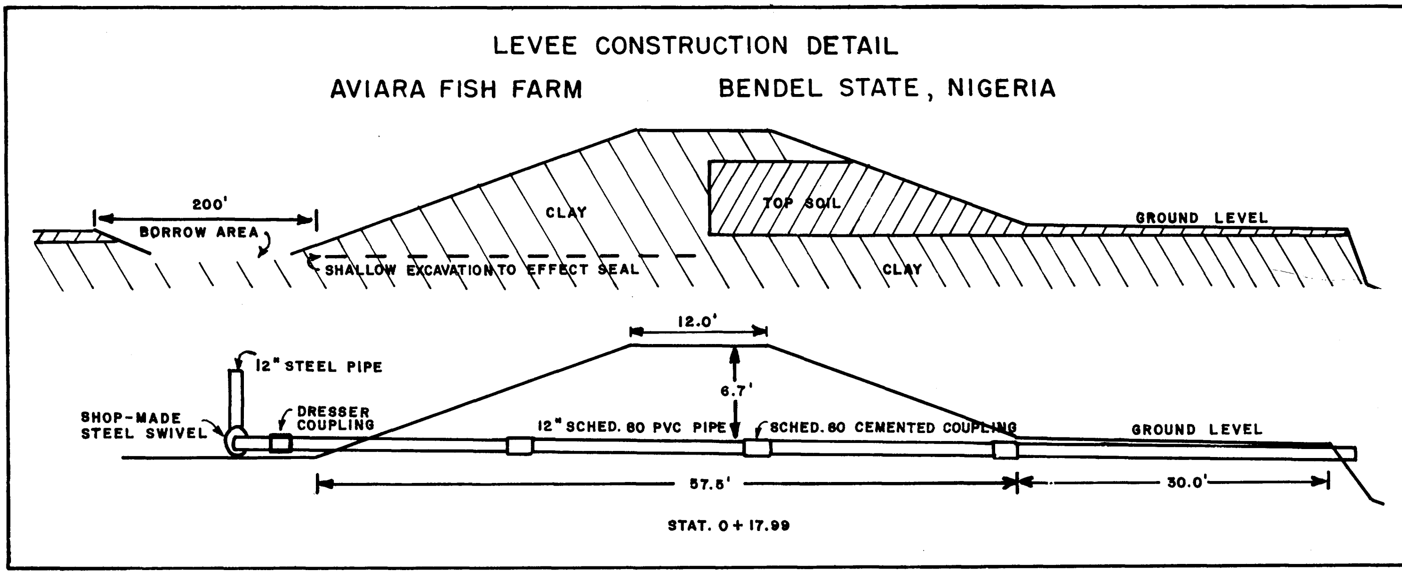


FIG. 6. TOP—upper-cross-section of dam depicting cut (borrow area) and fill area; BOTTOM—lower-cross-secton of dam showing detail of drain pipe design.

pit exposed. Next, a cut penetrating the exposed clay soil to a depth of about 1 foot was made between the opposite toe and the center line, forming a shallow core trench. This soil was deposited with the previously deposited topsoil. The core trench was necessary to break up soil stratification and secure a seal of clay to clay. Next, clay soils in borrow areas on both sides of the levee were used to complete the levee. At least one-half of each levee was of good clay. Additional topsoil was mixed with clay in the portion of the levee above the water line to help stabilize the roadways.

While these precautions were advisable, it may have been sufficient, given the excellent quality of the clay and the thin layer of topsoil, to provide a shallow core trench and push soil indiscriminantly onto the levee site from adjacent areas.

A harvest pit about 1/2 acre in size was excavated at the lowest point of each pond. Pond bottoms and borrow pits were formed to slope evenly to the harvest pits. The drainpipe used was schedule 80 (5/8-inch wall), 12-inch PVC pipe with cemented joints. The drain mechanism was a fabricated steel swivel to which was welded a 12-inch steel stand-pipe of the exact length to establish the pond water level when upright. This device was fastened to the PVC horizontal drain pipe by means of a 12-inch Dresser coupling. Each pond drains as an independent unit directly into a central drainage ditch that was constructed to approximate the course of the natural drainage for the site. This ditch runs east and west thus bisecting the site. It will drain all of the ponds as well as taking care of drainage runoff of the headquarters site.

Two adjacent production ponds with one common levee were constructed in 1977. Measured from center line to center line of the levees, Pond I was 13.6 acres and Pond II 18.0 acres (Ponds T-1 and T-2, respectively, on figure 5). The maximum height of fill in Pond I was 9.2 feet and the minimum 4.5 feet. The total volume of fill for Pond I was 26,613 cubic yards, which includes all the material in the levee common to Pond II. Pond I was built with two D-8 and one D-6 Caterpillar tractors in 14 days. Total D-8 tractor hours was 280, and total D-6 time was 140 hours. At an operating cost of N50.00 per hour per D-8, and N40.00 per hour per D-6, Pond I cost N1,876.90 (U.S. $2,871.66) per acre to build. Maximum height of fill in Pond II was 9.6 feet and the minimum 2.6 feet. The total volume of fill was 24,866 cubic yards, not including the common levee which was calculated as fill for Pond I. Pond II was built in 8 days using two D-8 and one D-6 Caterpillar tractors. Total D-8 time was 160 hours and total D-6 time was 80 hours. At the same unit costs as for Pond I, Pond II was constructed for N622.00 (U.S. $951.66) per acre.

The average cost per acre for the two ponds was N1,249.45 (U.S. $1,911.66). It should be noted that an almost equal volume of earth was moved in Pond II as in Pond I, but in about 40 percent less time. This was the result of training the relatively inexperienced tractor operators.

The combination of two D-8 and one D-6 caterpillar tractors, one instrument man, one rod man, two chain men, and two men to remove roots, stumps, or other material that was missed during land-clearing is an effective work unit. One instrument man and his team could service two such tractor units working near each other.

In land formations such as the one under discussion where the gradient is rather steep, it is often necessary to move soil long distances from the upper levels to the lower to balance the dirt budget without having excessive shallows or depths. Dirt scrapers with an aggregate capacity of 20 to 30 yards pulled in-line behind a suitable crawler tractor were obtained for this work. Sheeps-foot or other type compaction machinery may also be helpful, however early construction compaction did not present a problem because placement of soil by dozer blade and tractor was done properly.

Details of levee construction and drain-pipe installation are shown in figure 6. It was not necessary to alter this basic design and all ponds were thus similarly built.

Seven hatchery and nursery ponds were constructed (ponds H-1 to H-7). Four of these ponds were approximately 1 acre each, two ponds were 2.5 acres each, and one was 6 acres (measurements from levee center line to levee center line). Due to the higher cost of building small ponds, a conservative estimate of the costs per acre for hatchery ponds is N5,000.00 (U.S. $7,500.00) in the Nigerian situation.

In 1969, the River Niger flooded the present pond site to a greater depth than in any year in the memory of the oldest villagers that were interviewed. Since 1969 there has been no flood that has risen higher than the design height of the first pond levees constructed in 1977. Evidence accumulated more recently than 1977 indicates that the 1975 flood would have rested evenly at the tops of the levees had they been in existence at that time.

In 1978, 1.5 feet was added to the original design height for all future levees, and plans also were made to raise the old levees by the same amount. In determining this height, economy of construction was weighted against the risk of flooding over a reasonable period of years.

WATER SUPPLY

A well had been bored and tested by June 7, 1977. In the Aviara area, there are about 90 inches of rainfall per year. Pond draining and filling, however, will occur in the dry season during which there is practically no rainfall. Water requirements for this operation will thus be available from wells.

The well is 250 feet deep and has a 13 3/8-inch casing and 52 feet of 10-inch stainless steel Johnson well screen. Water production is in excess of 40,000 gallons per hour (about 700-750 g.p.m.). The test pump was replaced in September 1977 by a 50 h.p. electric submersible pump. At this time the well became a functional water supply. The well pump is powered by a 144 KVA (115 KW) generator driven by a diesel engine, and can supply 100 acres of ponds with water.

A water supply line was buried to a depth of 20 inches along the center line of the levees that paralleled the upper (shallow) end of all ponds. Inlet pipes were provided from the main line so that each pond could be watered independently. Schedule 40 PVC pipe was used throughout the pond watering system. Thinner PVC is available (schedule 20), but it is too fragile and should not be used for this purpose.

A pressure relief mechanism was incorporated into the water supply system. A 12-inch steel pipe was welded to a 24-inch steel pipe in such a way that the entire structure was a telescope shaped chimney about 15 feet high when resting on the larger pipe and standing upright. The top of this device was left open to allow the escape of air and the overflow of water. The well discharges into the lower 24-inch section of the standpipe. The water then flows under its own head into the supply lines to the ponds. Care must be taken to see that water is being discharged into the ponds in great enough amounts to utilize the entire bore-hole production or the stand pipe will overflow and waste water.

ACQUISITION OF FISH STOCKS

There have been negligible studies of life habits and suitability for cultivation of most indigenous west African fishes. The notable exceptions to this are the *Tilapia* and *Clarias* species. The former of these is considered the most desirable food fish. *Clarias* (catfish) cultivation will require additional research before commercial-scale production is possible in Nigeria. The well known propensity of the tilapias for over production resulting in large populations of small fish precluded their initial use in our project because Nigerians prefer large fish. Therefore, it was decided to import the known and proven technology of mirror carp for commercial culture.

The Oyo State Ministry of Agriculture has a small, 5-acre fish culture station in Ibadan. The principal species with which they are concerned is the mirror carp. This station is fairly well planned and constructed. Carp culture techniques and probably the original broodfish were obtained from the Pan Yam Fish Farm near Jos in Eastern Nigeria. Arrangements were made to secure 200 fingerling mirror carp from the Ibadan Station. These fish were to be grown to a large size and suitable age for spawning in a 3-acre pond that had been built for that purpose on the already cleared row-crop farm near the village of Agenebode in the northern part of the state.

It was anticipated that by the time land was cleared and spawning ponds completed at Aviara, a ready stock of brooders would be on hand. However, almost all of the juvenile brooders were lost to predation by crocodiles, which are revered by the animist residents of the Agenebode area and thus uncontrolled. The surviving brood fish, four in number, were subsequently transferred to Aviara, but due to lack of isolation ponds, lost their identity when additional carp were imported. It had been hoped that two strains of common carp could be kept separated and their growth compared.

Early in 1977, arrangements were made with Auburn University for their fisheries staff to spawn and rear to a size suitable for air shipment, specimens of mirror carp, largemouth black bass, channel catfish, and fathead minnows.

These species were selected for the following reasons: carp as the most promising commercial species; channel catfish as a possible supplement to carp for the gourmet or carriage trade; largemouth bass for biological control in future attempts at raising tilapia; and fathead minnows as forage for bass and channel catfish brooders. The last three applications would depend on the development of dependable methods of spawning bass, catfish, and minnows.

The carp were shipped in sufficient numbers to constitute a semi-commercial crop when reared to marketable size. From these carp the foundation brood stock was selected, and the remainder used for consumer acceptance and marketing studies. The other species were brought only in sufficient numbers (1,000 each) to establish a population of brooders. Careful preparations were made for the safe conduct of these fish from Auburn University to the Aviara Fish Farm. The fish were packed in heavy-duty styrofoam packing boxes. The number and weight of fish per bag were based on 100 percent survival for 48 hours in pre-shipment trials at Auburn University. Due to the uncertainty of the fate of air freight in some international airports, the fish were transported by accompanied luggage. A large number of styrofoam boxes were involved (about 50), so two Auburn University personnel were assigned as couriers.

The proper import permits were obtained from the Nigerian Federal Department of Fisheries. Nigerian customs and quarantine officials were enlisted to expedite the removal and clearance of the couriers, their baggage, and the live fish at planeside.

According to plan, the fish were to be transferred to two chartered twin-engine aircraft, flown to Warri, off-loaded either onto a flatbed truck still in their own containers or, depending on their condition, released to swim freely in a tank on a conventional live-fish transport truck. Either way, the final leg of their journey would be overland by truck from Warri to Aviara. Total scheduled time enroute from Auburn University was to be less than 48 hours. Departure from Auburn was at 6 a.m., August 2, 1977.

Due to mechanical difficulties, the flight arrived in Lagos about 3 hours late. This was past the final legal take-off time for Warri bound aircraft. The fish, still in their boxes, were held overnight in Lagos in an air-conditioned workshop. The following morning, one-half of the fish, still in boxes, were flown to Warri by a chartered aircraft; the fish in the remaining boxes were released into a live-fish transport tank on a truck that had been dispatched to Lagos as back-up in case of just such an emergency. The air-lifted fish arrived in Warri at 8 a.m., August 4. They were left in their containers, transferred to a flat-bed truck, transported to Aviara, gradually acclimated to the pond water conditions, and released by 12 noon, August 4, 1977. These fish were in transit from Auburn 56 hours.

The remaining fish left Lagos by truck in a live tank at 8 a.m., August 4. They arrived in Warri at 8 p.m. the same day. One hundred and ten-volt agitators were substituted for the 12-volt ones used in transit and the fish held overnight in Warri. By 11 a.m., August 5, these fish had been transported, tempered, and released in the pond at Aviara. The fish had been in transit from Auburn about 75 hours. This latter group of fish was much stronger when released than those that were airlifted in plastic bags, despite the fact that their total time enroute was approximately 20 hours longer. This emphasizes the need for properly designed transport units and the construction of a good live-fish holding and receiving facility prior to handling fish for any purpose at a new station. The existing one at Aviara had not yet been constructed at that time.

Although fish in some boxes suffered 100 percent mortality, overall mortality did not seem excessive in view of the unexpectedly long time in transit. Approximately 60 percent of carp, 75 percent of largemouth bass, 40 percent of channel catfish, and 95 percent of fathead minnows survived the trip. All survivors were released into an 18-acre pond partially filled with rainwater.

While still in the United States, the carp fingerlings had been found to be infested with *Lernea* sp. They were treated conventionally for this parasite while being held for shipment. No parasite, nor symptoms of their development, has been observed during the 5 years the fish have remained in Nigeria.

Samples were taken of the imported fish with seines at irregular intervals. Samples were examined for rate of growth and symptoms of parasites or diseases.

Both the largemouth bass and the channel catfish grew at an extraordinary rate. The catfish weighed about 6 pounds each and the bass about 3 pounds each at the end of 18 months. No attempts were made to induce spawning in either species. As new ponds became available, brood stock were isolated and furnished nesting opportunities that are conventional in U.S. hatcheries. There was no reproduction and most of both species have since succumbed to predation, theft, or natural mortality. Fathead minnows were not seen again after the day of their release, although they were strong when released.

FEEDS AND FEEDING

Livestock Feeds (Nig. Ltd.), a subsidiary of Pfizer Pharmaceutical Company, has a modern mill in Lagos and another in Aba. This farm agreed that a feed formulated by Dr. R.T. Lovell of Auburn University for carp at different levels of cultivation was to be supplied by them at our request. This arrangement has proven almost totally unsatisfactory. Even though fish feed orders were made months in advance and on a scheduled basis, the Aviara farm was without feed at times for periods of 2 to 3 months. There are no other commercial feed mills in Nigeria with feed pelleting capabilities with the exception of a small capacity blending and pelleting plant operated by the Nigerian Institute of Oceanography and Marine Research.

The lack of in-country infrastructure for the production of feeds compounded by difficulty in securing parts, supplies, and other commodities is the major impediment to development of commercial aquaculture in Nigeria.

Given a dependable flow of manufactured feed, there are certain other considerations. Due to a domestic deficit in the production of raw materials, embargoes, import quotas, and punitive duties on many raw materials, the Nigerian economy is greatly inflated. As of February 15, 1982, Pfizer quoted over N600.00 (U.S. $900.00) per metric ton for the "intensive culture" feed formulation. The formulations presented in the table contained primarily whole roasted soybeans (ground), which were assumed to be available at moderate cost for use in fish feeds. Assuming a 2:1 conversion factor, the cost of feed alone per pound of whole fish flesh would be N0.54 (U.S. $0.81).

If other production costs were added to the cost of feed, the product would be priced beyond the purchasing power of the Nigerian market. It was apparent that acceptable lower-cost feeds must be utilized even at a per acre production sacrifice to lower the price of fish in the market. Life Flour Mills, a miller of white wheat flour, is located in Sapele, midway between Benin City and Warri. Wheat bran, a by-product of their milling process, is pelleted into 3/8-inch pellets for export. This material was made available to Bendel Tiffany Farms for N70.00 (U.S. $119.00) per metric ton. The wheat bran and the Pfizer concentrate, when available, were blended on-farm in a ratio of 3:1 as the basic ration for fish being grown for market. Though satisfactory data were not obtained because of the irregular availability of the concentrate, this mixture appeared to be an adequate diet for carp. The costs per pound of whole fish flesh, assuming a 2:1 conversion ratio, would then approximate N0.18 (U.S. $0.27). The daily rate of feeding was based on estimated numbers of fish, estimated biomass per acre, and periodic observations of rate of growth, general appearance, and feeding activity.

There are two breweries in Benin City. The brewers by-products are discharged into natural drainage channels in a semi-solid state. No attempt is made to process or utilize this material for commercial purposes. It has been offered to the Bendel Tiffany Farms for the price of hauling. In the semi-solid condition, brewer's by-product would probably be utilized more as an organic fertilizer rather than a feed. The high content of vitamin B complexes and yeasts would, however, enhance its value as a feed if provided in a consumable form.

At one time, Nigeria was the world's largest producer of palm nut oil. Production is declining, possibly because of the migration of farm workers to the developing industrial areas. However, there is a large volume of residue from the oil extraction process that is largely exported to be used in the manufacture of animal feed, rather than utilized in Nigeria. This material is available locally wherever palm oil press facilities exist. One is in Warri. Production is seasonal and relatively small. Local prices have not been fixed, nor have available quantities been projected. Protein content is reported to be 18 percent. The Warri plant, when operating, dries and pellets this material in 1/4-inch pellets for export. Its value as a fish feed should be investigated.

A project owned and operated feed mill is to be constructed at the Bendel Tiffany Farms, Agenebode grain farm, to utilize farm-grown grains as fish food. Other locally available ingredients, such as wheat bran, palm kernel meal, and brewers by-products, may prove to be nutritious and economical additions or substitutes for these grains.

With the exception of wheat bran pellets and chicken manure, which is available for the price of hauling, none of the locally produced agricultural by-products has yet been utilized by the fish farm.

FORMULA FOR FEEDS FOR FISH

Ingredient	Extensive pond culture, 25% protein	Intensive pond culture 30% protein	Cage culture 32% protein
	Pct.	*Pct.*	*Pct.*
Ground roasted soybeans	60	60	55
Grain rice, corn, or sorghum	28	20	20.5
Rice bran, wheat bran, or other fibrous ingredient	8	8	8
Bone meal or dicalcium phosphate	2 or 1.5	1 or .75	1 or .75
Binder	2	2	2
Fish meal	--	8.5	13
Fish vitamin mix	--	.5	.75

REPRODUCTION

By June 1978, the small fingerlings that had been imported from the United States in 1977 had reached an average size of 3 pounds. Milt could be expressed from some of the males, and the abdomens of some individuals were distended to a greater extent than others; these were thought to be females. On this basis, 100 individuals considered to be females were placed in a 1-acre pond and 100 fish accurately identified as males were placed in another pond of the same size. This sexing process was reasonably accurate, but as sexual maturation advanced the females could be more easily identified to the point that the separation of the sexes approached 100 percent accuracy. The Pfizer concentrate formulation was available in small quantities and was reserved as a ration for the potential breeders.

Attempts at spawning fish were begun in late May 1978. At this time the brooders were approximately 12 months old. A number of females and males were injected with dried whole pituitary and released in a 1-acre pond. Field grasses on the pond banks had been allowed to grow for spawning substrate, and the ponds were flooded to a depth that covered these grasses just prior to introducing the brooders so that predators would not have had time to become established. Diesel oil was spread on the surface of the water to control insects. Neither a plankton net nor a 1/8-inch mesh nylon seine captured any macro organisms that would be considered predatory or competitive grazers on micro organisms that are thought to be essential to carp fry during the post larval stage.

Injection of a solution of powdered carp pituitary and sterile water was made at the rate of 3 milligrams per female in the late evening. The following morning this was repeated. At this time, the males were also given 3 milligrams per fish. In the late evening of the second day, the females were given another injection, but at the rate of 3 milligrams per kilogram of body weight. Sperm could be freely expressed from the males at this time and they were given no further injections. This same procedure was followed in all subsequent spawning attempts. All of the brooders were released in the ponds and watchmen with no previous knowledge of spawning behaviour of carp were posted as observers. The following morning they described the classic pattern of spawning behavior common to these fish. Eggs could be found lightly scattered among the grass. None of those found ever embryonated.

The Project Director took 60 days leave beginning June 1, 1978, and was replaced by an advanced Auburn University student who had prior Peace Corps experience with mirror carp in Nepal. This worker repeated the procedure described above several times with similar results. He also did chemical analysis of the pond water which had been obtained from the 250-foot-deep well. He found that the pH was approximately 5.0 and that the hardness approached zero.

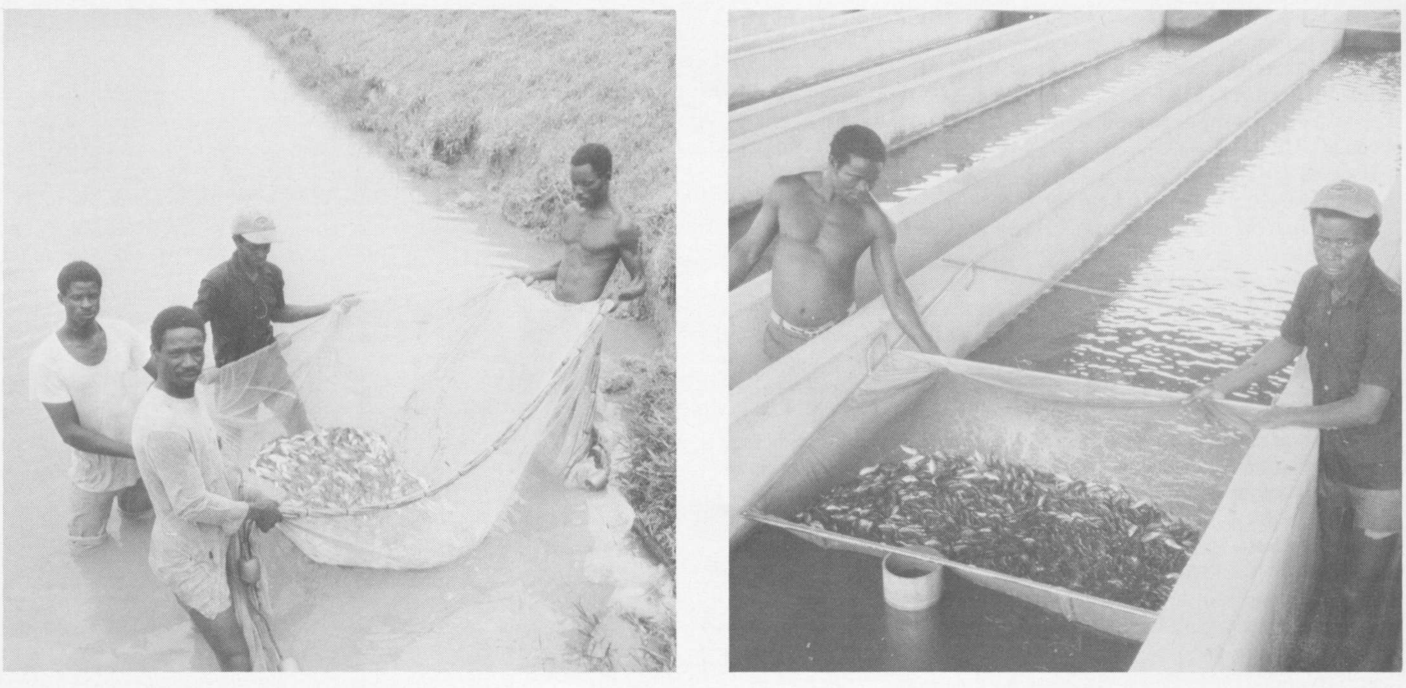
Calcium hydroxide (CaOH) and agricultural limestone (CA_2CO_3) were added to raise the pH and increase the hardness. It was found through repeated trials that relatively small amounts of these materials caused major changes in the chemistry of the unbuffered water. The addition of 100 to 500 pounds of limestone per acre increased the pH from 5.0 to around 8.0 or 9.0. At times it was necessary to make one or more additional applications. After a few days, the pH usually stabilized at 6.5 to 7.5. Hardness increased to at least a quantity measurable with a basic field type Hach kit, usually approaching 30 p.p.m. From this date forward, pH and hardness were monitored in all ponds on a regular basis and corrections made by liming when necessary. This procedure is also a continuing process in the production ponds.

After these improvements in water quality were made, successful hatching of carp fry resulted and ultimately 600 advanced fingerlings were obtained. Most eggs, however, even those from heavy spawns that appeared normal, failed to embryonate.

The Project Director returned in early August. Before the departure of his relief, many hours were spent discussing the dilemma. Water quality which had been corrected and brooder age were the obvious considerations except for a factor the Project Leader calls the "peachtree syndrome." That is the lack of cyclic dormancy during the winter months in temperate zones to which the carp is native.

The spawning procedure was altered slightly. The fish receiving pituitary injections were released into 4 x 4 x 10-foot nylon nets (hapas) suspended in ponds rather than being released free in the pond. This was done to ensure proximity of males and females during spawning. Two females and four males were placed in each

FIG. 7. LEFT—harvesting fish fingerlings from "fish seed" pond; RIGHT—selecting fingerling fish from concrete holding tanks prior to stocking grow out ponds.



hapa. Abundant quantities of fine, dried grass stems were placed in the hapas as substrate for the adhesive carp eggs.

This procedure resulted in heavier spawns of viable eggs, although all of the eggs in some spawns were still infertile. Some hatches were excellent both in the hapas and in glass aquaria to which some of the grass bearing eggs were transferred. The aquaria contained water from the spawning ponds. The fry that could be easily observed in the aquaria were vigorous, and remained so for several days until they were tempered with pond water and released in that pond.

The survival of the fry in ponds was poor. What at first appeared to be large numbers of 0.5-inch fry became progessively fewer until the survivors reached approximately 1.5 inches in length, at which time mortality then seemed to cease.

A total of 13,000 fingerlings representing the F-1 generation of Aviara carp was produced in 1978. Although the results of attempts to produce fingerling carp were poor, confidence remained that this problem was a temporary one that could be overcome with well planned procedures by specialists in a position to apply full time efforts utilizing well maintained brood fish and appropriate facilities.

The same procedures of spawning the carp were followed in 1979 and 1980, but with increased success. Production of 4- to 6-inch fingerlings totaled 49,000 in 1979 and 78,000 in 1980.

The frog and tadpole populations in the breeding ponds were negligible. Air breathing insects were controlled by diesel oil floated on the surface, or by selective insecticides when they were available. There were no water snakes observed. There was only minor predation resulting from fish eating birds preying on the larger fingerlings and stocker fish up to 1/2 pound. Poor survival of the fry and small fingerlings in 1978, 1979, and 1980 remains a mystery.

By early 1981, four additional spawning ponds of approximately 2 acres each had been constructed (I-series); these and two of 17.1 acres each were used during the 1981 spawning season. On February 10, 1982, 30,000 4-inch fish spawned in 1981 were captured from one of these ponds by seining only the four corners with a 50-foot-long net. The fish were transferred to a production pond to grow to a marketable size, figure 7. This pond, therefore, was only partially harvested. Previous samples of all of the reproduction ponds indicated that this pond contained the smallest number of fingerlings per unit area.

The total pond area devoted in 1981 to spawning and rearing fingerlings was 8.4 acres. No fingerlings had been removed from any of the other ponds as of March 1, 1982. On the basis of the easy removal of the 30,000 fish mentioned above, sampling judgement, and experience, it was estimated that the 1981 crop was approximately 250,000 4-inch fingerling carp as of February 10, 1982.

Possible reasons for increased success in spawning, hatching, and fry survival are listed below:

1. Adjusting the pH and hardness of the water within the limits prescribed for the culture of most warmwater fishes.
2. Improved timing in the flooding and fertilization of the hatchery ponds to ensure an appropriate level of food production for the fry.
3. The use of degradable and selective insecticides and diesel fuel to eliminate predators.
4. The use of aged brood fish, which had become increasingly adapted over time to pond conditions.
5. The use of brood fish that had fully matured sexually.
6. Postponing spawning until about September 1, which had been the most successful time in previous trials.
7. Increased staff experience.

The foregoing statements are largely speculative, based on the observations of the Project Leader.

The mirror carp is a notoriously poor spawner with low fry survival in equatorial zones. Although this fish spawns and hatches freely in the United States and other countries of similar latitudes, survival of the young is relatively low compared to other cyprinids indigenous to those areas. This is compensated for by production of large numbers of fry. The problem then becomes one of producing large numbers of eggs that are viable. The probability of this occurring is enhanced if the following conditions are provided: proper water quality and temperature, natural food organisms, conditioned broodfish, and timing of natural ovulation using aged females that are sexually mature. Hormone injections can be utilized to regulate ovulation within certain limits. Dechorionization, jar-hatching, and tank rearing of fry indoors may be an improvement on the use of hapas and straw substrates for the adherent eggs.

PRODUCTION

In 1977, small mirror carp fingerlings were brought in by air from the United States. The number of fish that survived after release into an 18-acre pond is unknown; however, fish did survive in sufficient numbers to provide an adequate stock of foundation brooders when they reached about 3 pounds average weight. In addition, there were enough survivors to conduct preliminary consumer acceptance studies and to test the stability of the market in the face of a relatively high price.

Except for roughly 200 fish sorted by sex and raised in separate ponds as brooders, all survivors were reared in one 18-acre pond. These fish were fed daily at a rate variously estimated to be between 0.01 and 0.03 of the total biomass, depending on rate of growth and condition of the fish. Biomass was estimated from assumed survival and periodic weight sampling. Physical condition was noted at the same time.

To avoid miscalculation of feed requirements due to error in estimating survival, automatic feeders made from oil drums were placed at intervals around the pond. The fish fed readily from the feeders and the assumption was that they consumed the proper amount required for growth.

No meaningful growth rates, food conversion rates, or per acre production rates were obtained due to unusual circumstances: (1) the actual number of fish being reared was unknown, and (2) survivors were held beyond a normal growing period to ensure adequate numbers of brooders in the event massive mortalities occurred in the brood fish conditioning ponds, and to be used to explore consumer acceptance and marketing potential.

The fish grew well; some individuals attained weights as great as 9 pounds by the end of 1978. Those removed for sale or other purposes averaged about 4 pounds after an 18-month period. Ultimately, 4,344 fish, with a total weight of 18,316 pounds, were removed.

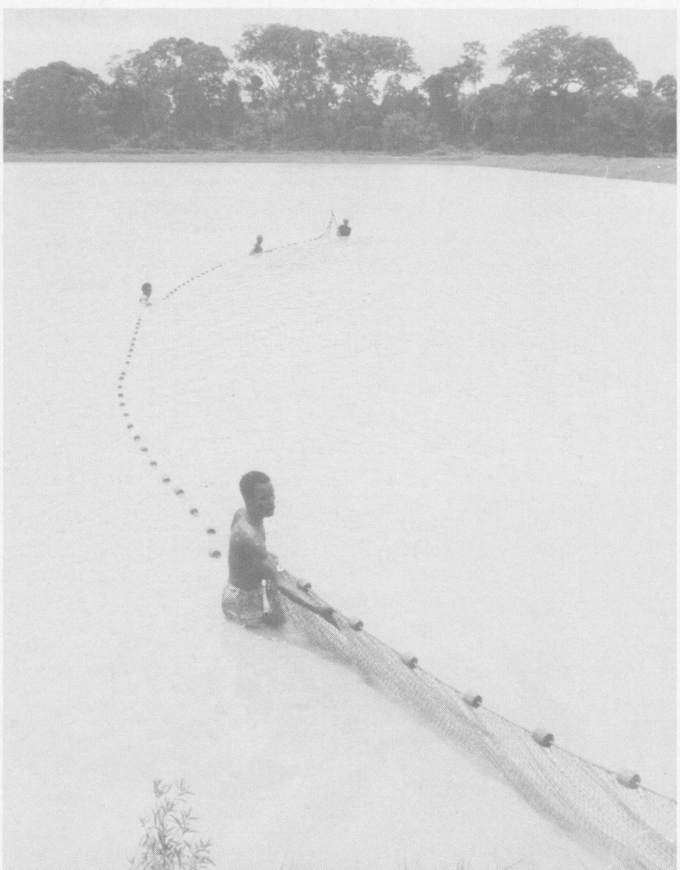
Fingerlings from both the 1978 and 1979 spawning seasons were stocked into grow-out ponds to be reared to a merchantable size. These fish were stocked at the rate of 1,250 per acre, anticipating a production of 1,000 2-pound carp (2,000 pounds per acre) in 6 months with heavy feeding, figure 8.

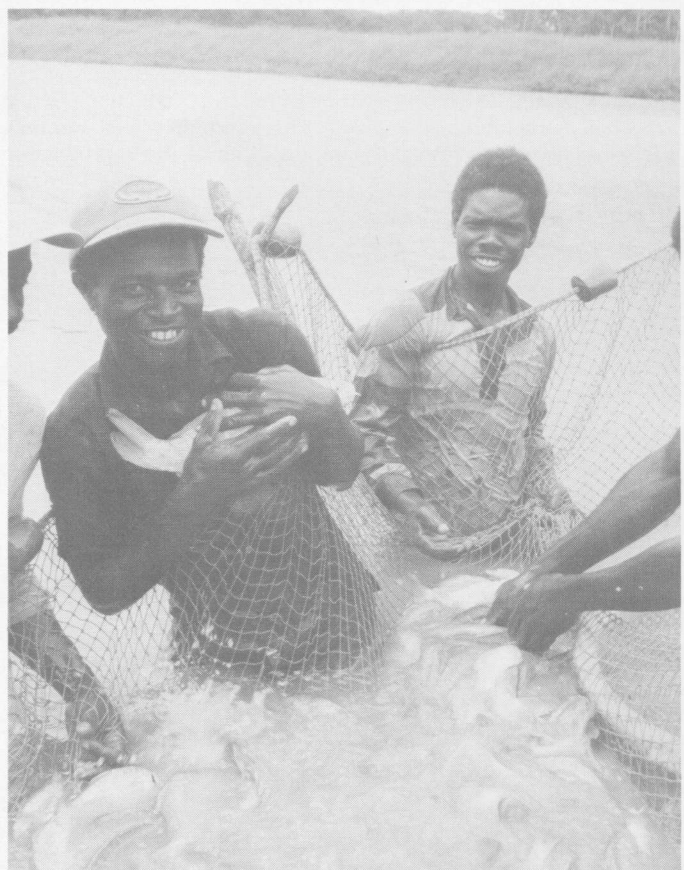
Unfortunately, periodic shortages of money, inability to secure fish rations, an 18-month gap in supervision by fully trained expatriate aquaculturists resulting in some mismanagement, and significant losses of fish due to theft and brutalization of fry and fingerlings by untrained personnel during pond to pond transfer made adequate measurements of growth rate, feed conversion, and production impossible. In fairness to both the Nigerian senior and junior staff involved, it should be made clear that inexperience, not neglect nor lack of dedication, was the principal reason.

An experienced expatriate staff member was employed in 1981, which allowed resumption of sophisticated management and record keeping. Fingerlings of the 1980 spawn were available for rearing.

In the proforma presentation to the Bendel State Ministry of Agriculture and Natural Resources (MANR), it had been projected at the beginning of the project in 1977 that two crops of 1,000 2-pound carp could be produced per acre per year (4,000 pounds per acre per year). The only field tests in support of these projections to date are tabulated below. There are other ponds that replicate the one cited, but they had not been harvested to substantiate or at least yield further data on average performance when the report was written.

FIG. 8. LEFT—seining operation in production fishpond to obtain fish for market; RIGHT—net of harvestable size fish being prepared for market.





Actual fish production data

Pond water surface area	7.0 acres
Date stocked	April 25-30, 1981
Stocking rate per acre	1,078
Feeding schedule	irregular
Date of complete harvest	January 30, 1982
Average size at harvest	1.68 pounds
Total harvest	11,900 pounds
Production per acre	1,700 pounds
Total feed	37,900 pounds
Total feed per acre	5,114 pounds
Feed conversion ratio	3.2:1
Survival	93 percent

The above data include a 9-month, rather than a 6-month, growing period. Also, the fish were harvested over a period of weeks to conform to a sales schedule. For 2 months of the 9-month period, feed was not available. For at least 2 additional months, the feed that was available was in the form of mash rather than pellets; 17 percent of the total feed fed was mash. Mash is not readily consumable by large fish and, therefore, an unknown portion was not utilized directly as food, but entered the nutrient chain as organic fertilizer. In fact, the waste was great enough to cause O_2/CO_2 imbalance, and corrective measures, such as liming and mechanized aeration, became necessary. In view of the overall inputs and lack of inputs, this experience does support the projections of 2,000 pounds per acre per crop of carp each 6 months, given the proper infrastructure on a consistent basis.

INDIGENOUS SPECIES

The Nigerian participants in developing Bendel Tiffany Farms expressed interest in rearing species indigenous to southern Nigeria.

Tilapia and Native Catfish

Such fish as tilapia and some of the native catfish are already familiar to the Nigerian palate and if grown to an acceptable size could be more easily marketed than carp. During one growing season, a 2.3-acre pond was devoted to the cultivation of tilapia. *Tilapia nilotica* brooders were secured from the Oyo State fish station. These fish were stocked at about 50 per acre in one 2-acre pond for multiplication purposes. The pond became contaminated with *T. zillii* and *Hemichromis fasciatas.*

When feed was available, it was added to the pond at daily rates estimated to be appropriate to the biomass.

Both species of tilapia reproduced heavily. *H. fasciatas* also reproduced, but in fewer numbers. Due to the press of problems encountered in carp reproduction and production, tilapia management was neglected. However, in spite of the presence of large numbers of *H. fasciatas,* a predator, the pond became overcrowded with stunted tilapia.

These small fish were sold to market women, but in small quantities and at a maximum price of N0.35 (U.S. $0.52) per pound. This price was considered below cost of production and harvest. Tilapia of approximately 1/2 pound or more would find a ready market at a price equal to or higher than that of carp.

Eventually 30 American channel catfish, the only surviving imports, were added to the tilapia pond in order for them to have live food and at the same time exercise some control over tilapia reproduction. All species in the pond will be stored in this manner until such time as a more systematic approach can be made to their culture.

Heterotis nilotica

Heterotis nilotica evidently spawns during floods, and large numbers of 2- to 3-inch fingerlings can be found schooling at the surface. These fish are easily caught by surrounding the schools with a small seine. Securing fingerling *Heterotis* regularly from wild stocks appeared to hold promise. One major advantage of this would be to release holding, spawning, and rearing ponds to be used for the production of market size fish. Furthermore, although *Heterotis* is known to spawn in ponds, the levels and cost of production are not known.

Between October 10 and 23, 1978, 9,783 *Heterotis* fingerlings were caught and stocked in an 8-acre pond (987 per acre). Total weight was 114.0 pounds and average weight per fish was 0.01 pound. An 11-acre pond was stocked with 6,445 fingerling carp (586 per acre) between November 27 and December 12, 1978. Total weight of these fish was 743.8 pounds and average weight per fish was 0.12 pound.

The 2,298 fingerling carp that were remnants of the 1978 spawning exercise had been previously stocked in this same pond on various dates. Total number of all fish stocked was 8,743 (795 per acre). The total weight of all fish at the time they were stocked was 877.0 pounds; average weight per fish was 0.10 pound.

The number of *Heterotis* and the number of carp stocked per acre were comparable, and rearing techniques were similar. Biomass was estimated in each pond every 2 weeks on the basis of seine samples. The feeding rate was adjusted at each interval to 3 percent of the total fish weight in each pond.

By mid-May the carp had been fed for 5.5 months and averaged 1.58 pounds each; *Heterotis* had been in the ponds approximately 6.5 months and averaged 0.35 pound each. These weights were calculated on the basis of samples from each pond taken with a 200-foot seine.

On this basis, and assuming 100 percent survival, carp production was 1,256 pounds per acre. Complete draining records are not available to support these data. However, the average size of the *Heterotis* remained the same over a period of several additional months.

It is thought that *Heterotis* consumed little of the feed directly. The pond developed a dense bloom of brown microorganisms, but problems with low oxygen levels were not encountered.

Some local market women purchased the small *Heterotis,* but at low prices and in small quantities. Eventually the pond was drained. The fish that could not be sold were discarded or given to the farm workers.

Heterotis is not highly prized by Nigerians. However, those few fish that did grow to 1 pound or more were readily sold at N0.50 (U.S. $0.75) per pound. One hundred *Heterotis* per acre were stocked in the 1981 carp production ponds in an attempt to judge their potential in polyculture. These ponds have yet to be harvested.

MARKETING

Initially, imported carp were given free to selected people at all strata of Nigerian society: villagers, fishermen, farmers, skilled workers such as mechanics and heavy equipment operators, policemen, civil servants of all ranks, bankers, and upper echelon military personnel. A number of these fish were served to expatriates of many nationalities at a large fish fry held on the farm site. While organoleptic tests were not conducted, the general reaction to the fish was highly favorable.

In May 1978, the surplus imported fish were made available for purchase. The price was arbitrarily pegged at a level thought to be well above production costs. This price was N1.00 (U.S. $1.70) per pound of whole fish in wholesale quantities, and N1.25 (U.S. $2.12) per pound at retail. There was some initial reluctance on the part of

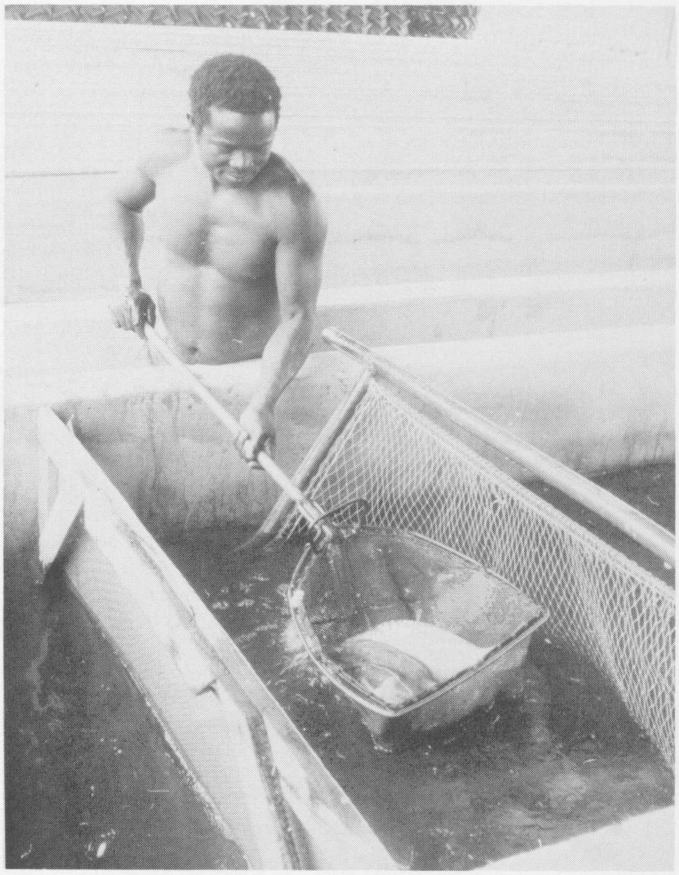


FIG. 9. LEFT—fish are sold live in Nigeria because of higher price and greater demand; RIGHT—fish are maintained in live-holding facilities for retail sales at the fish farm.

the buyer, but the high quality of the fish prompted sales of 12,756 pounds at an average price of N1.15 per pound (U.S. $1.95 per pound). Most fish were sold at pond bank. However, West African Shrimps (Nigeria) Ltd., a large offshore trawling, processing, and sales firm, purchased approximately 2 metric tons of these carp for resale. They found a good demand for these fish frozen during periods of low supplies of the cheaper "trash fish" captured as a by-product of shrimp fishing.

Both the wholesale and retail prices of the carp from subsequent crops were allowed to keep pace with the rapidly inflating Nigerian economy. By the end of 1981, the wholesale price per pound had been increased to N1.25 (U.S. $1.87) in lots greater than 500 pounds and N1.50 (U.S. $2.25) in lesser amounts. The retail price was uniform at N1:75 (U.S. $2.62). There was market resistance at these levels and downward adjustments were under consideration.

Fish were sold live in both retail and wholesale quantities at pond bank, and later at the live-holding facility on the farm, figure 9. Certain bulk customers, such as restaurants, catering services, and meat retailers, established standing orders for scheduled delivery. A nominal live-haul charge was added to the price of the fish. All fish were priced and sold live or dead, in-the-round.

The surplus imported fish had reached an average weight of about 5 pounds when they were marketed. These fish were in high demand and sold readily. F-1, -2, -3, and -4 generation Aviara fish were stocked at about 1,000 per acre, anticipating 2-pound-average-size market fish.

Due to factors mentioned above, it was necessary to put these fish on the market at a smaller size. One-pound carp were not favorably received. One and one-half pound carp were more favorably received, and carp weighing 2 pounds (approximately 1 kilogram) or more sold readily.

As inland aquaculture is expanded in Nigeria, the size at which fish are grown for market should be carefully considered in production planning.

AN ASSESSMENT OF COMMERCIAL FISH FARMING IN NIGERIA

The controlled production of fish in ponds in significant quantities could have a favorable impact on the Nigerian effort towards self-sufficiency in the production of food. The major portion of the Nigerian land mass is geologically and topographically unsuited to the construction of fish farms on a large scale. Those areas with suitable topography, such as the vast sub-Saharan north and the savanna and coastal plain regions to the south, are composed primarily of sandy soils.

Although rainfall is heavy in the rain forest areas of the south, the north is arid. Subsurface water is not abundant in the north. With some exceptions, even the larger streams are intermittent in terms of supplying adequate water for large irrigation schemes or fish farm complexes. In the latitudes of heavy rainfall, there is an overabundance of water during the rainy season, much of which is lost to runoff. During the dry season it is not uncommon for towns and villages to have difficulty in maintaining an adequate supply of water for domestic purposes.

Some geographical areas in Nigeria do lend themselves to the physical development of fish ponds on a meaningful commercial scale. The flood plains and deltas of the major rivers, principally the Niger and the Benue, are extensive enough in places to accommodate large acreages of ponds. Because of their alluvial nature, they are relatively flat and are formed of imperviums composed of silts and fine clays. Surface water is readily available, and waterbearing sands from which organism-free water can be drawn in quantity through bore-holes are usually close to the surface, figure 10.

Immense areas of tidal mangrove swamps lie between the beach ridges of the Atlantic Coast and the rain forest and coastal plain soils of the mainland. These swamps extend for almost the entire length of the Nigerian seaboard. The surface water is mostly of low salinities, except close to the sea. Tidal variation is great enough to permit managed flooding and draining of ponds, whose banks can be built of the sedimentary soil. The tropical and sub-Saharan climates of Nigeria afford a 12-month growing season for both crops and fish.

From the preceding discussion of the Aviara experience, it is apparent that there are certain biological problems and problems associated with water quality that must be overcome to affect a viable aquacultural procedure for Nigeria. These are not thought to be insurmountable, or even serious problems. The assumption is that they can be routinely solved.

The major constraint to medium-technology fish production in Nigeria is the lack of an internal infrastructure to supply the requirements of the industry. Almost all of both hard and soft commodities or some of their components must be imported. Tractors, trucks, spares, feedstuffs, special fish farm equipment, and many other items are in short supply due to the rapidly expanding Nigerian economy and industrialization.

Skilled workers are rapidly absorbed by the oil exploration and production companies, other industries, and commerce. There is a need for more highly trained and experienced aquacultural scientists, although there has been some improvement in this area during the last decade.

There is a shortage of private sector risk capital available for unproven ventures, even though certain government programs encourage private investments in agriculture.

The overall assessment by the Project Leader as to the potential of commercial aquaculture in Nigeria is optimistic. The Aviara Fish Farm compares favorably with similar farms in the United States, Israel, and elsewhere. In spite of major short-falls in the inputs, the production record is good. The chronic shortages in logistics and supply should become less and less severe as Nigeria's industrial and agricultural base widens.

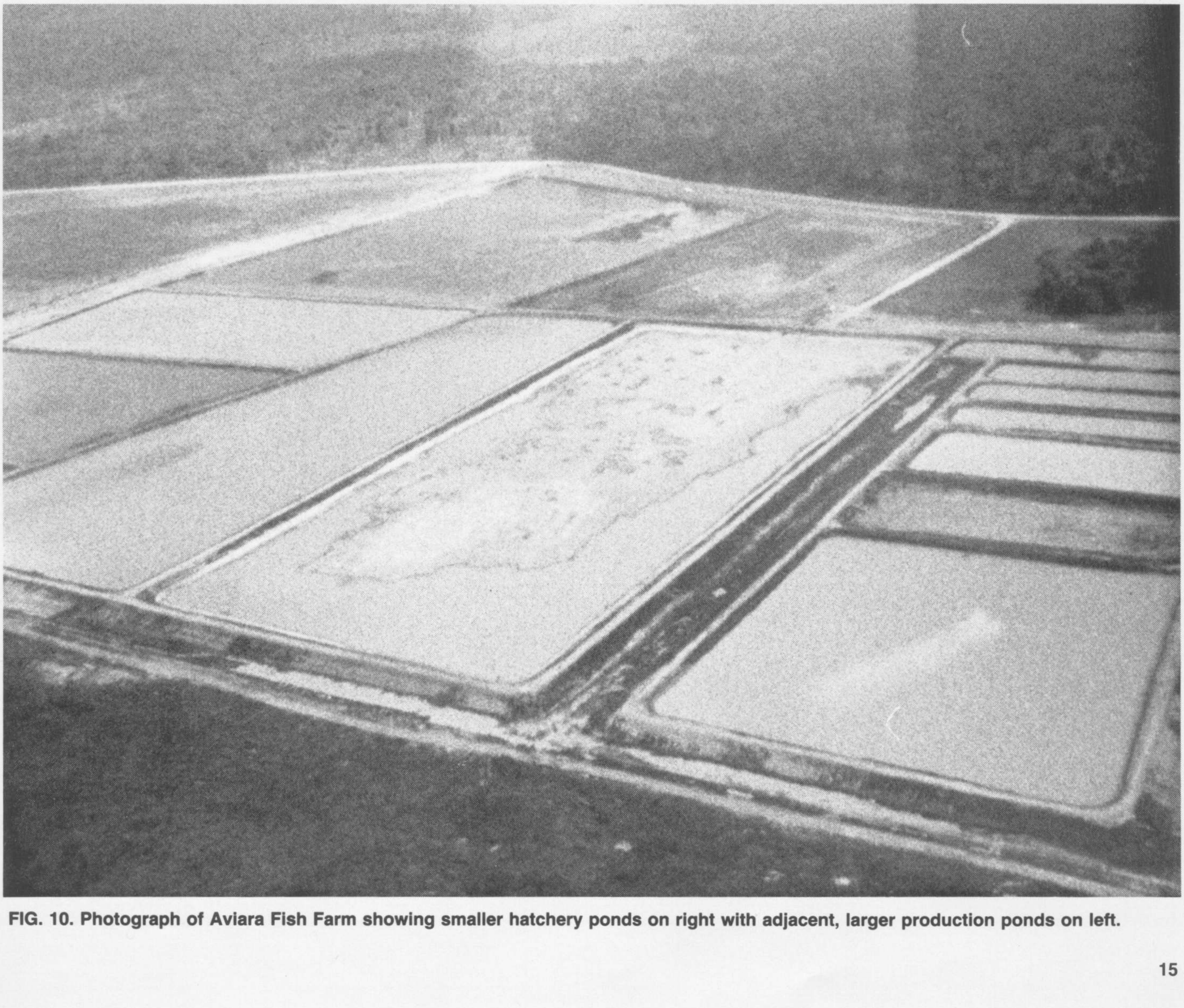


FIG. 10. Photograph of Aviara Fish Farm showing smaller hatchery ponds on right with adjacent, larger production ponds on left.