Franklin A. Purgason. CATFISH FARMING IN NORTH CAROLINA. (Under the direction of Dr. Philip Shea) Department of Geography and Planning, April 1985.

Since the 1950s, commercial catfish farming has grown into an industry worth in excess of 100 million dollars annually. The industry is established in fifteen states, principally in the south. The general purpose of this thesis was to trace the growth of the North Carolina catfish industry and to examine some of the factors that have influenced it. The specific purpose of the study was to compare the relatively small North Carolina industry to that of Mississippi, in order to determine some of the reasons for the differences between the two. Research methodology included a review of the existing literature and on-site interviews in North Carolina and Mississippi. The study areas were selected because Mississippi is the largest catfish producing state while North Carolina is one of the smallest producers.

The results of the research indicate that the southern portion of North Carolina's Coastal Plain is physically suitable for the production of catfish. It was noted that the North Carolina industry was not successfully established until 1980. This was probably due to a lack of a local market and a failure to adequately plan and finance early efforts. The North Carolina industry is quite different from the Mississippi industry: the North Carolina operations are

geared to supply a small local market while Mississippi supplies a large national market. This difference in markets dictates that techniques and equipment differ greatly between the two state industries.

The study concludes that North Carolina has potential as a commercial catfish producer, but that it probably will not become a significant producer on a national scale.

CATFISH FARMING IN NORTH CAROLINA

A Thesis

Presented to

the Faculty of the

Department of Geography and Planning

East Carolina University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts in Geography

by

Franklin A. Purgason

April 1985

CATFISH FARMING IN

NORTH CAROLINA

by

Franklin A. Purgason

APPROVED BY:

DIRECTOR OF THESIS Philip Shea

Dr. Philip Shea

CHAIRMAN OF THE DEPARTMENT OF GEOGRAPHY AND PLANNING

Mr. Wes Hankins

DEAN OF THE GRADUATE SCHOOL

Joseph A. Boyette

Dr. Joseph Boyette

ACKNOWLEDGEMENT

This thesis, like so many others, would not have been completed without the support of a number of persons. Recognition is given to Dr. Ennis Chestang, Dr. Paul Tschetter, and Dr. Charles Ziehr, thesis committee members who were remarkably patient and offered many helpful suggestions. Dr. Phillip Shea, thesis director and graduate advisor, earned and deserves special thanks for his encouragement and guidance. I am grateful to the many persons in North Carolina and Mississippi that provided me with material, information, and their time. A very special thank you is extended to my wife, Marjorie, who offered encouragement and support, and learned more than she wanted to know about catfish.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

CHAPTER 1

INTRODUCTION

The cultivation and harvesting of catfish, principally Ictalurus Punctatus, generates in excess of 100 million dollars in farm income annually in the United States (Bureau of the Census 1982). The cultivation of catfish is not an aspect of agriculture; it is more properly termed 'aquaculture'. Practiced for over 3,000 years, aquaculture is the controlled cultivation and harvesting of aquatic plants and organisms. As diverse in technical complexity and geographic distribution as agriculture, aquaculture accounts for 10% of the world's fish production, with 65% being cultured in Asia (JSA 1983, Shang 1981).

Fish provide over half of the human population with 50% or more of their animal protein (Shang 1981). With a projected population increase of 3 billion by the year 2000 A.D., man must find and develop food sources in order to feed himself. The world ocean, with a current annual catch (of all species) of 75 million metric tons, has an estimated sustainable annual yield of 100 million metric tons (Ryther 1981). The ocean cannot supply the fish to meet the expected demand, so aquaculture is seen as a possible, partial solution to feeding the growing population (Shang 1981). Some countries, such as China, India, and Israel, obtain 25% or more of their fish from aquaculture. Annual aquaculture production world wide has increased from 1 million metric

tons in 1966 to over 9 million metric tons in 1979 (JSA 1983). Production is expected to triple by the year 2000 (Brown 1977).

Aquaculture operations may be classified on the basis of the amount of labor and energy input required by the production system. This classification system ranges from extensive (using little or no labor and no supplemental feeding) to intensive (dependent on supplied feeds and requiring large amounts of labor).

The milkfish industry of the Philippines is an example of an extensive aquaculture operation. The milkfish, a marine species, is trapped in lagoons or coves by the local populace using nets or primitive fencing. The fish are allowed to grow to a usable size, then harvested for local consumption. There is no supplemental feeding, and the only labor required is to place the nets and in harvesting.

The catfish industry of the United States is an excellent example of intensive operations that control the fish from breeding to final consumption in the national market. Fish eggs are obtained and fertilized. The resulting fish are then hatched out in hatcheries, where they are medicated and fed man-made feeds. The growing fish are then held in man-made containments until they reach harvestable size. At that point they are processed in relatively 'high tech' plants, and at last are shipped to market. There is minimal waste, and that is recycled as an ingredient in the catfish feed.

The largest portion of the annual United States production of catfish goes directly into the food markets, either as fresh dressed or as frozen products. The remainder of the production is divided into stocking 'fish out' ponds, replenishing wild stocks, and establishing breeding stock (Table 1).

TABLE 1. FARM-RAISED CATFISH PROCESSED BY TEN LEADING PROCESSING PLANTS, 1969-1981

YEAR	PRODUCTION (live weight processed) (1,000 lb.s)	PERCENT INCREASE (from previous year)
1981	60,492	30.19
1980	46,464	14.34
1979	40,636	34.67
1978	30,179	36.38
1977	22,125	16.58
1976	18,978	17.58
1975	16,140	-4.7
1974	16,944	-13.87
1973	19,731	7.6
1972	18,331	62.84
1971	11,257	96.08
1970	5,741	79.35
1969	3,201	N/A

source: USDA Aquaculture Outlook and Situation, 1981, 1982

Humphreys County, Mississippi, claims the title of 'Catfish Capital of The World', with 90% of Mississippi's 62,289 acres of production ponds and 60 to 70% of the total United States production within 65 miles of Belzoni, the county seat. Arkansas is second in production with approximately

9,300 acres of ponds, and Alabama third, with around 8,200 acres of ponds (USDA 1982). North Carolina's production, while relatively small, is large enough to include the state in the list of significant catfish producing states (Table 2).

TABLE 2. CATFISH PRODUCING STATES

Alabama	Idaho	Pennsylvania
Arkansas	Louisiana	South Carolina
California	Mississippi	Tennessee
Florida	Missouri	Texas
Georgia	North Carolina	Virginia

source: USDA Aquaculture Situation and Outlook 1982

STATEMENT OF PROBLEM

This thesis traces the growth of the catfish farming industry in North Carolina, and establishes some of the reasons that may support catfish as a major economic product in the state by examining the following major factors:

1. Parts of North Carolina, specifically the southern Coastal Plains and the Piedmont, are suitable for catfish cultivation since they have similar environments to the leading catfish producing states (Mississippi, Alabama).
2. Past efforts to cultivate catfish in this state have suffered due to a lack of technical expertise on the part of the growers, and a local prejudice against the fish.

3. The North Carolina catfish industry consists almost entirely of 'fish out' operations and future expansion depends on supplying retail food fish markets.
4. The potential for the successful development of a local catfish industry does exist.

METHODOLOGY

Research information on the catfish industry was obtained through the use of interviews, maps, and published literature. In particular, the development of the industry was traced through interviews with current growers and state agricultural extension personnel, the use of statistical data obtained from the United States Departments of Agriculture and Commerce, and through information obtained from the various catfish growers and processors associations. The suitability of North Carolina for catfish farming was tested by comparing the requirements of Mississippi catfish culture: temperature range, growing season, availability of suitable land, and water quality and availability, to North Carolina's environment.

REVIEW OF LITERATURE

The catfish industry in the United States has been documented in literature at the national level and within the major catfish producing states. The majority of publications and studies are technical and are concerned with the

mechanics of the industry: growing, harvesting, transporting, and processing catfish. Most of these publications are published by the agricultural extension services of the leading catfish producing states; Mississippi, Alabama, and Arkansas. The United States Department of Agriculture has also published pamphlets on various aspects of catfish farming. Catfish Farming (1982) and Building A Pond (1973) are two of the USDA publications.

The United States Army Corps of Engineers (1982) and Wheaton (1977) deal with the engineering aspects of aquaculture in various situations. The Corps of Engineers have published limited data on the use of dredge spoil for constructing aquaculture containments, and the advisability of using such containments. Wheaton addresses the construction of various types of aquaculture operations with regard to the most efficient use of resources and space.

Several journals, such as Farm Journal, Feedstuffs, Aquaculture, and The American Fish Farmer, offer statistical and technical information about catfish farming, as well as other types of fish farming and conventional agriculture.

The Catfish Farmers of America, a national catfish growers and processors organization, publishes an industry magazine, The Commercial Fish Farmer, that is not restricted to catfish farming. It includes information about the cultivation of shrimp, trout, crab, and other aquatic organisms.

The Catfish Farmers of America also publishes market

research and technical papers, as do various state level grower and processor associations. These publications tend to be concerned with the technical aspects of catfish farming, processing, and marketing.

Mack (1971) and Lee (1973) deal with the basics of starting and operating catfish farms. Both authors have produced a basic, how-to manual that is aimed at the experienced conventional farmer. These books provide much general information about catfish cultivation.

Shang (1981), Brown (1977), Giachelli (1983), and Giachelli and Waldrop (1983) are major sources for the economic aspects of the industry. Shang provides management models for determining profit levels, as well as determining the economic feasibility of proposed or actual aquaculture operations. Giachelli and Waldrop provide extensive cash flow information concerning Mississippi catfish farms. Their joint publication, Cash Flows Associated with Farm Raised Catfish Production, is a description of various economic aspects of large catfish operations (1983).

Historical information is available from a variety of popular and technical publications. These articles are often oriented towards the general public, and thus are more 'popular' than 'scientific'. However, they do provide information concerning events, dates, and places. Madewell (1971) and Madewell and Bellew (1972) are the only sources that are concerned specifically with the historical

development of the national catfish industry. These two sources are not very detailed, and the latter appears to be a revision of the former.

The New Alchemy Institute and others have been publishing data on "backyard fish farming" or "fish-gardening", and on aquaculture as an "alternative agriculture" for the United States and other countries. Essentially, these publications concern small scale, management-intensive aquaculture operations rather than the large scale, labor-, energy-, and management-intensive operations typical of the current United States catfish industry.

The literature on the catfish industry of North Carolina is recent but less well-documented. The only state documents available concerning the catfish industry of North Carolina are lists of propagation permits issued by the North Carolina Wildlife Commission. The only other sources concerned directly with the North Carolina catfish industry are an unpublished list of catfish landings (Easley 1984) and the grant proposal for the newly-established Waccamaw-Siouan aquaculture project (Carden 1983). Trade and general publications concerning North Carolina catfish production have been searched,revealing no positive results. Several articles about the local industry, however, have been published in North Carolina newspapers (News & Observer 1984, News Reporter 1984a 1984b). A computer search using the DIALOG facility of Joyner Library and a search of geographic theses and dissertation titles revealed no other sources

concerning the North Carolina catfish industry.

HISTORICAL DEVELOPMENT OF THE CATFISH FARMING INDUSTRY

Catfish culture attracted the attention of the American scientific community in the early 1920's, and led to the establishment of research programs at numerous universities and colleges, notably in Kansas and Oklahoma (Madewell 1971, Madewell & Bellew 1972). This research was directed towards methods of breeding catfish in captivity, as it was believed that a commercial catfish operation could not be successful if it depended on fry harvested in the wild, as the size of the catch could not be predicted, the quality of fish grown from wild stock was variable, and wild fry would tend to bring disease into the cultivation areas with them.

In 1947, Ewell Nixon of Lonoke, Arkansas, began flooding his rice fields after the seasonal harvest and stocking them with channel catfish fingerlings (Popular Mechanics 1960). He then harvested the fish before preparing his fields for the next planting. The fish were sold to local markets. During the 1950's and early 1960's, commercial catfish farming developed in Arkansas and spread to Texas, Louisiana, Alabama, and Georgia. In 1965, the first pond built specifically for raising channel catfish for the food market was built in Sharkey County, Mississippi. One year later, three 10 acre ponds were built in Humphreys county (Wellborn 1984). For the next few years, ponds were 'clean cropped',

that is, all fish were removed from the pond and sold. Most of the production was sold to live-haulers, who carried the live fish in large, aerated tank trucks to processing plants or markets.

By the late 1960's, the industry had major problems. The industry practice of clean-cropping production ponds at the end of a production cycle appeared to be the root cause of many of these problems. Since most farmers tended to stock production ponds like they planted their fields (i.e. in the spring) this resulted in a huge number of fish reaching market size in a small time frame. Catfish cannot be held in ponds after reaching market size for two reasons: (1) when fed a normal diet, they will continue to grow and exceed the optimum market size, bringing lower prices, and (2) when fed a maintenance diet (one that should not allow them to lose or gain weight) they will grow long and skinny, with out-sized heads and relatively little flesh on their bodies (Steed 1984, Meyer 1984). The large amount of fish harvested swamped the available processing facilities, while the cyclic availability of fish alternately starved and flooded the markets.

In response to the problems facing the industry, cooperative associations of processors and growers were formed. These cooperatives led the way in obtaining state assistance in the development of new techniques for growing and processing catfish, development of new catfish products,

and in setting industry standards for quality and quality control procedures. At the same time, massive vertical integration occurred in the Mississippi catfish industry. Farmers, through cooperatives and individually, acquired shares in processing plants, processors built production ponds, and feed mill owners also constructed production ponds and purchased interests in processing plants. This vertical integration is a major reason for Mississippi's dominant position in the United States catfish industry (Meyer, 1984, Turner 1984, Steed 1984).

There are several state catfish associations and a national association. The purpose of these organizations is to promote market research and development, product research and development, and to provide information to members. The Catfish Farmers of America, the national organization, has been aggressive in expanding existing markets and in seeking out new markets for catfish products. The various state organizations work mainly within their respective states.

Many universities have research programs that involve catfish to some extent, Auburn University and Mississippi State University are the two primary research centers for the catfish industry in the United States. Auburn University was for many years the leading research institution, but Mississippi State has overtaken and passed it in terms of financial and personnel support. Mississippi has approved and will soon begin construction of a genetics research facility specifically for catfish. This facility will be

under the operational and administrative control of Mississippi State University, and is to be located at the agricultural research station at Stoneville, Mississippi.

CHAPTER 2

THE UNITED STATES CATFISH INDUSTRY

Since they are 80% lean, catfish are advertised by the catfish industry to be nutritionally superior to beef, pork, and chicken. They are more efficient at converting feed to flesh (Table 3) and can be raised in great density in ponds, raceways, or cages. With yields reaching 3,000 pounds per surface acre in ponds on average commercial farms, and higher in raceway and cage operations, channel catfish are far more economical to grow than field animals (Mack 1971, Lee 1973, Shang 1981).

TABLE 3. DRESSING PERCENTAGE(a) AND FEED/FLESH CONVERSION RATIOS FOR BEEF, PORK, CHICKEN, AND CHANNEL CATFISH(b)

FLESH	DRESSING PERCENTAGE	FEED/FLESH CONVERSION RATIO (lb.s feed: lb.s flesh)
BEEF	58	8.0:1
PORK	65	6.0:1
CHICKEN (broiler)	72	2.1:1
CHANNEL CATFISH	60	1.4:1

source: Lovell 1979, Sokolov 1982

a. marketable percentage of the carcass after dressing

b. conversion ratios of 1.17:1 have been attained under laboratory conditions (USDC 1979) commercial catfish farms average ratios of 1.7-1.8:1 (Steed 1984)

The channel catfish (Ictalurus Punctatus) is the first choice of the industry for commercial production. It is hardy, with good growth characteristics and marketability both as a food and sport fish. To a lesser extent, the blue catfish (I. Furcatus) and the white catfish (I. Catus) are grown commercially, and other species of catfish, such as the brown (I. Nebulosus), the yellow (I. Natalis), and the flathead (Pylodictus Olivaris), have received attention in research and field trials. These species show potential for commercial production, but the channel catfish is superior to them and remains the primary choice of catfish farmers in the United States (Table 4).

TABLE 4. ESTIMATED CATFISH PRODUCTION ACREAGE IN THE UNITED STATES BY YEAR

YEAR	ACRES	ANNUAL PRODUCTION (pounds)
1960	400	320,000
1970	40,400	40,000,000
1980	54,500	76,677,000
1982	80,000	200,000,000

source:Joint Subcommittee on Aquaculture 1983

There are three major divisions in the United States catfish industry: fingerling production, fee fishing, and food fish production. With the exception of Idaho, Pennsylvania, and California, these divisions extend over the same geographical area (Figure 1). This is due to the fact

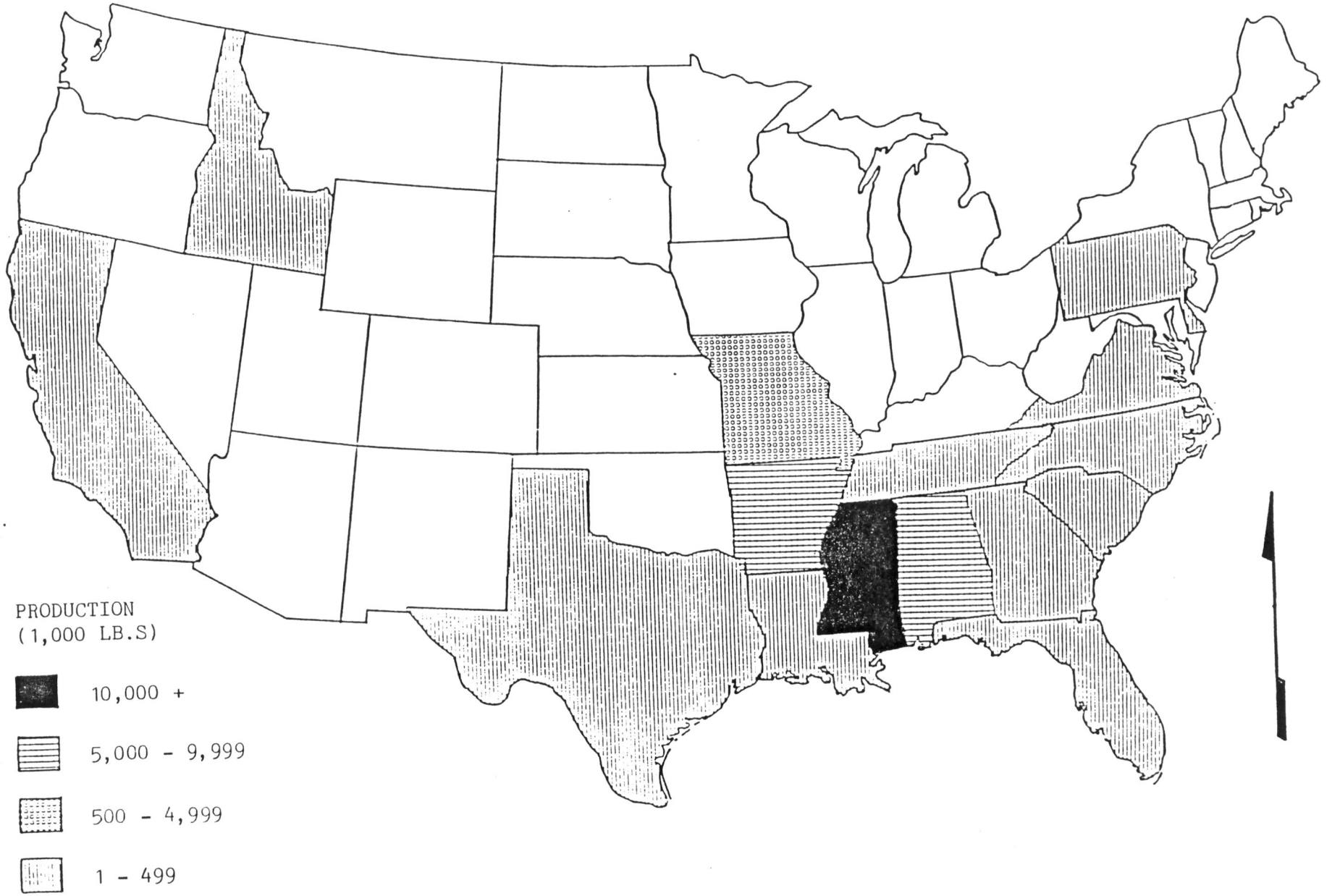

FIGURE 1. Catfish Producing States by Production

that fee fishing and food fish production depend on fingerling production for their existence. In addition, the physical environmental requirements of catfish remain the same, regardless of eventual use. The industry is located mainly in the south-central and southeastern states. Idaho is able to produce catfish by double cropping them with trout in raceways. When the summers grow too warm for the trout to grow well, catfish fingerlings are stocked in the raceways and grown to size and marketed. Pennsylvania's catfish production is due to using power plant effluent water as a source. The heated water extends the growing season, allowing the fish to reach a useable size in a reasonable time (Godfriaux 1979). California has high water costs due to extensive deep well pumping for irrigation. However, the local market and demand is great enough to offset the increased water costs in that state (Steed 1984).

FINGERLING PRODUCTION

Fingerling production is the key to the entire catfish industry. Without a reliable year round supply of high quality fingerlings, production of adult fish would be a gamble at best. Using fry or eggs obtained from the wild yields unreliable quality and the increased possibility of disease. In addition, the chance of introducing foreign fish, either predators or trash fish, is greatly increased when using fry or fingerlings obtained from the wild.

In general, commercial fingerling production is closely

associated with the other two divisions of the industry. Many commercial catfish farms operate hatcheries to supply fingerlings for their own use, as well as a separate product.

A small number of channel catfish are selected, on the basis of conformation to industry standards, to be brood fish. Starting at around three years of age, small female catfish (3-4 lb.s) can lay 4,000 eggs per pound of body weight, medium sized females (5-7 lb.s) 3,000 eggs per pound of body weight, and the large females (8-15 lb.s) can lay 2,000 eggs per pound of body weight. Larger brood fish are often used, as they produce a larger total number of eggs (USDA 1982).

The brood fish are maintained in special tanks or ponds and fed a diet similar to that of production catfish. The fish are separated by sex until they are needed for egg production. The natural breeding seasons occurs over a 15 to 20 day period at water temperatures ranging from 78 to 82 degrees (F). The fish can be encouraged to breed out of season by the use of hormone injections and by manipulating water temperature, by holding at or above 70 degrees (F) for 2 to 3 days.

The breeding pairs are placed in special brood ponds, either at a rate of 10 to 20 pairs per surface acre, or one pair per pen. The first method, called open pond spawning, requires less experience and equipment than the second. Nests, usually milk cans, wooden boxes open at one end, or large drain tile are placed in the pond at depths of two to

four feet (USDA 1982, Turner 1984).

The second method, pen spawning, uses several pens in a single pond (Figure 2). The pens are about five feet wide by ten long and extend into water two feet deep. Up to 20 of these pens have been used in a 1/4 acre pond. Each pen contains a nest for the fish to lay their eggs in. This method requires the brood fish to be handled more, and is used by experienced breeders, especially those specializing in fingerling production (USDA 1982).

In both methods, the eggs are laid in the nests provided by the farmer. The eggs can be allowed to hatch in the brood pond, or can be removed from the nests and placed in an 'incubator' (Figure 3). Catfish incubators are troughs equipped with paddles or paddlewheels that agitate the water, fanning the egg masses. This agitation simulates the fin action of the parent fish, who would stay in the nest until the eggs hatch after 6-10 days.

If the eggs are left in the brood pond until hatching, the fry can be handled two ways. They can be left in the brood pond until they reach fingerling size (2 inches or larger) or placed in separate rearing ponds shortly after hatching. In either case, they are fed until fingerling size is reached - the stage where the fish are ready to be placed in the production ponds.

If the eggs are hatched in an incubator, the number of fry are estimated (1,000 fry displace approximately 1 oz.

FIGURE 2. Catfish brood pens at Buck Trail Aqua Farms, Lake Waccamaw, N.C. This pond is also used to produce shrimp.

of water) and then are placed in holding tanks. The tanks can be built of a variety of materials, such as poured concrete, concrete blocks, wood, or galvanized metal. A typical vat is thirty feet long, four feet wide, and three feet deep. Clean water with an oxygen content of at least 5 parts per million (ppm) is run through the vats at 5-7 gallons per minute (gpm). After reaching fingerling size fry are transferred to rearing ponds (Mack 1971, Lee 1973) (Table 5).

Catfish fry grow faster and have fewer diseases and parasites if they are removed from the brood ponds and stocked in separate rearing ponds. The size of the fingerlings at the end of the first growing season depends on the stocking rates and the daily feedings.

Usually sold by the thousand, fingerlings are priced according to size and weight. The size of fingerlings purchased depends on the needs of the purchaser. Ninety percent of fingerlings sold in the United States are used to produce food fish, the remaining 10% are used in fee fishing operations, or as breeders (Sokolov 1982).

FEE FISHING

Fish out, or fee fishing, operations charge an access fee for the right to fish in lakes and ponds that are stocked and maintained by the operator. In some cases there is an additional 'per pound (live weight) of fish caught' fee. Fee fishing operators usually purchase larger fingerlings (8

TABLE 5. AVERAGE LENGTH AND WEIGHT OF 1-2 INCH FINGERLINGS AT THE END OF FIRST 180 DAY GROWING SEASON

NUMBER STOCKED PER SURFACE ACRE	FISH	TOTAL WEIGHT OF FISH	AVERAGE WEIGHT PER 1,000 FISH	AVERAGE LENGTH OF FISH
	number(A)	pounds	pounds	inches
40,000	30,000	600	20	4
30,000	22,500	720	32	5
20,000	15,000	900	60	6
15,000	11,250	1,050	93	7
10,000	7,500	840	112	8
5,000	3,750	675	189	9

source: USDA 1982
(A) assume a 25% loss

inches or more) for their ponds, because they take less time and feed to grow to a size that is acceptable to the fee-fisherman. Fee fishing is not uncommon in the United States, but catfish fee fishing seems to be most common in the southern and southeastern states. This is possibly due to the traditional use of catfish as food in some of these states, and to a regional preference in sport and food fish (Turner 1984, Rouse 1984). In addition, fee fishing operations seem to be most common near urban centers where they provide a satisfactory form of recreational outlet. Heavily stocked fee fishing ponds and lakes almost guarantee

FIGURE 3. Catfish hatchery troughs, or incubators. The eggs are placed in the wire baskets, and the rotating paddles agitate the water.

a catch. By stocking more than one species of fish, the fee fishing operation can attract a larger clientele. Fee fishing operations, however, consume less than 10% of catfish fingerlings produced, and the economic value of these catfish is considerably less than that of catfish produced for food (Steed 1984).

FOOD FISH PRODUCTION METHODS

The production of catfish for food is the largest, fastest growing, and most dynamic aspect of the United States catfish industry. There are several methods used to produce catfish for food; pond, raceway, and cages are the most common.

CAGES

Catfish production cages (Figure 4) are used in water bodies, man-made and natural, that are impractical to harvest by conventional means. They may be large, or simply have rough, uneven bottoms that limit the use of nets. The principle design requirement for the cages is that they be floated with several feet between them and the bottom of the water body. This is to allow waste materials to settle out of the cage. This method is used to some extent in several of the catfish producing states.

Stocking densities in cages are much higher than pond rates because waste falls away from the cages and fresh water can flow through them. Using the high densities possible in cages, a farmer can produce very high yields per unit of

FIGURE 4. Cages of this type are used in the production of catfish. The cages are suspended from floats or docks in deep water.

surface area. However, it is not possible to get multiple harvests from cages. The method does require deeper water that does pond production, and the fish can be lost if the cages are damaged.

When a cage is to be harvested, it is simply hoisted from the water and the catfish weighed and dumped into live haul trucks to be transported to the processing plant.

RACEWAY

Raceway production of catfish is very similar to typical trout production. Long narrow troughs, made of concrete, metal, fiberglass, or dirt, are stocked at high densities. The constantly flowing water in the raceways carry away wastes, maintain high oxygen counts, and allow the very high stocking rates. This method of catfish production is used in Idaho, where catfish are actually double cropped with trout. When water temperatures get too high for trout production, the catfish are substituted.

POND

Pond production is the most common method of raising catfish for food. Ranging in size from 1/4 to 80 acres, artificial ponds are constructed specifically for use in growing catfish. The size and shape of these ponds varies with the size and location of the operation, and the use for which it is intended. The ponds are designed for ease of access for easy stocking, feeding, and harvesting. The only common feature to these ponds is a smooth bottom.

Most ponds are diked (Figures 5 & 6) or built above ground level in order to prevent or minimize the amount of runoff entering the ponds. Runoff can carry pesticides and sediments, either of which can render catfish unfit for human consumption, into the ponds. The dikes are constructed such that they are just wide enough for required equipment to move on them, and usually rise only a foot or two above the normal water level. The sides of the dikes are planted in grasses in order to minimize erosion problems.

Other types of ponds used in catfish production are excavated and embankment ponds (Figure 7). Excavated ponds are simply scooped out of the earth and flooded. Embankment ponds are created by constructing a dam on a free flowing stream. These ponds are used for fish out operations in many parts of the United States, but they have disadvantages when it comes to the commercial production of food fish. The design of these ponds is such that runoff enters them easily. This can cause the water to be murky, and the pond to silt up fairly rapidly. Algae can also be a problem. These ponds can be difficult to harvest, as the embankment ponds often have irregular shapes, and the banks of the excavated pond may not be able to support heavy equipment.

Mississippi State University researchers have found that large diked ponds tend to have problems with wave erosion of the dikes. Wind-generated waves can reach a

FIGURE 5. Diked ponds under construction at the Pamlico Estaurine Laboratory, Aurora, NC. The topsoil is removed and the ground scooped out to a depth of one or two feet. The spoil is used to construct the dikes.

FIGURE 6. Dry diked pond at the Pamlico Estaurine Laboratory. This type of pond is most common in the industry and can be as large as eighty acres. Note the smooth bottom.

FIGURE 7. Embankment pond near Kinston, NC. This type of pond is used for the commercial production of catfish, but it has several disadvantages.

height of 1-2 feet on an eighty acre pond, and cause rapid and severe erosion of the dikes (Meyer 1984). Smaller ponds tend to have efficiency problems: maintenance and labor costs are not offset by the yield of the smaller ponds.

The researchers have found that the eighty acre, four pond production unit is the most economical and efficient combination possible for large catfish operations (Wellborn 1983). The production unit consists of four slightly rectangular ponds arranged two by two (Figure 8) The surface area of each of the ponds is 17.7 acres; the rest of the unit is made up of dikes, access road and ramp, a central well and pump, and feed storage areas. The energy useage of one of these units is estimated to be equivalent to that of a broiler (chicken) house (Wellborn 1983).

The advantages to these production units are:

1) The ponds are large enough to yield large quantities of fish.
2) The 2 x 2 arrangement of the unit's four ponds facilitates the efficient use of labor and machinery.
3) The small pond size retards the development of wind-generated, destructive waves.
4) The twenty-acre ponds are most cost effective in producing marketable catfish.

The eighty-acre production unit shares some of the disadvantages of regular production ponds. Both have

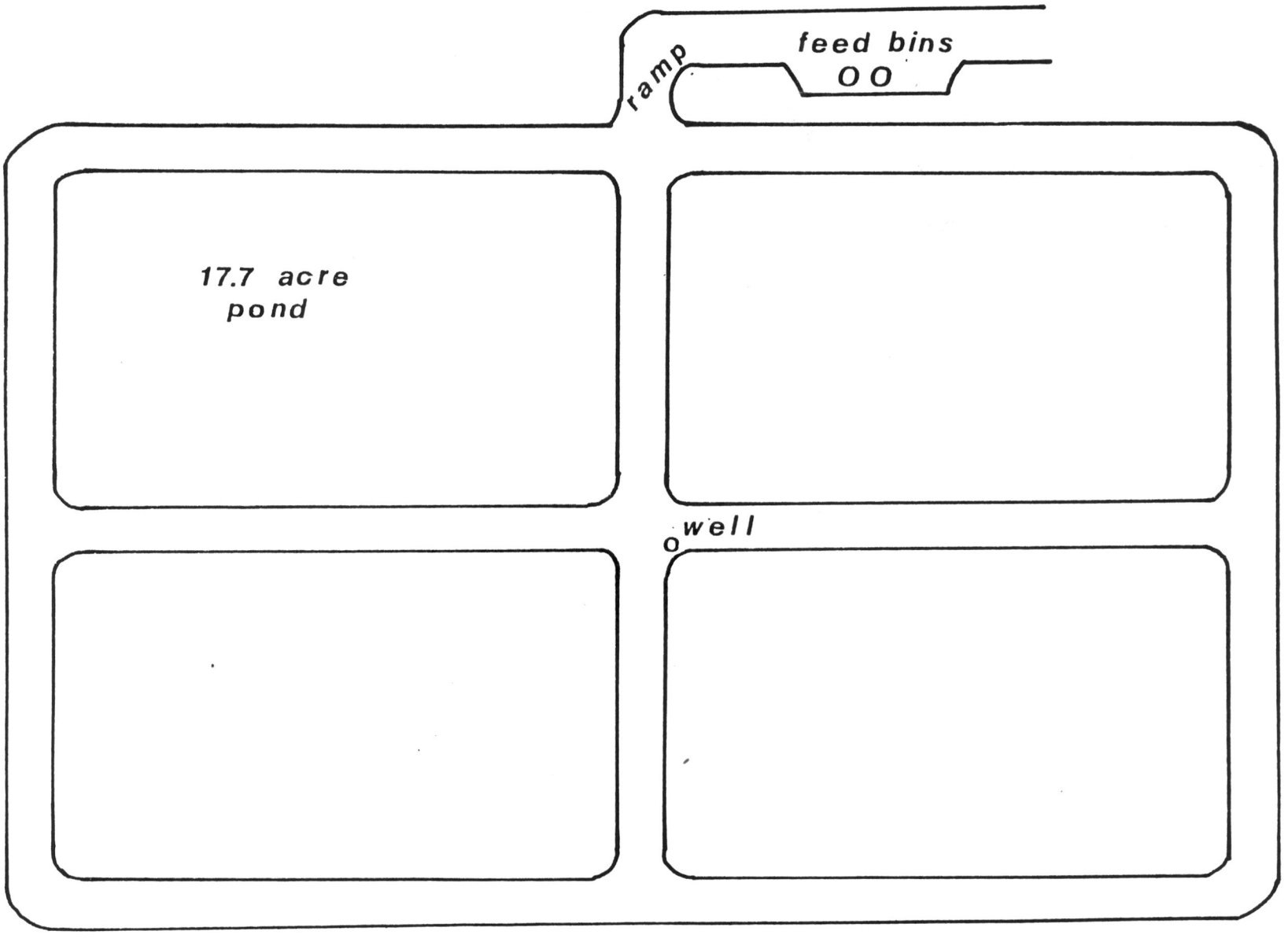

FIGURE 8. Typical eighty acre, four pond production unit.

problems with oxygen depletion. Oxygen content of the ponds is at its lowest in the early hours of the mornings. If oxygen content drops too low, many, if not all of the fish in the ponds die.

PROBLEMS IN PRODUCTION

Oxygen levels in all types of ponds are tested frequently, and anytime that the level drops below 2 parts per million (ppm) remedial action is taken. Oxygen is added to the water by spraying the water into the air with electric driven pumps, or with tractor driven paddlewheels and pump (Figure 9 A & B). The mechanical aerators consist of tractor power takeoff (PTO) driven paddles, paddlewheels, propellors, and pumps. All of these simply throw water into the air, where it absorbs oxygen as it falls back into the pond (Figure 9 C). All of these devices can be driven by electric motors, but the tractor driven units are portable, and can be moved from pond to pond. Floating, electric driven aerator pumps are common in smaller ponds, and some farmers use a 'bubbler' system. A bubbler system consists of an air compressor, air storage tanks, piping, and regulator valves. Compressed air is led into perforated pipes laid on the bottom of a pond, where it escapes and rises to the surface. The water absorbs oxygen from the rising air bubbles, which also agitates the water preventing stratification. Bubbler systems are, in theory, superior to mechanical aeration. In practice, however, this is not true. It is simply not

FIGURE 9 A. Floating electric aerator.

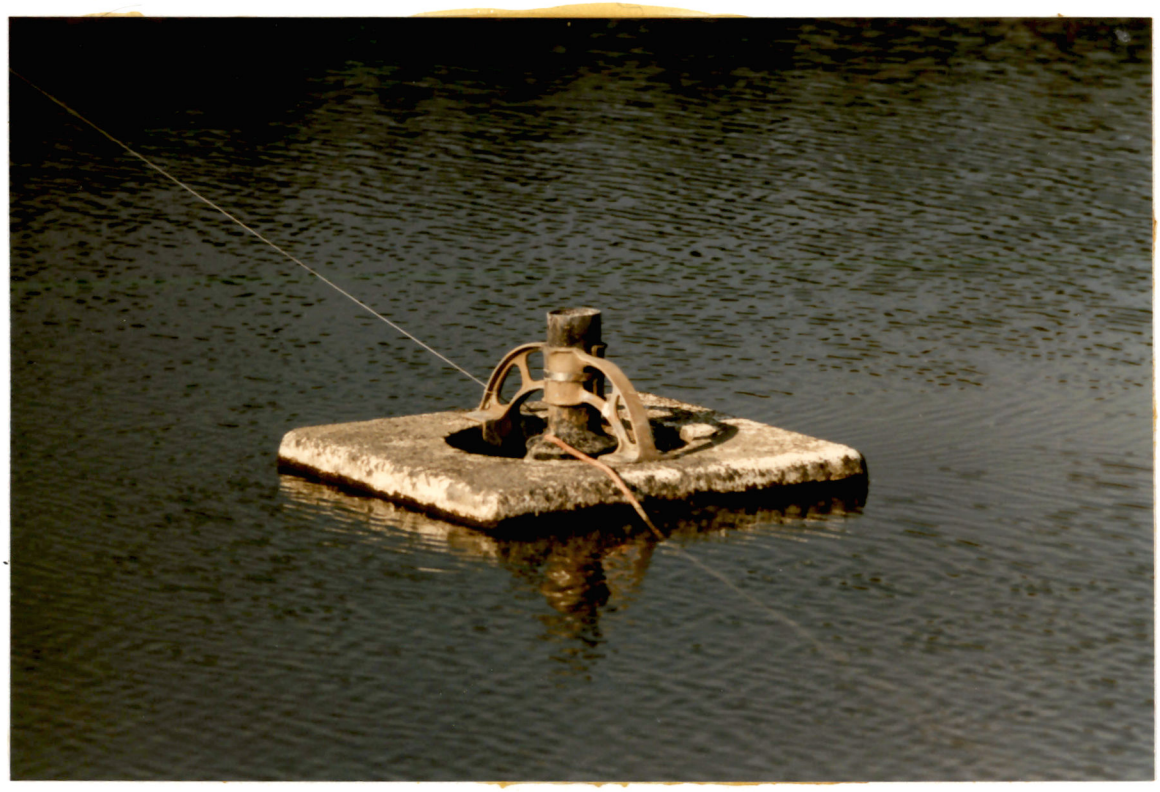

FIGURE 9 B. Floating electric aerator in place.

FIGURE 9 C. Floating aerator in use near Belzoni, MS.

practical to aerate large ponds efficiently with bubbler units (Turner 1984).

In addition to aeration, the aerators are also used to prevent, minimize, and correct stratification in ponds. Stratification of pond water is a problem in that some layers will become depleted of oxygen, and there is no natural circulation in the pond to correct it. Fish can easily die by simply moving into the depleted layers.

Aquatic plants are a problem in production ponds for a couple of reasons. The decaying plants remove oxygen from the pond water, aggravating oxygen depletion problems. Blue-green algae imparts an off-flavor to the flesh of catfish. Ridding ponds of plants is a major problem in itself.

Chemical agents can be used to kill the unwanted plants and their seeds, but only at the risk of contaminating the fish. Research efforts have developed methods of applying chemical agents that minimize the danger of contamination and tests to determine if the fish have been contaminated. Despite the new methods and tests, it is still more practical to prevent entry of foreign fish and plants.

The invasion of the production ponds by foreign trash fish or predator fish is limited by using filters which can also minimize the chances for algae to enter the pond. The use of deep wells as a source of water and diked pond construction are useful in combating several problems. Aquifers do not support a native population of animal or plant life, so using deep wells as water sources prevents

algae and foreign fish from entering the ponds.

Catfish farmers must also avoid over-feeding the fish. Feed that is not immediately consumed by the fish settles to the bottom of the production pond where it will deplete the oxygen supply as it decays; the decaying waste can also allow disease to become established in the pond.

HARVESTING

As harvesting begins a seine net is pulled through the pond, trapping the fish at one end. They are then lifted from the pond in large baskets mounted on hydraulic or mechanical booms, which are in turn mounted on trucks or tractors. The catch is weighed using dynamometers or industrial scales and is then dumped into a truck equipped with large water filled tanks. The truck then hauls the fish to a processing plant. These journeys are rarely more than 65 miles in length, as the stress from the harvest and subsequent ride can induce an off flavor in the fish (Steed 1984). The trucks have circulating pumps to keep the water in motion, and most have aerating equipment. This is usually a bubbler system supplied by a compressor or by bottled oxygen.

It takes about three years to bring a pond into full production, at which time it can be harvested every three months. Channel catfish reach marketable size (Figure 10) in about a year and a half. By stocking the pond several times over the first eighteen months it is in use, the catfish

FIGURE 10. 1.25 pound (standard size) catfish.

farmer will have appreciable quantities of fish in several uniform sizes. By using the appropriate mesh size (1.5"-2.5" for standard sized fish) in the seine nets, the marketable fish can be harvested while leaving the smaller fish in the pond. After the harvested fish are removed, they are replaced with a new batch of fingerlings. While each individual harvest is smaller, this method is more efficient than stocking a pond once, and then harvesting it once in eighteen months. The overall harvest is larger, and a steady supply of fish is obtained from the pond.

PROCESSING

The processing line consists of several steps. The fish are killed in the holding tanks by electrical shock. They are then dumped into tanks chilled to about 30 degrees (F). This stops any flavor changes in the fish that might occur at room temperatures. The dead catfish are beheaded on a specially designed high speed bandsaw. They are then eviscerated using a machine that literally vacuums the body cavity of the fish. The fish are skinned in a semi-automated procedure, and then are made into a variety of products (Figure 11).

The entire process takes as little as four minutes from the time the fish are dumped into the holding tanks to the time the processed catfish is flash frozen. Very little of the fish is wasted, as processing line offal is recycled into catfish feeds.

FIGURE 11. Fresh dressed channel catfish. These fish were about .5 pounds live weight.

Catfish processors currently market fish as fresh dressed or frozen. The fresh fish have a shelf-life of about two weeks while the shelf-life of frozen fish is about 90 days. 'Shelf-life' is defined as the period of time that the product can be kept without losing flavor. Catfish products include fresh dressed (headed, eviscerated, and skinned), filets, steaks, and 'nuggets' (boneless pieces cut from the leading edge of the filets).

Different products require different size fish. The standard fish size is 1.25 pounds. This standard size is convenient, economical, and processes out to a fresh dressed portion for one person (about 3/4 lb.). It is used so much in the industry that equipment, especially processing line machinery, is designed around it (Steed 1984). Larger fish are used to make steaks, while filets and nuggets can be made from the standard size and up. After a point (about 2.5 lb.s), the larger fish become uneconomical to process. They take too much time, and the cuts are not economical (too big for one portion). Fish smaller than 1.25 pounds are not useable, as they do not have enough flesh on them after processing to make up a portion. The timing of the harvest is critical: if a pond cannot be harvested on schedule, the fish will continue to gain weight on a normal diet, and will soon be to big to process economically. If placed on a maintenance diet, the fish will not gain weight, but will grow with little flesh and will not be acceptable to processors.

The catfish products are packaged and shipped to wholesale and retail markets, as well as restaurants.

Once the fish are processed and packaged, at least one processor will guarantee delivery to store shelves six states away within 24 hours (Steed 1984). This is made possible by the processing firm operating its own fleet of refrigerated tractor-trailer trucks.

QUALITY CONTROL

All of the major processors, especially those serving major markets, do extensive quality control testing on their products beyond taste testing. They test for any pesticide known to be in use within reasonable distance of their supply ponds, especially if it is applied by crop-dusters. They also test for chemicals used to control plants and trash fish. The processing firms cooperated fully with the United States Department of Commerce in setting quality control standards for the industry. These standards are as high or higher than those for any other fishery product in the United States (Steed 1984). The research performed by the processors has yielded new tests for agents that could not be previously detected.

ENVIRONMENTAL FACTORS

Catfish cultivation requires four factors to be present in a particular area. Three of these factors: suitable land, temperatures, and water, are environmental. The fourth item

is economic: there must be a market for the fish.

Land selected for excavated or diked catfish ponds must be topographically suited for the construction of the pond: it must be flat. In addition, the soil must be able to retain the water. Soils with high percentages of clays are best (USDA 1974, Bey 1985).

Properly fed, catfish grow rapidly at water temperatures between 75 and 85 degrees (F). Growth is slower between 65 and 75 degrees (F), and is minimal at temperatures less than 60 degrees (F) (USDA 1981). The leading production state, Mississippi, has a 200 day growing period (water temperature greater than 60 degrees) in its catfish producing areas (Turner 1984, Steed 1984).

Water is possibly the most critical factor in the cultivation of catfish. It must be clean, and available in large amounts. Most catfish farmers, especially those producing food fish, prefer to use 6"-8" diameter deep wells as a water source. Deep well water is clean, less likely to suffer seasonal variations, and not likely to be polluted by industrial or agricultural wastes.

MARKETS

The traditional catfish market is located in the lower Mississippi River valley. This market developed from a cultural acceptance of catfish as a food and sport fish (Meyer 1984). This market has nearly reached its maximum effective size (Steed 1984, Meyer 1984).

In order to continue its growth, the industry is making extensive efforts to expand into new regional markets in the United States and abroad. These efforts have been hampered in some areas by local prejudice against catfish (Rouse 1985, Bey 1985, Steed 1984). This prejudice is probably based on the facts that catfish are: (1) hardy animals that often live in relatively dirty water, (2) are non-selective bottom feeders, and (3) absorb flavors from their environment. In some areas, notably eastern North Carolina, catfish as food are also associated with poor persons (Rouse 1985, Bey 1985, Patrick 1985).

The national industry association, the Catfish Farmers of America, tries to create favorable impressions of catfish in potential markets by attending food shows, running free sample stands in stores and malls, and through advertising campaigns (Meyer 1984). Customer preferance surveys are used to develop new products and to improve existing products to aid in expanding markets. All of these methods are used to combat the bad image catfish have in some areas. It has been suggested that catfish be marketed under a false name, such as 'Delta Trout', in areas where they have an un-favorable image (Turner 1984).

The northeast has the most potential of any region of the United States (Meyer 1984, Steed 1984). This potential results from a large and dense population that has little or no knowledge of catfish. There is no prejudice about catfish in the northeast, and the industry feels that entering and

expanding in this market is a matter of introducing people to the fish (Turner 1984).

The industry began market surveys in Europe in 1983 with very good results. Many Europeans rated catfish as equal to Dover Sole (Turner 1984, Meyer 1984, Steed 1984). The industry will begin exporting catfish products to Europe in 1985 (Steed 1984).

CAPITAL INVESTMENTS

Giachelli has estimated the annual operating costs of a small (163 acres) commercial catfish farm to be 476,062 dollars, and 1,704,088 dollars for a large operation (643 acres) (Giachelli, Coats, & Waldrop 1982). A large part of these annual costs are interest on capital loans, depreciation of equipment and structures, and operating costs. These figures are comparable to conventional farms (Meyer 1984). The initial cost of establishing a commercial catfish farm is also high: at least 500,000 dollars (Turner 1984, Steed 1984, Bey 1985, Rouse 1984).

The initial capital investment will vary from area to area and over time. The primary components of the initial investment are land, construction, disease and pest control equipment, feeding equipment, harvesting equipment, and miscellaneous equipment. All of these costs vary with location and size of the planned project. A more detailed discussion will be found in the case studies (Chapter 3).

GOVERNMENT POLICY

Catfish farming has attracted the interest of the federal government. The Joint Subcommittee on Aquaculture, made up of representatives of the United States Departments of Agriculture, Commerce, Interior, Health and Human Services, and eight other federal agencies, has been established within the Federal Coordinating Council on Science, Engineering, and Technology. It is housed within the Office of Science and Technology Policy. This council has produced the National Aquaculture Plan. The Joint Subcommittee on Aquaculture has recommended expanded research, the establishment of means to make it less complicated to start fish farms, and provision for loans.

CHAPTER 3

CATFISH FARMING IN NORTH CAROLINA AND MISSISSIPPI

The North Carolina and Mississippi catfish industries represent opposite ends of an industrial spectrum. Between the small scale, moderately intensive efforts in North Carolina and the large scale, highly intensive operations in Mississippi lie twenty years of experience and technological development. This chapter will examine the two industries individually and then briefly compare them.

THE CATFISH INDUSTRY OF NORTH CAROLINA

The catfish industry of North Carolina consists of one food fish operation, eight hatcheries that produce catfish fingerlings, and numerous fee fishing operations. A second food fish operation is coming into production within the year. These operations constitute the North Carolina commercial catfish farming industry (Figure 12).

ENVIRONMENTAL CONSIDERATIONS

North Carolina has three physiographic regions: the Mountains, the Piedmont, and the Coastal Plain. The Mountain region of North Carolina is noticeably cooler than the other two regions, with an average annual temperature of 54.6 degrees (F), and has less than 190 frost free days annually. There are numerous springs that provide high quality water, however, the water is too cold for catfish. These springs

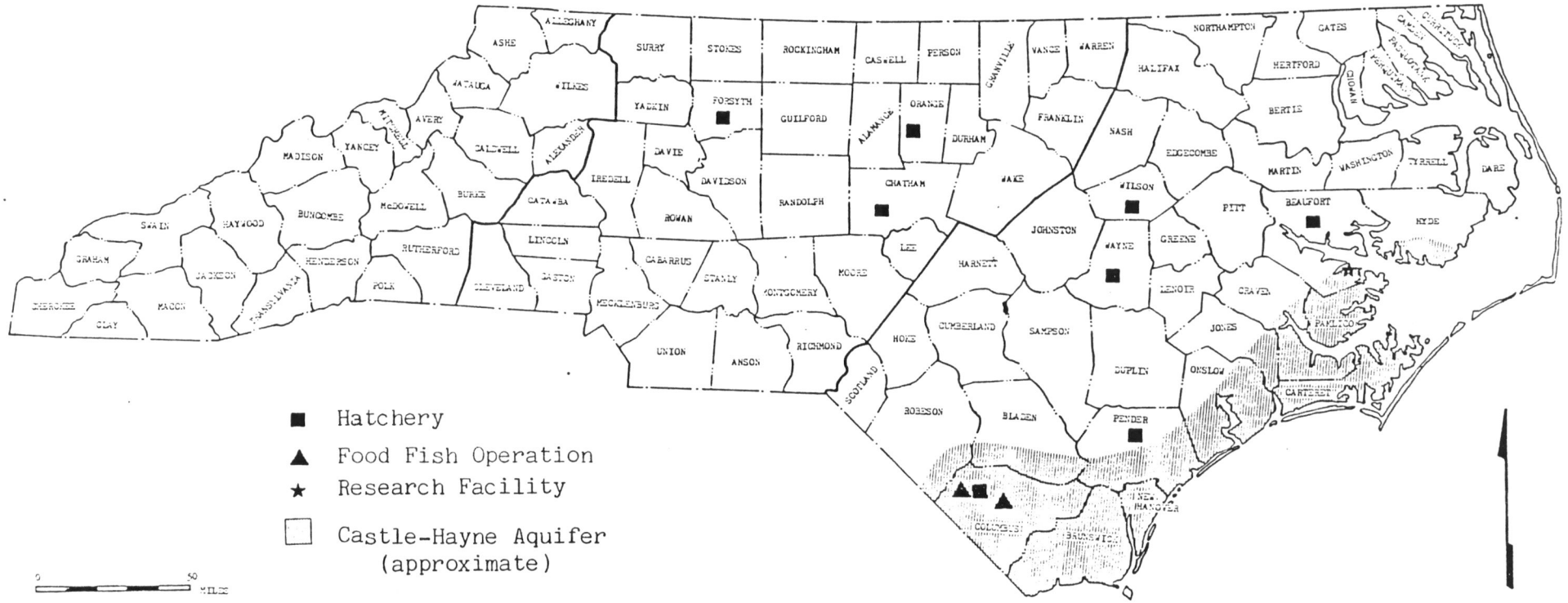

FIGURE 12. The North Carolina Catfish Industry

support a thriving freshwater trout industry that is second only to Idaho in production (Easley 1984). With cold water and an adverse climate, the Mountain region is not suited for catfish farming.

The Piedmont averages 190-210 frost free days per year, and has an average annual temperature of 60.4 degrees (F). The terrain features rolling hills. Excavated and embankment ponds are found throughout the region. Water is available from surface and ground water sources, but the ground water is deep (400-1000 feet) and well drilling operations are expensive ($25,000 for one 1000 gpm well & pump) (Hassler 1985). The marginal environmental conditions have probably contributed to the failure of all the attempts at commercial catfish farming in the Piedmont.

The Coastal Plain has an average annual temperature of 62.2 degrees (F), and a maximum of 210 to 270 frost free days per year. It is flat, rising from sea level to about 400 feet above sea level at the western side of the region. Most ponds seen in this area are excavated, and quite small (1/4 acre or less). The Castle-Hayne aquifer is fairly close to the surface in some areas (Figure 12) and provides high quality water at flows up to 1000 gpm in large diameter wells.

Both food fish operations are in the southern part of this region, within 10 miles of each other. In addition, the state's only aquaculture research station, the Pamlico

Estaurine Laboratory (Figure 13) located near Aurora in Beaufort County, is in this region. The laboratory supports University of North Carolina Sea Grant research, and also provides support for additional research done by North Carolina college and university personnel. The Laboratory is under the administrative control of East Carolina University. The southern section of the Coastal Plain can climatically support catfish farming and the soils are generally suitable for the construction of ponds, although some areas have layers of sand that can cause seepage problems.

HISTORY OF NORTH CAROLINA CATFISH FARMING

Attempts to establish commercial catfish farms in North Carolina began in the early 1960s. During any given year since 1965 there have been 2-3 catfish operations in business. Few of these farms, however, remained in business for more than 3-5 years (Thomas 1985, Easley 1985). Many of the early attempts occurred in the Piedmont, but the actual locations are difficult to document. Most of the North Carolina interviewees knew of at least one and usually two or three attempts, but could not remember more than the approximate location. Attempts to locate these relic operations by using aerial photography, 7.5' topographic maps,and ground surveys failed. It is probable that the early catfish operations did not leave distinctive traces because the operators did not construct special production ponds, relying instead on existing farm ponds or natural

FIGURE 13. The Pamlico Estaurine Laboratory, near Aurora, is North Carolina's on aquaculture research laboratory.

water bodies. It is also probable that most early catfish operations in North Carolina were attempts to diversify conventional farms.

Fee fishing operations that stock catfish are not uncommon, but most are found in the western part of the state (Hassler 1985). Most of the fee fishing ponds are stocked with several species: largemouth bass, smallmouth bass, brim, catfish, and several others species in many combinations. This variety increases the attraction of the pond (Rouse 1984).

Most of the fingerling production is used to stock private farm ponds (Moore 1985). Catfish are not a popular sport or food fish in the state and until 5-6 years ago were rarely found in local sea food restaurants (Bey 1985). The local market for catfish was very small, and it was dominated by less expensive catfish harvested by commercial fishermen. Most of the wild catfish were sold out of state (Thomas 1985).

Technical assistance for aquaculture in North Carolina is available from North Carolina state-supported universities in the form of agricultural economists and food scientists, and through the University of North Carolina Sea Grant program. North Carolina State University personnel are actively involved with the trout industry in the western part of the state while Sea Grant is primarily concerned with marine species. However, Randy Rouse, of UNC Sea Grant, is actively involved in the Waccamaw-Siouan Development Agency

project, and the Pamlico Estaurine Laboratory has done some research with catfish.

The principal causes of the high failure rate among would-be catfish farmers seems to have been: a lack of planning and experience, the failure to develop a market, and the underestimation of the cost of establishing and operating a catfish farm (Easley 1984, Thomas 1985, Bey 1985).

CURRENT STATUS

The North Carolina catfish industry is a minor producer of food fish and fingerlings. The food fish and fingerlings are sold for local use. The industry is located in the Piedmont and the Coastal Plain, and is growing slowly.

FINGERLING PRODUCTION

The number of North Carolina hatcheries producing catfish fingerlings has increased steadily since 1981. In 1980 and 1981 there were two producers, five in 1982, seven in 1983, and eight in 1984 (Harrison 1984). Prior to 1980, the number of catfish hatcheries licensed in North Carolina was usually 2-4, and only the Blue Ridge Fish Hatchery, located in Forsyth County, is known to have been producing catfish continually since the early 1970s (Harrison 1984). Five of the currently operating hatcheries are in the Coastal Plain while the others are in the Piedmont (Figure 11). Lack of documentation prevents detailed analysis of pre-1980 hatchery trends.

One hatchery is operated by Buck Trail Aqua Farms (Figure 14), in Columbus County, and provides fingerlings for its farms, as well as for use in a 'contract farming' arrangement by the farm. This is the only North Carolina hatchery that exclusively produces catfish fingerlings, and the only one to produce primarily for the food fish trade. This hatchery was established in 1983 and is scheduled for production of approximately one million fingerlings in 1985.

None of the other hatcheries exclusively produce catfish fingerlings. The Blue Ridge Fish Hatchery produces channel catfish fingerlings for the aquarium trade, while the others sell approximately 85% of their production to private use farm ponds. An estimated 15 percent of the total North Carolina fingerling production is used in fee fishing operations (LeFever 1985). The hatcheries do sell some fish as food, but only on an individual basis, and definitely not on a commercial scale (Bey 1985, Patrick 1984). When the Waccamaw-Siouan project began in Whiteville in 1984 it was necessary to obtain fingerlings from Georgia because no North Carolina hatchery could supply the required quantity at an economical price (Patrick 1984).

FEE FISHING

Fee fishing ponds can be found throughout North Carolina, many of which stock catfish (Figure 15). Most fee fishing operators stock their ponds with a variety of sport fish such as bass, brim, and catfish to increase the

FIGURE 14. Buck Trail Aqua Farms is the first successful commercial catfish farm in North Carolina.

FIGURE 15. Fee fishing near Charlotte, NC. This pond has been stocked with catfish, bass, and brim.

attraction. There are few fee fishing ponds stocked only with catfish (Harrison 1984). Many farmers, having stocked their farm ponds with catfish, will charge an access fee to fishermen. This allows them to recover a portion of the cost of the fingerlings (Cox 1985).

FOOD FISH PRODUCTION

Both food fish operations are in Columbus County. Buck Trail Aqua Farms is located near Lake Waccamaw, has been in operation since 1980, and is steadily expanding. The Waccamaw-Siouan food fish operation, funded by state grants, is a trial project which began construction in 1984, and expects to produce its first crop in the fall of 1985.

Buck Trail Aqua Farms is owned and operated by Robert Bey, who indicates that he sited his operation and began construction only after thorough research in aquaculture, catfish farming, and North Carolina environmental conditions and markets (Bey 1985). Bey believes that the large intensive catfish farms typical of the leading catfish states are not practical in North Carolina. He has twenty-three acres of ponds, none of which exceed two-acres in area or four feet in depth. The majority of the Buck Trail ponds are less than .5 acres in size and are two to three feet deep. Construction of the ponds is also unique: diked ponds are built from earth removed from excavated ponds alongside, thus Buck Trail alternates excavated and diked ponds (Figure 16).

FIGURE 16. Production ponds at Buck Trail Aqua Farms. Note the alternating excavated and diked pond construction.

The small size of the shallow excavated ponds eliminates problems of bank cave-in, and the use of spoil to build dikes is a major savings. The smaller surface area minimizes evaporation, and reduces the required well size to three inch diameter pipe with a volume of 400 gpm. The smaller pond size also lowers construction costs.

Buck Trail obtains yields as high as 15,000 pounds live weight per acre (Bey 1985). This is equivalent to yields obtained in the leading production areas of the United States.

Buck Trail sells most of its production to seafood restaurants in North and South Carolina. The remainder of the production is sold to other growers, fee fishermen, or fresh dressed to walk-in customers. Food fish production in 1984 was approximately 50,000 pounds while the 1985 production is expected to be approximately 60,000 pounds.

In addition to catfish fingerlings and food fish, Buck trail cultivates shrimp in a two acre catfish brood pond. By using the pen method of catfish spawning, a very large portion of the pond, 90% or more, is left unused. This is stocked with shrimp fry seined from brackish coastal waters. They are fed on grasses that are grown on the pond bottom before it is flooded. Total shrimp production is unpredictable, and despite the high value ($5.50 per pound), shrimp are a minor aspect of the Buck Trail operation.

Since 1983, Buck Trail Aqua Farms has formed a cooperative with four conventional farmers. These four

farmers have diversified their operations by stocking existing ponds with catfish fingerlings obtained from Buck Trail. The cooperative ponds vary in size from one to seven acres and have been modified as required for catfish farming. All of the cooperative ponds are within a few miles of Buck Trail. The cooperative has plans to construct, during the summer of 1985, a catfish processing plant with a capacity of 200,000 pounds per year. This plant will be located on one of the farms in the cooperative and is expected to process fish from independent growers as well as cooperative members. Bey stated that none of the cooperative operations has received any financial or technical assistance from state or federal agencies.

The Waccamaw-Siouan food fish operation is located near Bolton, six miles from Lake Waccamaw. This operation represents the first known instance of state agencies and personnel becoming officially involved in promoting and assisting a catfish operation. The Waccamaw-Siouan Tribal Development Agency, Inc., was founded in the mid 1970s to promote economic development among tribal members. It does this by means of economic and cultural education programs, demonstrations of new technology and methods, and by assistance to tribal members to obtain professional advice and support from state and federal agencies. In 1984 the Agency applied for and obtained a $50,000 grant from the North Carolina Technological Development Authority. The

purpose of the grant was to construct and operate a pilot aquaculture project designed to demonstrate the feasibility and economic possibility of cultivating eels, hybrid striped bass, and catfish. It was expected that the successful pilot project would form the nucleus of expanded aquaculture operations by tribal members, thus having a direct and positive effect on the local economy.

Using equipment, labor, land, and machinery donated by tribal members, eight .3 acre diked ponds and four .4 acre diked ponds were constructed at three sites within two miles of the Agency offices. The .4 acre ponds were intended for the striped bass hybrids, and are eight feet deep, two feet deeper than the smaller ponds. A .1 acre farm pond was modified for use as a fingerling holding pond.

Thirty thousand catfish fingerlings were obtained from a hatchery in Georgia. The fingerlings were held in the .1 acre pond until the larger ponds were ready and then transferred to them. The first harvest of one pound fish is planned for the fall of 1985 with an expected yield of six thousand pounds.

Processing of the fish will be performed by commercial seafood processors in nearby Wilmington, North Carolina. The Waccamaw-Siouan Development Agency hopes to construct a catfish processing plant if the project is successful.

Information concerning the Waccamaw eel project is limited at this time. It was to be a one person, twenty-six week project designed to collect data about eels and

demonstrate and test the feasibility of commercial eel harvesting in southeastern North Carolina. Information as to the success of this project is unavailable. The hybrid striped bass project was canceled due to objections from state and federal agencies. There is a danger of the bass escaping into the Lake Waccamaw drainage basin where they could decimate the local population of a rare and endangered species of snail darter. The ponds built for the bass have been used for catfish.

In addition to The Buck Trail cooperative and the Waccamaw project ponds, at least two Columbus County agricultural farmers have stocked ponds on their respective farms with catfish. These ponds are not larger than seven acres in area, and are intended to produce food fish although both farmers will allow fee fishing (Cox 1985). The purpose of stocking catfish for food fish production is to diversify their conventional farms as four of the Buck Trail cooperative members have done. Initial investment is being kept to a minimum, although it will be increased if the venture is successful. Several of the farmers investing in catfish production have relied on tobacco as their main cash crop in the past, but the instability of the federal tobacco price support program has caused them to look for replacement cash crops. These individuals believe that catfish can partially replace tobacco (Bey 1985, Cox 1985).

CAPITAL INVESTMENTS

There have been no studies conducted to determine the costs of establishing a commercial catfish farm in North Carolina, nor are there statistics available to show what the annual operating costs are. A minimum of 500,000 dollars is required to construct the equivalent of Buck Trail Aqua Farms (Bey 1985, Hassler 1985, Easley 1984). The largest part of this would be spent on land acquisition and pond construction. The Waccamaw-Siouan aquaculture project was put into operation using 50,000 dollars, but almost all of the labor and construction costs and all of the land costs were donated to the Agency and were not included in the budget. The project proposal lists total 'inkind' contributions of 39,880 dollars, but this does not include the actual value of the land used (Carden 1984). It does note that rent valued at 2,000 dollars per year for eighteen acres of land was donated.

MARKETS

The market for farm raised catfish in North Carolina has grown steadily since 1980 (Bey 1985, Carden 1984). Principal customers are North Carolina seafood restaurants and fee fishing enterprises. There is a possibility of building a regional market. At present, the North Carolina catfish industry market is limited by the lack of processing plants, and a lack of fish for the market. Robert Bey states that the existing market can absorb 100,000 to 200,000 pounds of

catfish per year. This is far in excess of North Carolina's current production, and the market is still growing steadily. The growth in the North Carolina market is the result of the efforts of Robert Bey and the national catfish industry (Bey 1985).

Bey actively promotes his catfish products in the southeastern part of North Carolina and the national industry advertises and promotes various catfish products in national magazines and at regional and national events such as cooking contests and the annual Catfish Festival in Belzoni, Mississippi.

SUMMARY OF THE NORTH CAROLINA INDUSTRY

Attempts to farm catfish in North Carolina began in the Piedmont region during the early 1960s. A lack of experience, capital, and a market combined to cause the failure of most of these farms. There are currently two food fish operations, both in the Coastal Plain, one of which has not yet gone into production. The majority of catfish fingerlings in the state are produced for use in private farm ponds, where they provide sport fishing for the pond owners. Production figures for the state are quite low, and are generally combined with other minor production states when they are published by the USDA and USDC.

The official position of the North Carolina state government towards catfish seems to be one of mild interest. If the Waccamaw project succeeds, it would be reasonable to

assume that state agencies and universities will begin to provide more support, both financial and technical.

THE MISSISSIPPI CATFISH INDUSTRY

ENVIRONMENTAL CONSIDERATIONS

There are three physiographic regions in the state: the Delta, the Northeast, and the South. The Delta is an alluvial plain formed by the Mississippi River. The Northeast is a hilly region that includes two flat areas: the black prairie and the flatwood. The South is separated from the Delta and the Northeast by the Jackson Prairies. It consists of pine-covered, gently rolling coastal plain. All three regions have similar precipitation and temperature patterns. (Figure 17).

The Delta region contains most of the production ponds. This area contains the self-proclaimed 'Catfish Capital of the World', Belzoni (Humphreys County), and all of the major processors in the state. Twelve of sixteen major U.S. processing plants are located here. The Southern region ranks second, and the Northeast is third in production.

Since the areas are only different in their physical aspects, it is probable that this is the major reason that the Delta leads in production. This is supported by the opinion of several persons associated with Mississippi catfish farming (Turner 1984, Steed 1984). The soil in the Delta is 'gumbo' containing a high percentage of clays, which

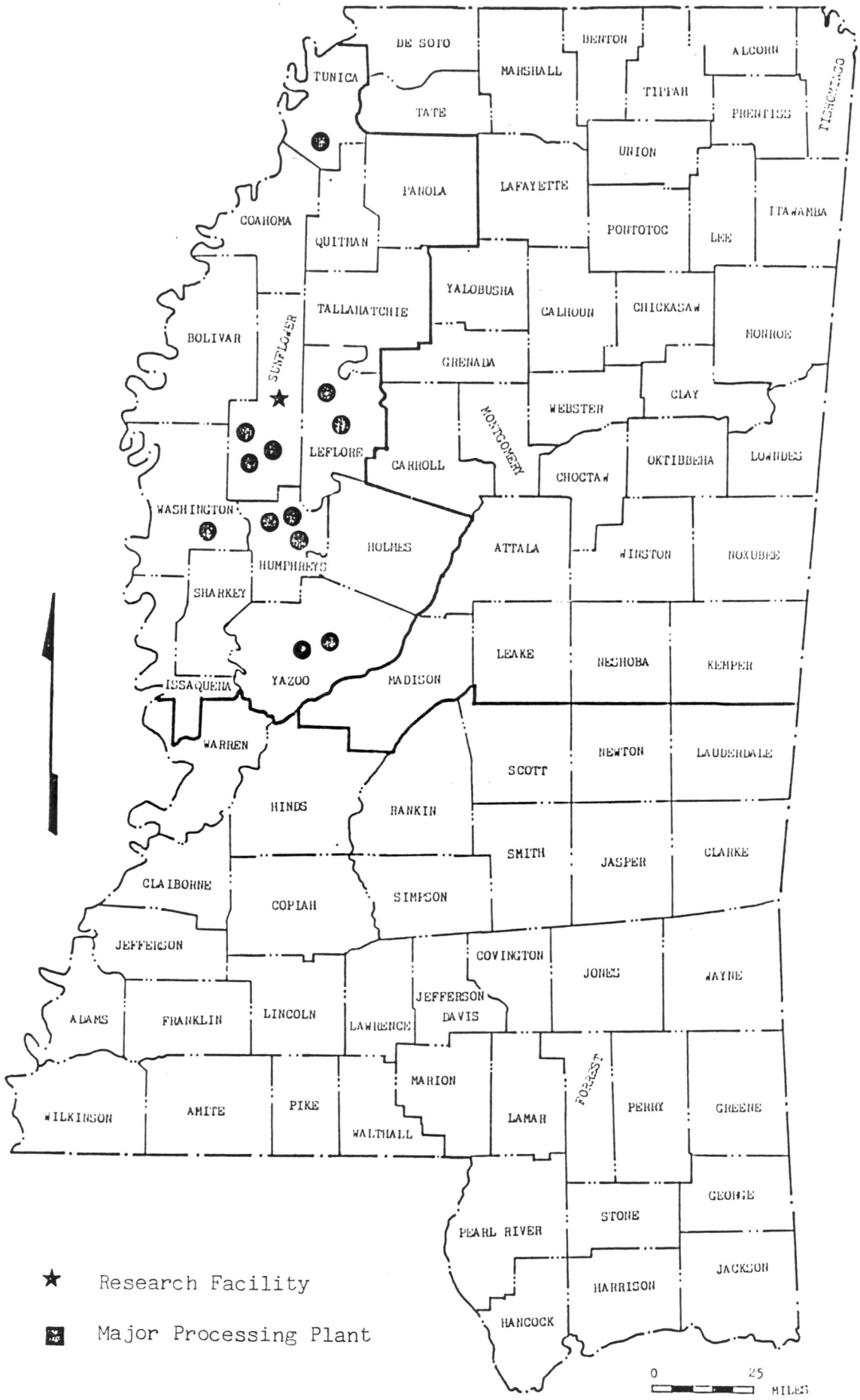

FIGURE 17. The Mississippi Catfish Industry

makes the soil very suitable for pond construction. Pond production is the prevalent method in Mississippi, although there is some cage production in the Northeast region (Steed 1984). In addition to suitable soil, the Delta has flat land, a factor that lends itself to pond construction.

Ground water is available in shallow and medium depth aquifers in the Delta, and in medium to deep aquifers in the Northeast and South. The shallow aquifers are an advantage for the Delta, since it is less expensive to drill for than the deeper water supplies.

HISTORY OF MISSISSIPPI CATFISH FARMING

Mississippi catfish farming began in 1965 with the construction of a forty acre production pond in Sharkey County. The following year, three 10 acre ponds were built in Humphreys County. From this beginning, Mississippi farmers have built the core of the United States catfish industry. Within sixty-five miles of Belzoni, the Humphreys County seat, are 90% of Mississippi's production ponds and approximately 65% of the total catfish production acreage in the United States (Turner 1984, Steed 1984).

Early catfish operations were part of larger more diverse conventional farms. Ponds were stocked and harvested every two years. The results were cyclic gluts of the market, and production soon exceeded processing capacity and market demand. Research efforts developed methods of production that ended the cyclic supply problems, and

cooperatives formed and built processing plants that keep their collective capacity slightly larger than the predicted production. Pond sizes and shapes varied considerably in the early years. Experience and research led to the development of the four pond production unit. (Figure 8). The industry has grown at a rate that has exceeded 150% annually in the past (Steed 1984). (Table 6)

The state government took an early and aggressive interest in catfish farming. Mississippi State University has been funded for catfish research, and has several persons, notably Dr. Thomas Wellborn, actively working on improving the industry. A genetics research facility specifically for catfish studies is to be built at the Stoneville, MS, agricultural research station. This station already has experimental catfish ponds on site. State supported research has assisted Mississippi to construct a large service industry (Figure 18).

The catfish industry is so successful and valuable in Mississippi that large agri-business firms, such as Conagra and Ralston-Purina, are moving into the area and becoming involved in all phases of catfish production. These large corporate operations dovetail neatly with the tightly vertical integrated operations. Characterized by cooperatives, the Mississippi catfish industry boasts twelve of the nation's sixteen major processing plants, each having the capacity to process several hundred thousand pounds of

FIGURE 18. This facility is located in Belzoni, Mississippi. It is used exclusively by the catfish farmers of the area, and is a good example of the sophisticated support services available to Mississippi catfish farmers.

catfish per week.

CURRENT STATUS

The Mississippi catfish industry concentrates on the production and processing of food fish. It is the leading catfish producing state for food fish and fingerlings, and markets its products nationwide. It is growing steadily (Table 6, Figure 19 & 20).

TABLE 6. MISSISSIPPI PRODUCTION POND ACREAGE BY YEAR

	ACRES IN PRODUCTION			
MONTH/YEAR	FOOD FISH	FINGERLINGS	TOTAL	%INCREASE (from previous year)
Dec. 1982	56,191	6,098	62,289	11.4
Dec. 1981	50,688	5,249	55,937	38.6
Dec. 1980	36,437	3,932	40,369	63.4
Mar. 1979	22,541	2,171	24,12	44.1
May 1977	15,182	1,969	17,151	-

source: Wellborn 1983

FINGERLING PRODUCTION

There are approximately 230 fingerling operations in the state, most of which are associated with a food fish operation. There are, however, several hatcheries that specialize in producing high quality fingerlings for sale to any type operation that needs them. The Delta region has

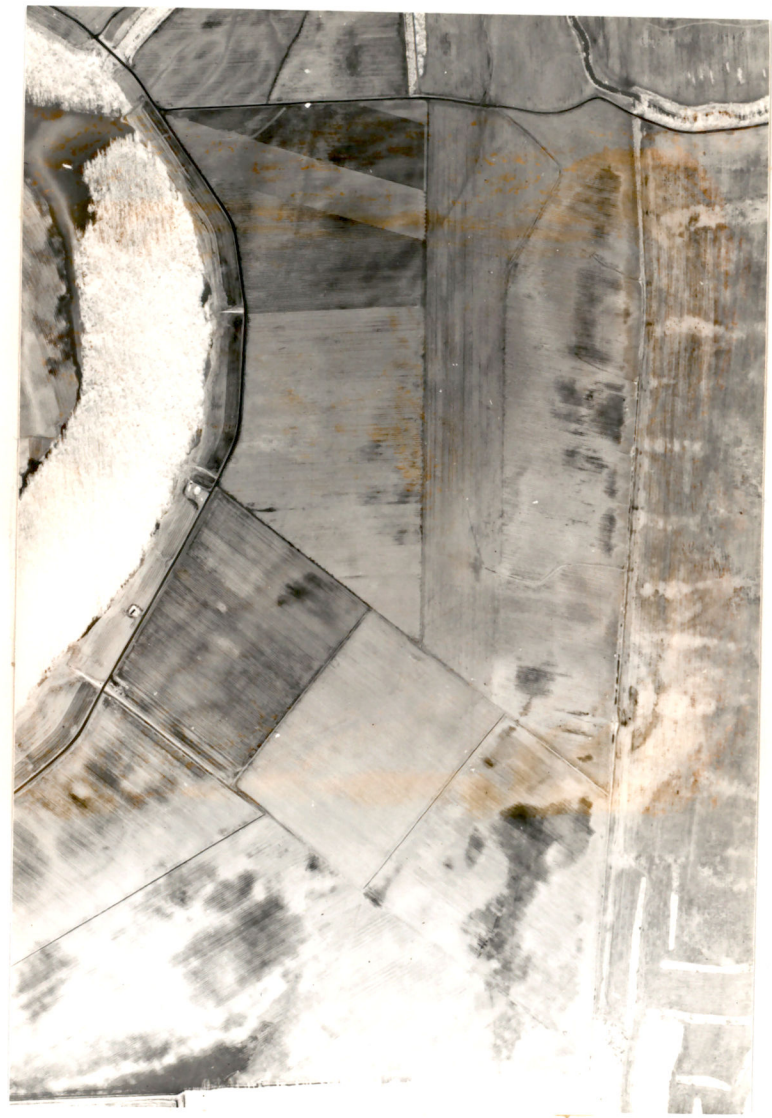

FIGURE 19. This aerial photograph of part of Humphreys County, MS, was taken in 1976. Compare it to Figure 20.

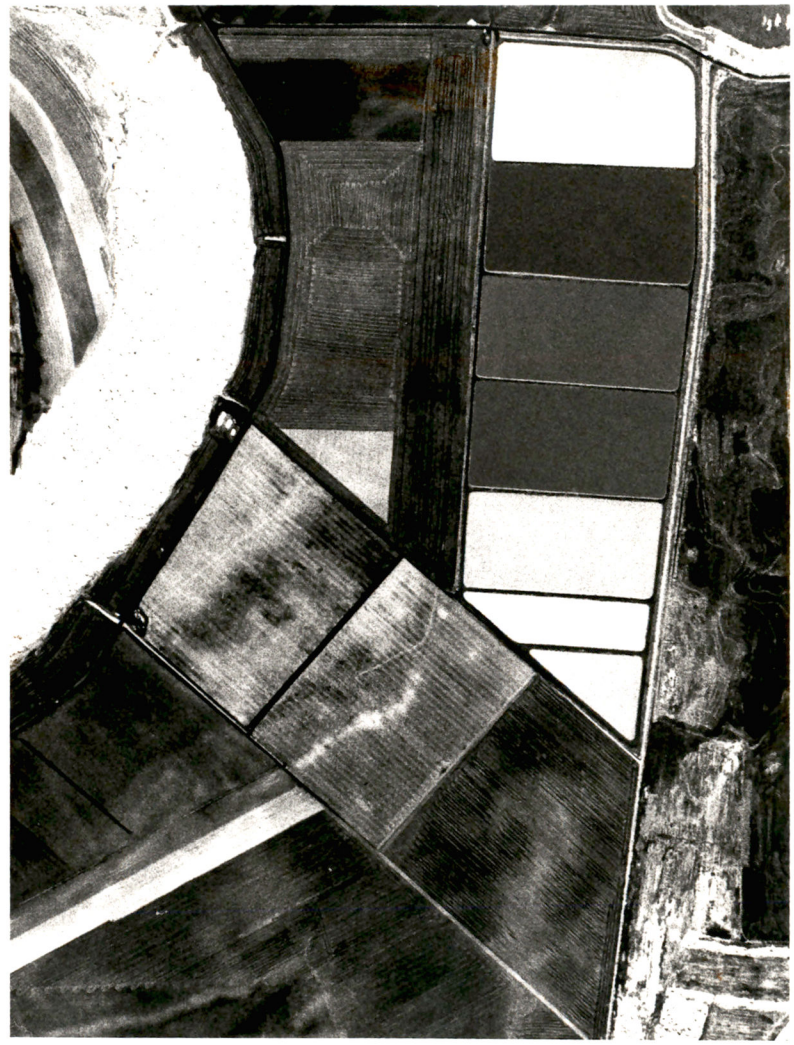

FIGURE 20. This aerial photograph is of the same area and approximate scale as Figure 19. It was made in 1982. Note the production ponds that have been constructed. This is an example of how rapidly Mississippi catfish growers have expanded their operations.

5,891 acres of fingerling production ponds, the Northeast 564 acres, and the South 140 acres. This distribution is due to the physical characteristics of the various regions and the distribution of food fish acreage. The Delta region is highly suited to food fish production and contains most of the food fish production acreage. It also has the largest concentration of fingerling ponds. The South and the Northeast regions are rolling hill country that is not very suitable for the construction of large food fish production ponds, and they have about the same food fish acreage. The Northeast has four times the fingerling acreage of the South. This is due to the proximity of the main food fish production areas of the Delta.

FEE FISHING

Fee fishing for catfish is common throughout Mississippi (Steed 1984, Turner 1984). The value of fee fishing operations is minor in comparison to food fish production, and most fee fishing operators are not dependent on the operation (Turner 1984).

FOOD FISH PRODUCTION

Approximately 62,000 acres are devoted to food fish production. Ninety-five percent of the acreage is in the Delta region, and the Northeast and Southern regions each have approximately 2.5 percent. This distribution is directly related to the physical characteristics of the Delta

region: soil highly suited for pond construction, excellent water supplies, and flatland.

Pond production is the principal method used. The ponds are harvested in the manner described in chapter 2. Catfish harvest operations begin about three weeks before the fish are removed from the pond. A sample of fish is netted when a pond is due for harvest. They are killed, cleaned on the pond bank, and cooked in microwave ovens. The fish are then taste tested by a group of three tasters. If any one of the three feel that the fish have an off-flavor, the pond will not be harvested on schedule. Instead, the farmer and the processing plant try to identify the source of the off-flavor. In the case of sediment or algae contamination, the pond is cleaned, and the fish are allowed to remain in the pond for several weeks. At the end of this time, the fish are re-sampled. If they fail the taste test a second time, they may be rested longer, or the entire pond is condemned as unfit for human consumption. In that event, the fish can be sold to fee fishing operations, or in extreme cases they are simply killed and dumped. If the pond passes the first taste test, the harvest is scheduled. Just before the harvest starts, the pond is sampled again. If the fish pass, the pond is harvested. If they do not pass, the harvest is postponed, the fish rested and retested at a later date.

Once harvested and loaded into the live-haul trucks (Figure 21), the fish are transported to a processing plant. At the processing plant, the fish are taste tested once more

FIGURE 21. This live haul truck is equipped with large aerated water tanks. It is used to haul catfish from ponds to processing plants in Mississippi.

before unloading. If they fail the test they are returned to the pond, rested, and then the test sequence begins again. If they pass, the fish are dumped into holding tanks and processed.

Most of Mississippi's processing plants are automated to some extent. The major plants employ up to 580 persons, and can move a catfish through the processing line in four minutes or less.

COST OF ESTABLISHING A COMMERCIAL CATFISH FARM

A cost of production estimate for the Delta region of Mississippi was produced by Mississippi State University in 1982. This publication assumed three hypothetical farm situations: 163 land acres, 323 land acres, and 643 land acres. In each case three acres were used for buildings, operations, parking, etc. The authors determined that these situations are representative of the Mississippi Delta catfish industry. It was assumed that catfish enterprises were separate from all other economic activity.

Investment requirements for each farm situation is segmented into six classes: land, pond construction, water supply, feed, disease, parasite, and weed control, harvesting, and miscellaneous equipment. Land was the largest single factor in the costs. Land was valued at approximately $1,500. per acre at the time the production estimate was researched. [as of mid-July, 1984, land values were approximately $1,500. per acre (Turner 1984)]

Feed costs were made up of feeder and bulk storage costs. The proximity of several large catfish feed mills affects the feed costs (Figure 22). Water requirements were set at one 3000 gallon per minute well per four 20 acre ponds (Table 7).

MARKETS

The Mississippi industry serves the United States national market through truck and rail networks. The market is composed of bulk purchasers such as the United States armed forces, institutions, and restaurant and grocery store chains. It is working steadily to expand that market and is seeking new ones. Recently, the Catfish Farmers of America sent representatives to Europe to promote catfish products. They met with notable success and exports to western Europe have begun on a small scale (Steed 1984). The United States market growth is expected to exceed production growth over the next few years (Meyer 1984).

SUMMARY

The Mississippi industry is characterized by large scale, highly intensive operations. It is vertically integrated and becoming more mechanized (Figure 22). It is steadily increasing production acreage and expanding its markets. Already marketing on a national scale, the industry is beginning to expand into the European market. The industry expects to grow at an annual rate of about 15% per

year for the next few years and may triple in size by the year 2000 (JSA 1983).

TABLE 7. ESTIMATED INVESTMENT REQUIREMENTS FOR CATFISH PRODUCTION IN THREE SITUATIONS, DELTA OF MISSISSIPPI, 1982

ITEM	FARM SITUATION COST IN DOLLARS		
	I	II	III
Land (@ $1500/acre)	244,500	484,500	964,500
Pond construction	122,865	233,005	465,911
Water supply	35,000	70,000	140,000
Feed equipment	16,750	22,650	34,300
Disease, parasite & weed control equipment	10,363	17,742	32,914
Miscellaneous equipment	131,968	182,868	298,328
Total	561,446	1,010,765	1,935,953
Investment			
per acre of land	3,444	3,129	3,011
per surface acre of water	3,974	3,541	3,384

source: Giachelli, Coats, & Waldrop 1982

FIGURE 22. This feed mill is located in Indianola, Mississippi. It is owned and operated by a catfish cooperative, and produces catfish feed for use by local growers.

CHAPTER 4

SUMMARY AND CONCLUSIONS

The major problem encountered during the research for this thesis was a lack of documentation, and the unavailability of some existing literature. It is possible to construct a comprehensive information base for the state and national aspects of the catfish industry, but it requires extensive use of popular and trade journals. Several of the leading catfish producing states have published a great deal of technical and statisical data concerning their respective industries, but the minor producers have little or no available literature.

Research in aquaculture requires extensive fieldwork and personal contacts with persons involved in the field. These contacts can be established through the various state agricultural extension services and university agricultural economics departments.

SUMMARY

Aquaculture is of increasing importance in today's world. It is more efficient to cultivate aquatic animals and plants than to hunt them: energy use is reduced, yields are predictable and higher per unit area, and natural stocks are not driven into extinction. Of the numerous types of aquaculture practiced in the United States, catfish farming is

one of the most intensive and valuable.

The catfish industry in the United States is principally concerned with the production of catfish as food for humans. Recreational enterprises (fee fishing) based on commercially produced catfish are common, but are of minor importance in comparison to food fish production.

In general, the industry is characterized by highly mechanized, large scale operations using large (more than ten-acre) production ponds. Mississippi is the leading production state while North Carolina is one of several minor producers.

In comparing the catfish industries in North Carolina and Mississippi, the difference in scale of the two is immediately apparent. North Carolina has a maximum of eighty acres devoted to the production of catfish for fingerlings and food fish. Mississippi has approximately sixty thousand acres devoted to catfish production.

The technology, techniques, and characteristics of the two industries differ greatly. The Mississippi catfish industry is characterized by large scale management-, labor-, and energy-intensive operations. Vertical integration of all phases of catfish production is a hallmark of the Delta industry. Commercial production ponds range in size from ten to eighty acres, with twenty acre ponds being considered most efficient. The industry produces a high quality, volume product and supplies a national market. The Mississippi

industry is seeking to expand into the European market. The North Carolina industry is small scale and moderately management-intensive. North Carolina production ponds are generally less than two acres in area. The small ponds are easier to manage than the larger ponds, require less equipment for harvesting, feeding, and maintenance, and are less expensive to construct and operate. The North Carolina industry supplies fresh dressed fish to local seafood restaurants.

The Mountain region of North Carolina is too cold for the production of catfish, and the Piedmont is marginal due to potential water problems. The North Carolina Coastal Plain, and all three of Mississippi's regions are suitable for commercial catfish operations. The growing season of Mississippi (200 days) is matched by that of the southern Coastal Plain of North Carolina.

The topography of the two states is reasonably similar: the Piedmont and Coastal Plain of North Carolina are somewhat equivalent to the two hill regions and the Delta of Mississippi. The Mountains of North Carolina have no counterpart in Mississippi.

In soils there are some differences. The Piedmont and Coastal Plain of North Carolina possess Ultisols, as does the eastern two-thirds of Mississippi. The western third of Mississippi, the Delta region, is covered by alluvial soils deposited by the Mississippi River. The Mountains of North Carolina have thin, young soils typical of mountain areas.

The soils of both states are similar in one respect: they are generally suitable for the construction of catfish production ponds.

Water is no problem in Mississippi. There are numerous shallow and medium depth aquifers which provide high quality water suitable for the production of catfish. It is relatively inexpensive to drill wells in the state, and there appear to be few problems with pollution. North Carolina's water situation is somewhat different. There are several medium to deep aquifers in the state that can provide water suitable for the production of catfish, notably the Castle-Hayne aquifer in Coastal North Carolina. Due to agriculture, peat and phosphate mining, and industrial development in the Coastal Plain, North Carolina is beginning to experience water availability and quality problems along the coast. The possible extent and severity of these problems are beyond the scope of this paper to predict, other than they may cause problems for aquacultural development in North Carolina.

Mississippi has twelve major processing plants with capacities as high as 1.4 million pounds per week. North Carolina's first catfish processing plant should open in the summer of 1985, with a design capacity of 200,000 pounds per year.

The state government of Mississippi began to actively support catfish farming in its infancy. From the mid-1960s, Mississippi extension agents, universities, and government

agencies have provided funds, research, and technical assistance to the state's catfish farmers. North Carolina has not actively supported catfish farming until recently. Most of the aquaculture and fisheries research in North Carolina has been focused on marine and brackish water species such as eels, oysters, clams, and striped bass. An exception to this has been support for the trout industry of North Carolina's mountain region. This support has principally been in the form of research done by the state universities, and technical advice by Sea Grant and extension personnel. Support for catfish farmers has been available on an individual basis from state personnel over the years, however, none of this aid was in a formal program designed to promote the industry. In 1984, state and federal agencies gave a 50,000 dollar grant to the Waccamaw-Siouan Development Agency to establish a pilot catfish/eel/striped bass production farm. The purpose of this was not so much to promote catfish as it was to demonstrate new methods and products to a section of the state that is heavily agricultural, rural, and economically lagging. Later intervention by state authorities removed the striped bass from the program.

Mississippi expects its industry to continue to dominate the national catfish industry, and for it to grow at an annual rate of 15%. The North Carolina industry is expected to grow slowly and realistically cannot hope to compete with Mississippi or any of the other leading production states in

the near future. The potential does exist for North Carolina to produce high quality food fish for the restaurant trade, as well as high quality fingerlings for resale.

CONCLUSIONS

1. Catfish farming is practical in the south-eastern counties of North Carolina. This is due to a combination of suitable climate, soils, topography, and water quality and availability.

2. The catfish industry of North Carolina is lagging behind the national industry by twenty years or so. This is due to a lack of a local market and a lack of interest on the part of farmers and state government.

3. The catfish industry of North Carolina has the potential, based on suitability of the southern Coastal Plain and the success of one operation, to expand. It is possible that it may become economically important in the southern Coastal Plain, but it will probably not become a major crop at the state level. It seems unlikely that the North Carolina industry will ever be comparable to or compete with that of the leading catfish producing states.

4. The industry has received a stimulus from the possible demise of the tobacco subsidy program, and from the efforts of North Carolina farmers to diversify their operations over the last few years.

5. Expansion of the industry will depend upon the successful development of the local catfish market.

6. The future North Carolina catfish industry will probably be characterized by small scale, moderately intensive efforts.

BIBLIOGRAPHY

BOOKS:

-----. Regulations Relating to Fish Propagation. Raleigh: North Carolina Wildlife Resources Commission, 1983.

Ammerman, G. K. Catfish Processing - MAFES Technical Bulletin 68. Mississippi State: Mississippi Agricultural and Forestry Experiment Station, 1973.

Bardach, John E.; Ryther, John H.; and McLarney, William O. Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms. New York: Wiley-Interscience, 1972.

Boleware, Valerie and Dillard, James G. Second Survey Consumer Awareness and Acceptance of Farm Raised Catfish. Mississippi State: Mississippi Agricultural and Forestry Experiment Station, 1984.

Borghese, Elizabeth M. Seafarm: The Story of Aquaculture. New York: Harry N. Abrams, 1980.

Brown, E. Evan. World Fish Farming: Cultivation and Economics. Westport: The AVI Publishing Co., Inc., 1977.

Bureau of the Census, US Department of Commerce. 1982 Census of Agriculture. Washington: GPO, 1983.

Brown, E. Evan and Gratzek, John B. Fish Farming Handbook - Food, Tropicals, and Goldfish. Westport: The AVI Publishing Co., Inc., 1980.

Carden, Gary. Project Proposal - Waccamaw-Siouan Aquaculture Project. Bolton: The Waccamaw-Siouan Development Agency, Inc., 1984.

Clay, James W.; Orr, Doulas M. Jr.; and Stuart, Alfred W. North Carolina Atlas Portrait of a Changing Southern State. Foreword by James E. Holhauser, Jr. Chapel Hill: University of North Carolina Press, 1975.

Columbus Division, Battelle Memorial Institute. Agriculture 2000 A Look at the Future. Columbus: Battelle Press, 1983.

Easley, J. N. C. Mountain trout Production. Raleigh:

North Carolina Agricultural Extension Service, 1982.

Economic Development Administration, US Department of Commerce. A Statistical Reporting System for the Catfish Farming Industry, Methodology, and 1970 Results. Washington: GPO, 1972.

Economic Development Administration, US Department of Commerce. Factors affecting the Growth and Production of Channel Catfish in Raceways. Washington: GPO, 1972.

Economic Research service, US Department of Agriculture. Catfish Processing..A Rising Southern Industry. Washington: GPO, 1972.

Effluent Guidelines Division, Office of Water and Hazardous Materials, Environmental Protection Agency. Development Document for Effluent Limitation Guidelines and Standards of Performance for the Catfish, Crab, Shrimp, and Tuna Segments of the Canned and Preserved Seafood Processing Industry Point Source Category. Washington: GPO, 1974.

Foster, John E. Clam Gardening. Raleigh: UNC Sea Grant, 1981.

Gardner, Dan. Mississippi Fish farming - 1973 Information Sheet 607 (5M-6-7). Mississippi State: Mississippi Cooperative Extension Service, 1973.

Giachelli, Jeffrey W.; Coats, Robert L.; and Waldrop, John E. Mississippi Farm raised Catfish January 1982 Cost of Production Estimates. Mississippi State: Department of Agricultural Economics, 1983.

Giachelli, Jeffrey W. and Waldrop, John E. Cash Flows Associated With Farm Raised Catfish Production. Mississippi State: Department of Agricultural Economics, 1983.

Godfriaux, Bruce L., ed. Power Plant Waste Heat Utilization in Aquaculture. Montclair: Allanheld, Osmun, and Co., 1979.

Henderson, Scott., et al. Arkansas Commercial Fisheries Report July 1, 1977 to June 30, 1980. ____: National Marine Fisheries Service, 1980.

Jensen, John. Channel Catfish Production in Ponds. Auburn University: Alabama Cooperative Extension Service, 1981.

Joint Subcommittee on Aquaculture, US Departments of Agriculture, Commerce, and Interior. National Aquaculture Plan. 2 vols. Washington: GPO, 1983.

Lee, Jasper S. Commercial Catfish Farming. Danville: The Interstate printers and Publishers, Inc., 1973.

Limburg, Peter K. Farming the Waters. New York: Beaufort Books, Inc., 1980.

Mack, Jerry. Catfish Farming Handbook. San Angelo: Educator Books, Inc., 1971.

McCoy, E. W. and Sherling, A. B. Economic Analysis of the Catfish Farming Industry. _____:_____, 1973.

Muir, James F. and Roberts, Ronald J., ed.s Recent Advances in Aquaculture. Boulder: Westview Press, 1982.

National Academy of Sciences. Aquaculture in the United States: Opportunities and Constraints. Washington: National Academy of Science, 1978.

Reay, P. J. Aquaculture. Baltimore: University Park Press, 1979.

Rickards, William L. A Discussion of Aquaculture Candidates for Eastern North Carolina. Raleigh: UNC Sea Grant, 1981.

Rouse, R. Dennis. Alabama Catfish Producers, Fingerling Producers, and Catfish Processors 1974. Auburn: Agricultural Experiment Station of Auburn University, 1975.

Shang, Young L. Aquaculture economics: Basic Concepts and Methods of Analysis. Boulder: Westview Press, 1981.

Smith, Leah J. and Peterson, Susan, ed.s Aquaculture Development in Less Developed Countries, Social, Economic, and Political Problems. Boulder: Westview Press, 1982.

Stickney, Robert R. and Davis, J. T. Aquaculture in Texas, A Status Report and Development Plan. ____:Texas A & M University, 1981.

Stickney, Robert R. Principles of Warmwater Aquaculture. New York: John Wiley and Sons, 1979.

The University Of Georgia Cooperative Extension Service. Home-grown Catfish - Bulletin 881. Athens: The

University of Georgia, 1982.

Todd, Nancy Jack, ed. The Book of the New Alchemists. New York: E. P. Dutton, 1977.

US Army Corps Of Engineers. Aquaculture in Dredged Material Containment Areas. Washington: GPO, 1982.

US Department of Agriculture. Catfish Farming - Farmers Bulletin 2260. Washington: GPO, 1982.

US Department of Agriculture. Building A Pond - Farmers Bulletin 2256. Washington: GPO, 1973.

Virginia Department of Agriculture and Consumer Services. Virginia Agriculture Organizations. Richmond: Virginia Department of Agriculture and Consumer Services, 1983.

Waldrop, John E. and Smith, Roy D. An Economic Analysis of Producing Pond Raised Catfish for Food in Mississippi - A January 1980 Update (Department of Agricultural Economics Report No. 103). Mississippi State University: Department of Agricultural Economics, 1980.

Wheaton, Frederick W. Aquacultural Engineering. New York: John Wiley and Sons, 1977.

MAGAZINES AND JOURNALS:

AQUACULTURE ON THE RISE. Consumer's Research Magazine (February 1983): 26-28.

ARKANSAS FARMERS HARVEST FISH AND RICE. Popular Mechanics 113 (January 1960): 138-141.

CATFISH. Aquaculture Digest 9 (March 1984): 16-20.

CATFISH FARMERS OUTLINE PLANS FOR 1983. Aquaculture Magazine (March-April 1983): 30-31.

CATFISH FARMING HOW TO MAKE IT A PROFITABLE OPERATION. The Commercial Fish Farmer 2 (March 1976): 9-15.

CATFISH FARMING IN CALIFORNIA. The American Fish Farmer 1 (February 1970): 10-11.

CATFISH HARVEST: THRIVING INDUSTRY IN THE SOUTH. Time 93 (16 May 1969): 112.

CATFISH: DOWN HOME DELICACY BECOMES BIG BUSINESS. Ebony 23 (October 1968): 140-142.

CRAWFISH PRODUCTION IN GEORGIA. County Agent's Fisheries Update 3 (November 1982): 1-16.

CRABBERS TURN SOFT-SHELLS INTO HARD CASH. Coastwatch (September 1983): 2-3.

FISH FARMING - ITS CATCHING ON. US News 78 (21 April 1975): 74.

JUMPING CATFISH. Newsweek 78 (27 September 1971): 70.

LOBSTER BODEGA. Time 113 (4 June (1979): 46.

SOFT-SHELL CRABBING. Coastwatch (September 1983): 5-8.

SUPERFISH. Newsweek 80 (27 August 1973): 50.

WARM-WATER FARMING. Sea Frontiers 14 (September 1968): 314.

Ackefors, Hans and Rosen, Carl G. FARMING THE WORLD'S WATERS. Environment 21 (November 1979): 16-20.

Bailey, J. H. TEST TUBE ABALONE: RAISING ABALONE UNDER LABORATORY CONDITIONS. Sea Frontiers 19 (May 1973): 148-153.

Bartonek, Frank A. CATFISH FARMING. The American Fish Farmer 3 (July 1982): 4-7. (reprinted from Farmland News)

Bay, Ovid. BIGGEST FISH STORY OF THE YEAR: FEEDING OUT CATFISH. Farm Journal 85 (April 1961): 38.

Bay, Ovid. HOW TO KEEP BIG FISH IN YOUR POND. Farm Journal 87 (October 1963): 48J.

Billington, Tom H. BEY ANGRY THAT STATE IS FUNDING COMPETITION. The News Reporter 88 (30 August 1984): A1, A14.

Billington, Tom H. SUFFERIN' CATFISH! BEY MAKES FISH FARM WORK. The News Reporter 88 (30 August 1984): B1, B12.

Billington, Tom H. INDIAN'S FISH FARM UNDER WAY. The News Reporter 88 (27 August 1984): A1, A12.

Boykin, John E. CATTLE PRECONDITIONING, CATFISH COMPLEMENT TEXAS FIRM'S GRASS OPERATION. Feedstuffs 43 (15 May

1971): 17-18.

Brown, Robert H. GEORGIA CATFISH PRODUCTION STUDY EVALUATES TECHNIQUE. Feedstuffs 43 (16 October 1971): 57.

Brown, Robert H. REPORT ANALYZES CATFISH FARMING BOOM. Feedstuffs 42 (17 January 1970): 36-37.

Coffman, B. GROSS $28,000 ON CATFISH IN A BARN. Farm Journal 95 (July 1971): 22D.

Collins, Richard A. CULTURING CATFISH IN CAGES. The American Fish Farmer 1 (February 1970): 5-8.

Davis, R. K. IS YOUR TROUBLE TOO MANY FISH? Farm Journal 88 (July 1964): 34J.

DeCrosta, Anthony. TOWARDS A BACKYARD FISH GARDEN. Organic Gardening 26 (May 1979): 134-141.

DePuy, Percy C. THE CATFISH. Nature Magazine 52 (August / September 1959): 349.

Duncan, A. SOME EASTERNERS GO WEST, EXPERIMENTATION IN LOBSTER CULTURE. Sea Frontiers 21 (May 1975): 162-167.

Dupree, H. K. CATFISH AQUACULTURE IN THE UNITED STATES. Proceedings of the 8th US-Japan Meeting on Aquaculture at Bellingham, Washington, October 17-18, 1979 (1982): 23-25.

Fiegel, D. H. and Freeze, Mike. THE AQUACULTURE INDUSTRY OF ARKANSAS IN 1979-1980, STEPS IN AQUACULTURE PRODUCTION PROCESSES. Arkansas Academy of Science Proceedings 35 (1981): 40-42.

Freeze, Mike and Henderson, Scott. THE AQUACULTURE INDUSTRY OF ARKANSAS IN 1979. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 34 (November 1980): 115-126.

Freeze, Mike and Henderson, Scott. THE WILD COMMERCIAL FISHERY IN ARKANSAS - 1 JULY, 1978 TO 30 JUNE, 1979. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 34 (November 1980): 372-378.

Gannon, R. BACKYARD FISH FARMING. Science Digest 73 (June 1973): 85-89.

Glasner, R. SLOWEST CATTLE DRIVE - TURTLE FARMING. Science Digest 77 (January 1975): 68-72.

Gunnar, K. SALMON WITHOUT SPAWNING: HATCHERIES IN THE PACIFIC NORTHWEST. National Wildlife 13 (October 1975): 22-23.

Hartley, E. GROWING SHELLFISH WITH GARBAGE. Science Digest 74 (December 1973): 73-75.

Hopkins, Harold. AQUACULTURE, THEY'RE GROWING FOOD UNDER WATER. FDA Consumer (November 1981): 10-15.

James, Carol. CATFISH FARMERS ASSESS THEIR FUTURE. Feedstuffs 42 (7 February 1970): 1-2.

Jones, Michael A. MARKET RESEARCH REVEALS INFORMATION ABOUT MARKET POTENTIAL OF CATFISH. Aquaculture Magazine (November-December 1982): 49-51.

Kirby, Martin. CATFISH VS. POVERTY? The American Fish Farmer 4 (December 1972): 8-9.

Lovell, R. T. FISH CULTURE IN THE UNITED STATES. Science 206 (December 1979): 1368-1372.

Madewell, C. E. HISTORICAL DEVELOPMENT OF CATFISH FARMING. Conference Proceedings - Producing and Marketing Catfish in the Tennessee Valley (1971): 7-14.

Madewell, Carl E. and Bellew, Ralph J. HISTORICAL DEVELOPMENT OF CATFISH FARMING. The American Fish Farmer (February 1972): 8-11.

Mahan, P. and Mahan, J. RAISING CATFISH IN A BARREL. Organic Gardening and Farming 20 (November 1975): 112-117.

McLarney, William O. INTRODUCTION TO AQUACULTURE ON THE ORGANIC FARM AND HOMESTEAD. Organic Gardening and Farming 18 (December 1971): 71-77.

McLarney, William O. RAISING CRAYFISH IN A FARM POND. Organic Gardening and Farming 18 (December 1971): 84-85.

Menezes, Frank. NITTY GRITTY OF CATFISH FARMING. The commercial Catfish Farmer 3 (March 1977): 13-21.

Meyer, Fred P., et al. FISH PRODUCTION IN ARKANSAS DURING 1969 AS COMPARED TO OTHER STATES. Proceedings of the 24th Annual Conference of the Southeastern Association of Game and Fish Commissioners 24 (1970):

497-506.

Mullins, Troy. CAPITAL REQUIREMENTS FOR INITIATING A CATFISH PRODUCTION ENTERPRISE. The American Fish Farmer 1 (February 1970): 12-14.

Newton, Scott H. REVIEW OF CAGE CULTURE INDICATES CONTINUING INTEREST. Aquaculture Magazine (November-December 1980): 32-36.

Oravetz, Charles A. MARKETING AND STATISTICS - FARM-RAISED CATFISH. The American Fish Farmer 4 (June 1973): 10-12.

Page, J. K. and Clark, W. NEW ALCHEMY: HOW TO SURVIVE IN YOUR SPARE TIME. Smithsonian 5 (February 1975): 83-89.

Reiger, G. GREEN SEA TURTLE FARMING: A GROWING DEBATE. Sea Frontiers 21 (July 1975): 215-218.

Rickards, William L. SELECTING AN AQUACULTURE SITE IN NORTH CAROLINA. Blueprints 81 (April 1981): 1-2.

Ryther, J. H. MARICULTURE: HOW MUCH PROTEIN, AND FOR WHOM? Oceanus 18 (February 1975): 10-22.

Simco, Bill A. and Cross, Frank B. FACTORS AFFECTING GROWTH AND PRODUCTION OF CHANNEL CATFISH, ICTALURUS PUNCTATUS. University of Kansas Publications, Museum of Natural History 17 (June 1966): 191-256.

Sokolov, J. A MATTER OF TASTE: FISH FRESH FROM THE FARM. Natural History 91 (July 1982): 76-80.

Stickney, Robert R. INTENSIVE CATFISH FINGERLING PRODUCTION. The American Fish Farmer 2 (June 1971): 9-13.

Stramel, Gib. TRAPPING CATFISH CAN BE SUCCESSFUL. The American Fish Farmer 1 (February 1970): 17-18.

Tatum, Walter M., et al. ALABAMA RESEARCHERS STUDY GULF KILIFISH: PRIME CULTURE CANDIDATE IN COASTAL REGIONS. Aquaculture Magazine (May / June 1982): 20-25.

US Department of Agriculture, Economic Research Service. Aquaculture Outlook and Situation (April 1982): 1-9.

Wade, N. NEW ALCHEMY INSTITUTE: SEARCH FOR AN ALTERNATIVE AGRICULTURE. Science 187 (28 February 1975): 727-729.

Wellborn, Thomas L. LIVE HAULING CHANNEL CATFISH. Aqua-

culture Magazine (March-April 1983): 22-23.

White, James T. VISIT TO A MISSISSIPPI FINGERLING FARM. The American Fish Farmer 2 (February 1971): 8-13.

Interviews

Bey, Robert. Owner/Operator, Buck Trail Aqua Farms, Lake Waccamaw, N.C. Telephone conversation, 19 Feb. 1985.

Bey, Robert. Owner/Operator, Buck Trail Aqua Farms, Lake Waccamaw, N.C., Interview, 21 Feb. 1985.

Cox, Winston. Tobacco/catfish farmer, Lake Waccamaw, N.C.,interview, 21 Feb. 1985.

Easley, J. W. Department of Agricultural Economics, North Carolina State University. Interview, May 1984

Harrison, Fred. Inland Fisheries Division, North Carolina Fish and Wildlife Commission, Raleigh, N.C. Interview, 9 September 1984.

Hassler, William W. Dr. Cape Fear Fish Farm, Raleigh, N.C. Telephone Interview, 13 Feb. 1985.

Lefever, Randy. Blue Ridge Fish Hatchery, Kernersville, N.C., Telephone Interview, 13 Feb. 1985.

Meyers, Lester. Delta Western Feed Mills. Indianola, MS. Interview, June 1984.

Moore, James. Bonlee Fish Hatchery. Bear Creek, N.C. Telephone Interview, 12 Feb. 1985.

Patrick, Gloria. Waccamaw-Siouan Development Agency, Inc., Whiteville, N.C. 18 September 1984.

Rouse, Randy D. UNC Sea Grant, Pamlico Estaurine Laboratory, Aurora, N.C., Interview, 19 Dec. 1984.

Rouse, Randy D. UNC Sea Grant, Pamlico Estaurine Laboratory, Aurora, N.C., Telephone Conversation, 4 Dec. 1984.

Steed, Larry. Delta Catfish Processors, Inc. Indianola, MS. Interview, June 1984.

Thomas, Frank. Food Sciences, North Carolina State University, Raleigh, N.C. Telephone Conversation, 24 January 1985.

Television, Films, & Tapes

"Farmers of the Sea". NOVA. first broadcast 13 November 1984.

RAISING CATFISH - TAPE 3032. "Extension Tele-Tip". North Carolina Agricultural Extension Service, North Carolina State University, Raleigh, N.C.