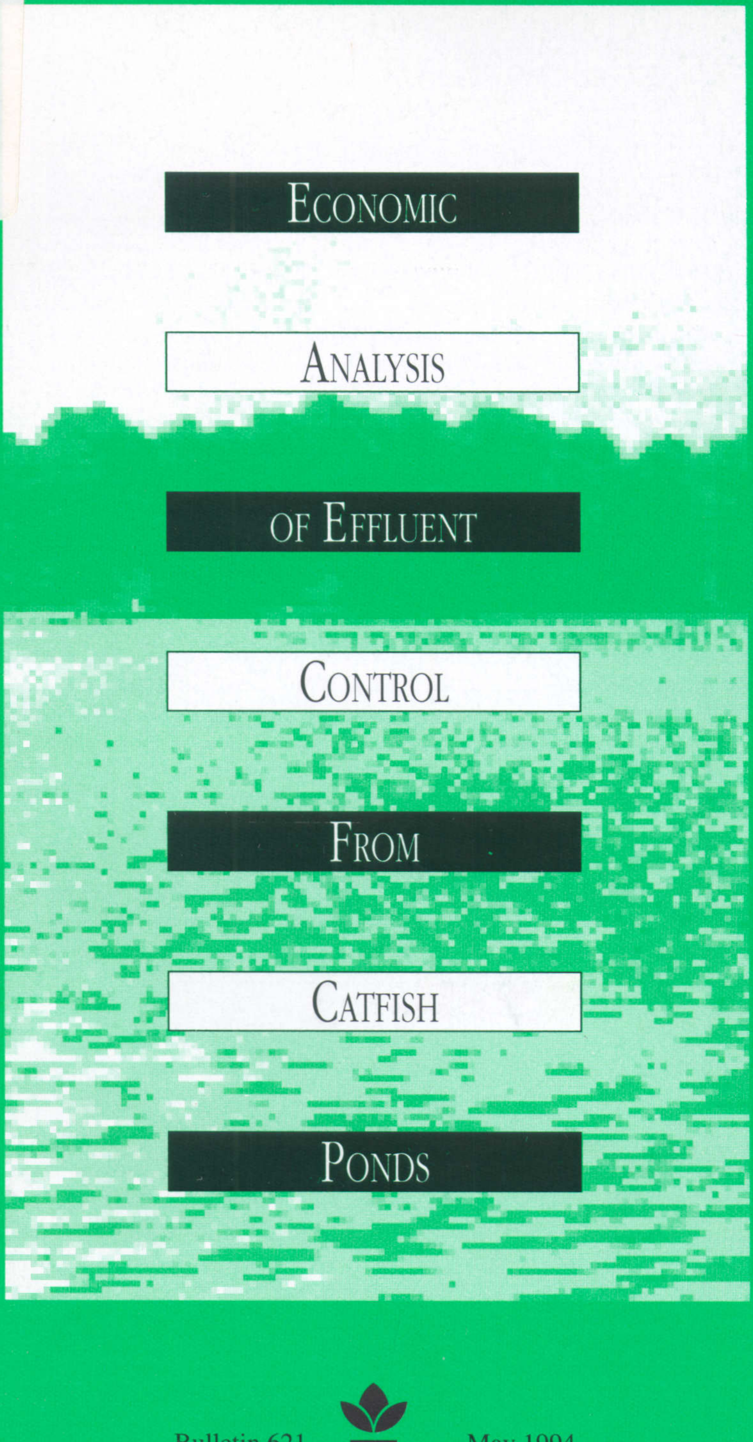

ECONOMIC ANALYSIS OF EFFLUENT CONTROL FROM CATFISH PONDS

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ECONOMIC ANALYSIS OF EFFLUENT CONTROL FROM CATFISH PONDS[1]

German A. Cerezo and Howard A. Clonts[2]

INTRODUCTION[3]

THE SIZE OF THE CATFISH aquaculture industry in the United States has increased tremendously in the last 25 years. By 1990, the total water acreage had increased to 157,490 acres. In 1992, Alabama ranked third in the nation in catfish production, after Mississippi and Arkansas, respectively *(23)*. More than 20,000 acres of water were used in commercial catfish farming in Alabama in 1990 *(14)*, an increase of about 17,000 acres over the past 20 years. Despite the already considerable size of this growing industry, little attention has been devoted to the potential polluting effects that effluents discharged from catfish ponds might have on the environment.

In 1974, the United States Environmental Protection Agency (EPA) identified fish culture ponds as potential point sources of pollution. Since then, regulations restricting water quality discharged from catfish ponds have been in place, but in their current form they apply to few actual farm situations. In Alabama, discharge from fish ponds must meet Federal EPA standards as set by the Alabama Department of Environmental Management. Permits are necessary for catfish farms that annually produce over 100,000 pounds of fish and discharge water 30 days or more each year *(14)*. Under existing regulations, most catfish producers do not need discharge permits; however, changes in effluent regulations are expected in the future.

Some of the water discharged from catfish ponds into streams, rivers and other water courses could have a potentially significant impact on the ecosystem both at the point of discharge and downstream. Pollutant problems reportedly associated with fish farming include chemicals and drugs, pathogenic bacteria and parasites, and chemical and/or physical

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change in water quality of the receiving stream. The latter problem constitutes, possibly, the most significant source of pollution *(1, 3)*.

Environmental consequences of fish culture pollution depend largely on production technologies, location and the type of farm *(18)*. Therefore, the catfish industry must use technologies and procedures that will protect the environment, as the success of the industry in the long run could largely depend on the sustained quality of the environment *(17)*.

At least two concerns regarding fish hatchery and fish farm effluents are apparent: *(1)* the economic feasibility of reducing the waste load from fish culture operations, and *(2)* the changes in fish production practices that may emerge under any permitted discharge limitations.

OBJECTIVES

The objective of this study was to estimate possible economic consequences for Alabama catfish farmers if pond effluent discharge is restricted. Estimates of economic consequences were achieved by simulating the use of constructed wetlands and water recycling systems with and without the imposition of taxes and standards on catfish pond effluent discharges. Both watershed and levee pond designs were considered to determine profit maximizing strategies under constraints on effluent discharge from catfish ponds. Results of this study may offer farmers and policy makers more useful information as well as a broader understanding of the potential economic impact of regulating effluent discharge from catfish ponds.

CATFISH POND EFFLUENT AND RELATED RESEARCH

Water Quality and Fish Waste

Aquacultural systems present problems not found in land-based culture systems. Fish waste products are deposited in the water, and feed that is not consumed by the fish cannot be recovered and thus decomposes in the pond. The waste from these activities results in high concentrations of nitrogen, phosphorus, and organic matter that settles to the pond bottom and is disturbed during fish harvest *(22)*.

With new technologies and management practices it is now possible to produce over 6,000 pounds of fish per acre of surface water compared with 3,500 pounds, which was thought of as the maximum just a few years ago. These production changes obviously require significantly more feed which is a major cause of water quality problems and high loads of waste discharged during pond draining. Feeding practices are important in fish culture management, but because of the associated environmental problems, feeding rates must be carefully managed to minimize potential losses *(22)*. Cole and Boyd *(5)* determined that the deterioration of water quality limits the amount of feed that can be safely provided as well as the quantity of catfish that can be produced. They found that water quality problems may be managed by restricting feed applied per day to a linear function of stocking density.

Barker et al. *(1)* evaluated catfish pond water quality parameters during growing, draining, and seining phases. Water samples taken during seining had the highest pollutant concentrations compared to samples taken during the growing and draining phases. This is explained by the physical agitation of the water and the stirring of the pond bottom during harvesting. Boyd *(2)* showed that pollutant concentrations are highest in the last five percent of pond water which may be drained during the seining phase. However, not all types of fish ponds are partially or totally drained when harvested. Those identified as levee ponds have the potential for harvesting without being drained annually.

Cole and Boyd *(5)* also evaluated water quality parameters which are useful in comparing stocking and feeding rates. For example, one measure of the polluting effects of an effluent is the quantity of oxygen needed for effluent decomposition, or biological oxygen demand (BOD). BOD is a measure of the amount of oxygen necessary to oxidize the readily decomposable organic matter. The measure is expressed as milligrams of oxygen demanded per liter of water (effluent) in a five-day process (BOD)[4]. Thus, BOD levels are useful in assessing the polluting potential of pond effluents. In contrast, the chemical oxygen demand (COD) the amount of oxygen necessary to completely degrade the organic matter, is used in aquaculture primarily as an index of organic matter concentrations. Nevertheless, it is also an indicator of effluent quality *(3)*.

Catfish Effluents and the Environment

Hollerman and Boyd *(12)* and Seok *(19)* reported the effects of non-annual draining on pond water quality. These studies compared ponds drained annually with ponds that were not drained for two and three years, respectively. The results indicated that failing to drain catfish ponds during harvesting does not lead to rapid water quality deterioration over time. Catfish ponds may be operated for many years without draining, if moderate feeding rates are applied. Seok *(19)* concluded that there was no significant difference in water quality variables and fish yields between drained ponds and those ponds not drained for

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[4] Alabama BOD is the technically correct term, the general term BOD was used throughout this report to denote the oxygen demand pond effluent load.

two years. Thus, the impact of effluent discharge on the environment could be minimized, and external water demands reduced by retaining water longer in ponds.

As an alternative to draining into nearby streams, ponds could be partially or totally drained by pumping or draining the water to neighboring ponds during the seining operation so that effluents may settle out and the water stored for recycling *(13)*. Later, water could be pumped or drained back to the harvested pond so that no pond effluents would be discharged from the farm. Pillay *(17)* recommended the construction of settling facilities in the form of a basin, tank, or pond when the concentration of suspended solids and BOD needs are above permissible limits. This recycling process also could help producers avoid other environmental problems that may emerge if large volumes of either ground or surface water are used for fish production, eg. a falling ground water table or surface flow reductions.

Pond Construction and Pond Design

Site selection and pond construction are the most important and expensive aspects of developing a catfish farm *(26)*. In traditional site selection and farm pond design, greater attention is paid to water quality and quantity for production and almost no attention is given to the discharge and dispersion of effluents *(17)*.

Catfish production ponds are typically of watershed or levee design. Watershed ponds, constructed in rolling terrain are usually less expensive to build than levee ponds, although, it is often more difficult to harvest fish from them. Because of the terrain and uneven sides and bottoms, many watershed ponds require complete draining at harvest.

Levee ponds are more conducive to fish production and harvest. They are constructed generally in level areas and their shape and access make feeding and harvesting much easier. Most can be harvested without complete water drainage. However, they are more expensive to build.

Water supplies for filling levee ponds are usually limited to ground and surface water sources *(13, 25)*. Watershed ponds, on the other hand, have the advantage of using runoff water from rainfall. A dam is built across a sloping depression or valley so that storing the runoff from rainfall on the watershed is possible. However, ground and surface water also are used to fill watershed ponds *(14)*. Even though water for watershed ponds is relatively inexpensive or free, and there may be less competition from other agricultural activities, water quality problems tend to be more severe in watershed ponds than in levee ponds. Water from wells and springs is generally considered best for catfish operations and watershed ponds are fed by less desirable watershed supplies which may contain nutrient or pesticide runoff.

Water Recycling

Some fish farms have systems to drain effluents through central pipes into either treatment reservoirs or bio-filters to remove nutrients and organic matter. In both systems oxygen may be replenished via action of photosynthesis. Treated waters are then available for reuse or discharge into receiving streams.

A recirculating system which uses treated water typically is a completely closed system where, theoretically, no water loss or discharge occurs. External water is supplied only to replace losses by seepage and evaporation, not to improve water quality. The problem of effluents discharge is resolved by not allowing water to leave the system *(17)*. Arrangements such as this have been recommended by several researchers *(10, 17, 13, 27)*. Most recommended systems allow the transfer of water from one pond to another or to a common reservoir for subsequent redistribution and reuse. Such a system must have all the plumbing and handling facilities necessary to expedite water transfers economically. Normally, investment costs for such a system are quite high. However, because water is reused, the high annual cost of water pumping for refilling a non-circulating system may be minimized.

According to Pillay *(17)*, when the species being cultivated can tolerate relatively high concentrations of metabolic waste, simple recycling systems may be adopted. However, there are occasions when an alternative system is required. Bio-filters provide such an alternative to simple recirculating systems. Constructed wetlands are the most common form of bio-filter system. In wetland systems, discharged water is filtered through a marshland for purification, and then pumped back to production ponds for reuse, there is some evidence that bio-filters will reduce the incidence of fish disease and off-flavor problems common in catfish production *(8)*. In the study being reported, both the recirculating and wetland systems were considered.

Constructed Wetlands

A constructed wetland is an engineered marsh designed for waste removal and treatment processes. Processes are based on physical, biological, and chemical factors. Treatment consists of sedimentation, absorption, and filtration of solids. The number of "filtration" units in a constructed wetland depends on waste water volume and quality, site, topography, and the desired level of water quality. Typically, each "unit" is designed to handle the waste load for a specific water volume and the hydraulic rate at which waste waters flow into the system at discharge. A wetland acts as a sedimentation basin in which a portion of BOD is absorbed, and suspended solids settle and then decompose. The remaining BOD and suspended solids are metabolized by microorganisms.

McLaughlin *(15)* reported that simple settling appears biologically to be the best way to remove pollutants from hatchery effluents. However, it is unlikely that settling ponds would be feasible for the effluent discharge from large ponds (10 to 50 surface acres) such as those used in the southeastern United States for catfish production.

In a comparison between wetlands and sand filters, Hebicha *(11)* showed that wetlands provided the lowest cost means for removing BOD prior to discharge into public waterways. He estimated the BOD and phosphate removal efficiencies for wetlands and intermittent sand filters using regression analysis. His analysis was based on earlier research by Gearheart, et al. *(7)*, which consisted of 12 artificial marsh cells (constructed wetlands), each one subject to different operating conditions. The 12 cells were 200 feet long and approximately 4 feet deep including the berm with an operating depth of 16 inches or less. The diversity of plant species inside the wetlands was similar to that in natural marshes.

Gearheart used hydraulic loading rates of four, eight, and 16 gallons per minute (GPM) and hydraulic detention times ranging from 29 to 141 hours. The marsh cells proved to be extremely effective and consistent in removing non-filterable residues (NFR) with an 84 percent removal rate. The effectiveness in removing NFR's did not appear to be a function of hydraulic detention, water temperature, incident radiation, wind speeds, or type of aquatic macrophytes. Rather, NFR was dependent upon density and distribution of aquatic macrophytes and hydraulic loading rates. BOD removal efficiencies varied from 41 to 65 percent with an average of 56 percent. This study also showed that dissolved oxygen concentrations critically affect the effectiveness of artificial wetlands.

Public Policy for Effluent Control

The technical term for the discharge of catfish pond wastes into public waterways is externality. An externality occurs when the action of one person has an effect on another, and over which the person affected has no control. If the quality of water used by one person is reduced by actions of someone else, and the one using the water last cannot control the activity, then an externality has occurred.

In an ethical as well as economic sense, the use of public waters for wastes disposal is a real problem. If the quality of water in the stream is reduced because of the wastes, there is an ethical issue. In addition, the transfer of production costs from a catfish producer to another water user downstream creates an economic gain for the producer and a loss for the subsequent user. In either case, one remedy is for the waste discharger to absorb or "internalize" the costs associated with waste disposal.

There are a variety of policy forms designed to internalize externalities. Governmental policies include taxes, subsidies, standards (regulations), and the use of marketable permits. The most commonly used tools are the standards and taxes. Standards establish maximum acceptable levels of waste discharged. Taxes are punitive means to enforce adherence to standards or provide incentives for standard compliance. Both methods induce businesses to find cost-effective methods to meet environmental constraints.

An emission charge (tax) is a fee (collected by the government) imposed on each unit of pollutant discharged into the water *(21)*. A subsidy is a payment (by the government) to the producer to not make the planned discharge. The key difference between the two is their effect on the farm versus the effect on the industry as a whole. If the taxes charged equal the subsidies paid, the two policies will have the same immediate effect on the farm. However, over a longer time period, subsidies have been proven to actually increase the amount of wastes discharged by the industry because the payments attract more firms seeking to dispose of wastes in order to get the payments *(9)*. Thus, this research did not consider the opportunity for subsidies. Rather, the effect of charges (taxes) on producer incomes and waste disposal decisions was examined.

The alternative to taxes or subsidies is the use of regulations to limit the amount of waste discharged into public waters. Typically, standards alone are not sufficient to cause people to reduce the use of public waters for waste disposal. There must be some incentive other than the altruistic motive. Thus, the typical approach is to use both taxes and standards in a combined approach. No tax would be paid if the producer kept discharges from fish production within the specified limits.

The approach taken in this research was to evaluate the costs to producers and effects on production and income for limits set on waste discharge. Various levels of permitted wastes were considered. Any excess waste discharge above the alternative limits was subject to a tax levy. Both the standard and tax represented an increase in the variable cost of production for fish farmers.

An objective of this type of research is evaluation of public policy alternatives. Public policy attempts to find mechanisms to internalize externalities in such a way as to achieve desirable and acceptable social conditions with minimum burdens imposed on those regulated. Generally, a social optimum cannot be determined because information regarding the nature of benefits and costs (damages) from a particular activity is lacking. In this case, the benefits and costs of pollution control in the catfish industry are both poorly defined and irregular. However, some form of constraint on the catfish industry with respect to waste levels discharged into public waters is likely in the foreseeable future. This is especially true since the U.S. Environmental Protection Agency has already determined that catfish ponds are point-sources of pollution. A primary question of concern for policy makers is; what will be the effect of alternative constraint measures on catfish production and producer income?

Theoretically, a profit-maximizing catfish producer when faced with constraints that increase production costs, should reduce waste discharges until the marginal cost of waste reduction equals the cost (tax penalty) of not treating the waste. However, from a social perspective, the producer is not the only entity to which costs of control will accrue. An additional cost which may be passed on to the producer is cost of enforcing regulations. If so, then the proper level of effluent control from a social perspective is the point at which marginal damages (from losses in water quality) equal the marginal cost of waste reduction plus the marginal cost of implementing and enforcing controls. Since no controls are actually in effect at present, only the cost of waste reduction was considered as a decision criterion in this study.

THE LINEAR PROGRAMMING MODEL

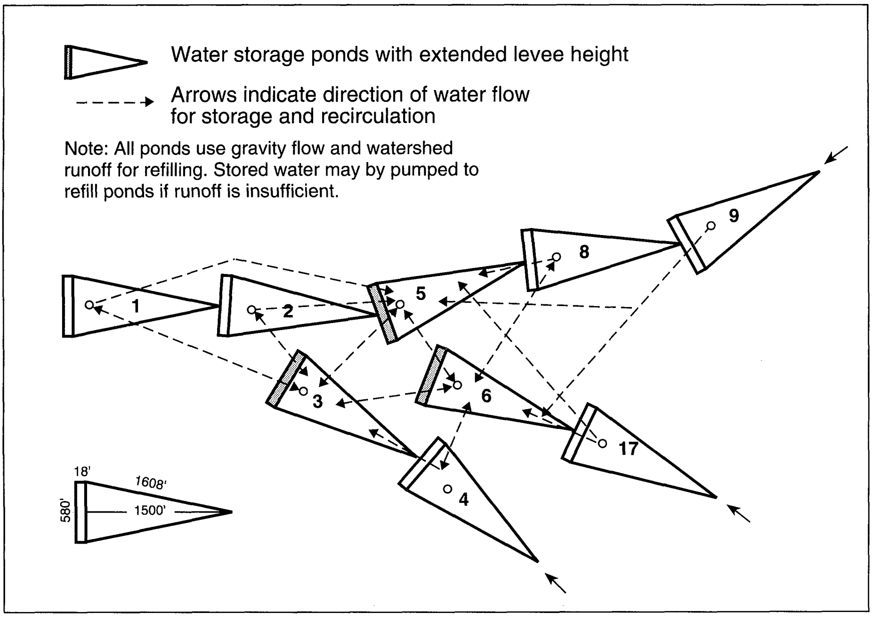
Linear programming (LP) has been used as a management tool for many years. The process provides a sophisticated budgetary technique which allows optimum resource use to be determined. Both Hebicha *(11)* and Schmittou *(18)* used linear programming in assessing alternative pollution control strategies in the Alabama catfish industry. Their models provided the initial framework for this study.

The LP technique allows measurements of the impacts of selected constraints such as waste management on farm profit, resource use, and long-term management strategies. In this case, environmental standards limiting the amount of catfish pond effluents discharged into public waters and possible taxes on excess BOD loads generated by those discharges were imposed as constraints on production. Alternative strategies to handle possible pond wastes were then evaluated to determine the optimum strategies under different constraint levels.

MODEL ASSUMPTIONS

Pond Systems

Hypothetical 10-acre levee and watershed ponds, constructed in West Alabama, were assumed to be available for use. Each production system was further assumed to have sufficient land and water available to develop 12 ponds (120 acres of water surface) each. The figure shows how such a watershed-pond system might be designed to capture diffused surface waters, and allow pond water recycling. Typically, levee ponds would be arranged in a grid so that levees would serve contiguous ponds. All ponds were considered to be production units, and management decisions were made with respect to maintaining production in each pond on a more or less continuous basis.



Note: All ponds use gravity flow and watershed runoff for refilling. Stored water may by pumped to refill ponds if runoff is insufficient.

Fig. Schematic illustrating a watershed pond system for recirculating water used in catfish production, 10-acre ponds.

The system, as designed, provided for partial drainage of all watershed ponds annually and complete drainage every three years. Levee ponds were assumed drained once every three years. Complete drainage for both types of ponds every three years was based on work by Seok *(19)* and Hollerman and Boyd *(12)* which indicated no loss in water quality in the time period, but a serious problem with respect to oversized fish and pond maintenance needs. Partial draining each year allows some fish to escape during seining. Consequently, larger fish remain in the pond when the next crop is stocked. These larger fish continue growing, eating large amounts of feed, and preying on smaller (4 to 6 inches) fingerlings restocked annually. Many such fish may exceed two pounds. After a few years the problem can become so severe that profits may be severely affected. Consequently, a complete harvest at least every three years is recommended to remove larger fish and maintain survival and growth rates of the new fish crop. In addition, water and wave action on pond levees causes sufficient damage over a three-year period to warrant maintenance activity.

Waste Handling Systems

As indicated earlier, several methods may be used to handle waste water before it is discharged into the receiving watercourses. These include dilution, sand filters, bio-filters, and water recycling . However, water recycling as suggested by Pillay *(17)* and Jensen *(13, 25)* and constructed wetlands (bio-filter) as suggested by Gearheart *(7)* and Hebicha *(11)* may be the more feasible treatment alternatives for the reduction of effluent discharged from commercial catfish ponds.

Data Sources

Average costs for a hypothetical farm in west Alabama were used in this study. These costs were derived from actual costs obtained from the Alabama Fish Farming Center in Greensboro, Alabama. The data were derived from ponds constructed in west Alabama between 1988 and 1992. Construction costs included: clearing, earth fill, excavation, pipe and drain systems, concrete, seeding and road gravel, Table 1. Estimated costs for recycling systems and constructed wetlands were derived with assistance from personnel at the Fish Farming Center and agricultural engineers at Auburn University.

TABLE 1. ESTIMATED CONSTRUCTION COST PER ACRE FOR DIFFERENT TYPE 10-ACRE CATFISH PONDS AND DEPTHS, WEST ALABAMA, 1988-1992

Pond type	Depth	Average cost
	Ft.	*Dol.*
One sided watershed pond (production)	10	11,530
One sided watershed pond (recycling)	13	14,760
Three sided levee pond	6	12,160

Although different water quality parameters may be used as indicators of water pollution, BOD as recommended by Boyd *(2)* was considered most useful in assessing the pollution potential of pond effluents. Consequently, BOD was used in this study as an index of effluent quality reduction.

The standard, or maximum limit of wastes a farmer may be allowed to discharge, is measured as milligrams per liter of BOD (mg/L). Three different effluent discharge standards were evaluated; 0, 15, and 30 mg/L of BOD. There is little justification in mandating a zero discharge level since there is some assimilative capacity in all waterways. Obviously, if the cumulative effects of many dischargers severely impact a receiving stream, then sharp reductions in waste loads may be the proper action to return waters to acceptable quality levels. However, for study purposes a zero discharge level was tested to estimate its impact on production. In most instances some tolerance level, say 15 or 30 mg/L, would be expected. When a water treatment method was not sufficient to meet the standard, excess BOD loads were considered subject to a tax fine. For example, wetlands, as considered in this study, were able to absorb only about 50-55 percent of the BOD load *(7)*. The remaining 45 to 50 percent of the BOD load would be subject to the tax assuming that the standard was zero discharge. An imposed standard of, say, 15 mg/L would represent approximately 25 percent of the BOD load. Thus, with a 15 mg/L standard, taxes would be levied on 75 percent of the relevant discharge (the 45 to 50 percent not absorbed by the wetland).

The imposition of standards and taxes on the two different pond systems was further tested by simulating alternative waste control methods. These included pond water recycling systems, constructed wetlands, and reduced stocking densities. Overall, the full combination of alternatives tested in this research included:

1.- imposition of standards for authorized levels of BOD discharged
2.- imposition of taxes on units of BOD discharged above standards
3.- use of a constructed wetland to reduce BOD concentration
4.- use of a water recycling system
5.- decreased stocking densities as a strategy to reduce pollutant levels of discharged waters, and
6.- imposition of capital limitations to reduce risk as well as waste loads associated with intensive production.

Mixed Integer Linear Programming (MILP) models were analyzed for each of the effluent reduction alternatives. Data from Crews et al. (6) and Masser et al. (14) were used to develop production budgets for each activity, Appendix Table 1.

Stocking rates of 2,000, 4,000, and 6,000 fish per acre were used. Each stocking activity assumed different maximum feeding rates to reduce water quality deterioration. The assumed feeding schedules limited the amount of feed per acre administered daily as recommended by Cole and Boyd *(5)*. Cole and Boyd and Seok's *(19)* results were employed in this study to relate stocking densities and feeding rates to water quality parameters, specifically biochemical oxygen demand (BOD), Table 2.

TABLE 2. BIOLOGICAL OXYGEN DEMAND CONCENTRATIONS FOR DIFFERENT CATFISH STOCKING DENSITIES AND DAILY FEEDING RATES

Stocking density	Feed applied	BOD
(Fish/ac.)	*(Lb/ac.)*	*(Mg/L)*
2,000	55	50
4,000	75	55
6,000	95	60

Alternative production activities included three different fish sizes at harvest: 1, 1.5, and 2-pound fish. The 1.5 and 2-pound fish production system prolonged the production cycle to more than one-year and over-wintering costs were assumed. Typical over-wintering costs as calculated by Schmittou *(18)* were updated for this study. The number of days in production was determined by ending weight, stocking density, feed conversion, and maximum daily feed.

Ponds where fish were produced in short production cycles were assumed to be harvested and restocked during the period required for fish grown to heavier harvest weights. For example, fish stocked at rates of 2,000 - 3,000 fish per acre for a one-pound ending weight could be stocked, grown, and harvested in the time required to produce fish of two pounds. Since larger fish are not sold annually, it was necessary for budgetary comparisons to estimate their value (in the pond) at the time of harvesting the one-pound fish. Thus, to account for the annual value of fish grown to heavier weights, an opportunity cost (sale value of unharvested fish) was assumed. Such a procedure assumed that the fish could be harvested if desired; thus they had an opportunity cost equal to the asset value.

A normal mortality rate for catfish grown in Alabama ponds at lower stocking densities of 2,000 to 3,000 fish per acre is six percent. However, when stocking densities are increased, the probability of higher mortality rates is quite high. From a biological perspective, a maximum standing crop of fish in Alabama ponds is about 7,000 pounds per acre. Thus, mortality rates were increased as stocking densities and harvest weights were raised so that a maximum standing crop of 7,000 pounds per acre was maintained throughout the growing period.

Stocking fish at 5,000 to 6,000 per acre obviously involves much more intensive production and waste management and considerable added risks. Many farmers will not accept these higher risk levels. Thus, the analysis included capital constraints, either self or externally imposed, on production. Three different capital constraint levels, 100, 75, and 50 percent of capital needed for maximum profit, were tested. Such a constraint effectively limited stocking densities and subsequent effluent loads to levels which may be more acceptable to all but those most prone to risk-taking.

Wetland System

Construction costs for wetlands depend on factors such as topography, labor, availability of suitable vegetation, and equipment needs. Land space for the construction of wetlands to treat effluents from catfish ponds was assumed available on each farm. Wetland construction and maintenance costs were obtained from Hebicha's *(11)* study and updated based on the Consumer Price Index.

Table 3 presents wetland sizes, investment, maintenance, and annual costs to treat the last five percent of the effluent discharged from catfish ponds *(11)*. The other 95 percent of pond water was considered acceptable for direct discharge into receiving streams. Hence, no treatment was necessary.

TABLE 3. ESTIMATED WETLAND INVESTMENT, MAINTENANCE AND ANNUAL COST FOR A 10-ACRE CATFISH POND, WEST ALABAMA, 1992

Pond type	Wetland size	Investment cost[1]	Maintenance cost	Land opportunity cost	Total annual payment[2]
	Acre	*Dol.*	*Dol.*	*Dol.*	*Dol.*
Watershed pond	2.7	3,308	71	128	864
Levee pond	2.5	2,680	65	117	672

[1] Investment costs for the two pond types differed because in a levee pond system, levees would be shared by two or more ponds, whereas in watershed systems each pond requires a separate levee.

[2] Net returns above costs from catfish production on 2.7 and 2.5 acres respectively.

Wetland size was simulated as being sufficient to treat five percent of the total pond volume at a hydraulic loading rate equal to 0.24 million gallons per acre per day (MGAD). Land opportunity costs were based on Crews et al. *(6),* and indicates net return above variable cost to land, labor, and management. Total annual investment costs were amortized over five years at nine percent interest, with four payments per year.

WATER RECYCLING SYSTEMS COSTS

Watershed Ponds

A recycling system was assumed possible with the added construction of two extended-levee (dam) watershed ponds 13-feet deep for water storage. Water levels in all watershed ponds were assumed to be lowered to six feet for harvesting purposes. Following harvest, the ponds were considered refilled with water previously pumped to and stored in the deeper ponds. Special characteristics and added costs for building recycling capabilities into watershed ponds are shown in Tables 4 and 5. All pumps used in the respective systems were assumed to be electric with the cost per kilowatt hour equal to $0.075. Electricity needs for aeration, recycling, and refilling were based on studies by Cole and Boyd *(5)* and Crews, et al. *(6)*.

TABLE 4. ANNUAL RECYCLING CHARACTERISTICS ASSUMED FOR A 10-ACRE WATERSHED POND FOR CATFISH IN WEST ALABAMA, 1992

Recycling characteristics	Value	Units
Water volume to be pumped	24	ac-ft.
Hydraulic flow	1,100	gpm
Pipe diameter	8	in.
Total dynamic head	40	ft.
Pump size	20	hp.
Hours of operation	120	hr.
Power	1,790	kwh
Pumping cost per pond	134	dol.

Since watershed ponds are built on sloping terrain, the cost of lifting water vertically from the lowest to highest elevation must be considered. A total dynamic head of 30 feet vertically plus a 10-foot head loss due to water friction in pipes and valves was assumed. An average of five days was considered necessary to refill each watershed pond after harvest.

TABLE 5. ESTIMATED INVESTMENT COST FOR A 10-ACRE WATERSHED POND FOR CATFISH, ALABAMA 1992*

Description	Expected life	Total cost	Annual (12 ponds)	Annual cost per pond
	Yr.	*Dol.*	*Dol.*	*Dol.*
Extended dam height for watershed ponds (cost of extended dam only)	5	6,460	1,365	115
Pipe installation cost	5	540	115	10
Pipe cost (16,000 ft.)	10	3,600	760	55
Pump cost	10	6,000	630	55
Pumping cost	annual	1,610	1,610	135
Maintenance cost	annual	300	300	25

*All numbers rounded to nearest $5.00

Capital requirements for pond development and alternative waste management systems were based on construction capital and materials costs at nine percent interest. Annual payments were included as fixed cost assessed against the operation. Charges for various capital items were based on the expected life of each item. For example, water pumps were amortized over a 10-year period; whereas other items such as aerators were amortized over lesser time periods.

Levee ponds

A recycling system for levee ponds was assumed possible through the construction of one extra pond. Levee ponds may not require drainage during harvesting activities for several years, but a well-managed catfish pond would need full drainage once every three years for pond maintenance and proper fish management. Construction cost, such as pipes, pumps, etc. for a 10-acre levee pond are presented in tables 6 and 7. The elevation difference for a levee pond system is not as great as in watershed-pond systems, but a recycling system will require moving water up and over levees, and along ponds banks. Consequently, the total dynamic head for estimating pumping needs and costs was based on a 20-foot vertical lift and a 10-foot head loss due to water friction in pipes and valves. Pond draining, cleaning, and refilling was assumed to require and average of 10 days.

Annual fixed costs for levee ponds included amortization payments, maintenance, operating expenses, and an opportunity cost. The opportunity cost was based on the alternative of using the extra levee recycling-storage pond as a production pond *(6)*. Annual fixed investment payments

TABLE 6. ESTIMATED RECYCLING CHARACTERISTICS FOR A 10-ACRE LEVEE POND FOR CATFISH IN WEST ALABAMA, 1992

Recycling characteristics	Value	Units
Water volume to pumped	56	ac. ft.
Hydraulic flow	1,300	gpm
Pipe diameter	8	in.
Hour of operation	120	hr.
Total dynamic head	30	hr.
Pump size	15	hp.
Hours of operation	120	hrs.
Power	2,688	kwh
Pumping cost per pond	200	dol.

TABLE 7. ESTIMATED RECYCLING INVESTMENT COST FOR A 10-ACRE LEVEE POND FOR CATFISH, ALABAMA 1992*

Description	Expected	Total	Annual	Annual
	Yr.	*Dol.*	*Dol.*	*Dol.*
Extra levee pond (6 ft.)	5	12,160	2,565	215
Pipe cost (1,100 ft.)	10	7,980	840	70
Pipe installation cost	---	1,500	210	20
Pump cost	10	6,400	670	55
Pumping cost	annual	2,425	2,425	200
Maintenance cost	annual	600	600	50
Opportunity cost	annual	865	865	70

*All numbers rounded to nearest $5.00.

for levee ponds were based on a declining balance method and calculated by the same procedure as the watershed-pond recycling system. All production ponds were assumed to use the same water pump and storage pond for recycling purposes.

Refilling Levee Ponds

Water budgets for a hypothetical 10-acre pond were developed for both pond types. The volume of water in a pond is directly related to physical factors such as pond depth, evaporation, rainfall, ground and surface runoff, and seepage rates. Rainfall onto the pond surface, surface runoff, ground inflow, evaporation, and spillway discharge rates specifically for watershed ponds in west Alabama were taken from Parsons *(16)*. Watershed ponds were not assumed to need an external water source to maintain desired water levels in the pond. However, levee ponds required an external water source in order to maintain desired water levels. Since pond water level maintenance is in addition to initial filling or recycling activities, wells and water pumps for refilling purposes were assumed to be in place. The volume of water pumped was based on water budget requirements for the west Alabama area. Total dynamic head was based on a 100-foot deep well and a 20-foot head loss due to water friction in pipes and valves. Additions to pond water levels for maintenance of water volume was assumed to require 15-days. Table 8 presents the refilling characteristics needed to maintain desired water levels in a 10-acre levee pond.

Complete drainage and refilling of levee ponds every three years is necessary. The pumping costs per pond per year assumed that levee ponds will be handled in this manner. As before, wells and pumps were considered in place and available. Pond filling was assumed to require an average of 55 days. Table 9 presents the characteristics and costs to refill a 10-acre pond with six-foot levees. No additional investment costs were assumed.

TABLE 8. ESTIMATED ANNUAL REFILLING CHARACTERISTICS TO MAINTAIN DESIRED WATER LEVELS FOR A 10-ACRE LEVEE POND FOR CATFISH IN WEST ALABAMA, 1992

Characteristics	Value	Units
Water volume	15	ac ft
Hydraulic flow	230	gpm
Pipe diameter	4	in.
Total dynamic head	120	ft.
Pump size	10	hp.
Hours of operation	120	hr.
Power	2,642	kwh
Pumping cost per pond	200	dol.

TABLE 9. ESTIMATED CHARACTERISTICS FOR FILLING A 10-ACRE LEVEE POND FOR CATFISH IN WEST ALABAMA, 1992

Characteristics	Value	Units
Water to be pumped	56	ac. ft.
Hydraulic flow	230	gpm
Pipe diameter	4	in.
Total dynamic head	120	ft.
Pump size	10	hp.
Hours of operation	1,322	hr.
Power (kwh)	9,864	kwh
Pumping cost per pond (every three years)	740	dol.
Annual pumping cost per pond	247	dol.

RESULTS

Initial Analysis

Baseline situations with no effluent reducing constraints such as taxes, standards, capital limits, wetlands or recycling were developed to show conditions as they may exist in some systems today. Thus, the initial analysis evaluated *(1)* watershed ponds drained every year, and levee ponds drained every three years, and *(2)* both watershed and levee ponds drained every three years. All ponds were assumed stocked in the spring with six-inch fingerlings. The initial optimum resource use situation called for catfish to be stocked at a rate of 4,000 per acre in 12 watershed ponds. Fish should be harvested at a two-pound size when the ponds were drained. The net return to fixed resources per 10-acre pond was $8,980, table 10.

Obviously fish price is a key variable in farm income. A sensitivity analysis was performed to test the full effects of price on income and production decisions affecting that income. Price was reduced incrementally from $0.65 per pound to $0.55 per pound. No change in the resource combination was observed, but, as expected, net income fell... to $6,465 per pond.

The baseline analysis provided a good indicator of income in situations where there are few constraints on management decisions. However, the analysis showed that a tax constraint would not significantly affect income from fish production. For example, the addition of a tax at the nominal rate of $5 per mg/L of BOD, and a standard allowing

30 mg/L discharge, which is a relatively low tax rate, would lower income per pond to $8,860, a 1.4 percent reduction, Appendix Table 1.

TABLE 10. RESULTS OF OPTIMAL RESOURCE ALLOCATION FOR CATFISH PRODUCTION, NO CONSTRAINTS ON PRODUCTION, BY RISK ACCEPTANCE, NINE PERCENT MORTALITY RATE, ALABAMA, 1993

Capital available (pct)	Pond number and type	Stocking density of fish	Ending weight	Price (per lb)	Tax mg/L	Net revenue (per 10-ac.)
		Acre	*Lb.*	*Dol.*	*Dol.*	*Dol.*
Risk intensive:						
100	12-watershed	4,000	2.0	0.65	0.0	8,980
100	12-watershed	4,000	2.0	0.60	0.0	5,500
100	12-watershed	4,000	2.0	0.55	0.0	6,465
100	12-watershed	4,000	2.0	0.46	0.0	0
Risk reduction:						
75	10-watershed	4,000	2.0	0.65	0.0	8,980
	2-watershed	4,000	1.5	0.65	0.0	6,286
Risk averse:						
50	7-watershed	4,000	1.5	0.65	0.0	6,286
	7-watershed	2,000	1.0	0.65	0.0	500

Production Constraints

Risk

To test the constraint imposed by risk, capital needed to achieve the optimum production was reduced in increments up to 50 percent. At a 25 percent reduction, the profit maximizing production system changed to allow the production of 1.5-pound fish in two of the 12 watershed ponds and two-pound fish in the remaining 10 ponds. Net returns to land, labor, and management were $6,285 or less per pond, depending on fish size and stocking density, Table 10. More severe capital limitations obviously have negative impacts on farm income. For example, restricting capital needs to half of that required for unrestrained optimum production indicated that risk averse farmers would favor lower stocking densities for at least a portion of their operations. As a result, net income from production would be reduced.

Taxes

As Table 1 shows, a BOD load of 55 mg/L was assumed present in wastes from catfish production ponds. In the event that this level of wastes is unacceptable, it is conceivable that some form of measures may be needed to provide incentive for waste reduction. Thus, for investigative purposes, a tax per unit (mg/L) of BOD in wastes from ponds was assessed to determine what impacts such measures might have. Initially, a tax of $5 per unit of BOD was used to see if any of the waste reduction techniques being tested would become cost effective. As Appendix Table 1 shows, a tax at this rate had no effect on waste reduction; it only lowered net income per pond by approximately $275. Only when the tax was increased to $10 per unit of BOD did pond water recycling become an efficient alternative to paying the tax. If the tax were lower, farmers would prefer to pay the tax, rather than incur the cost of installing the waste control measures tested in this study. In other words, farmers seeking to maximize profit would probably continue normal production without reducing waste discharges unless the tax was at least $10 per mg/L of BOD. If that occurred, they likely will shift to pond water recycling. Because of the added costs of recycling and taxes on any wastes discharged when ponds were actually drained (every three years), net revenue per 10-acre pond fell by about $500.

Constructed wetlands are considered more expensive to develop and operate than other waste management procedures considered. Consequently, none would be feasible unless taxes were increased to an exorbitant $185 per unit of BOD. If that did occur, net revenues per pond would be reduced by nearly $1,612 to $7,370. In an earlier study, Hebicha *(11)* estimated that constructing a wetland for fish pond wastes would add approximately $20 per acre of surface water to the annual cost. Applying that added cost to this study would mean an additional $200 in variable cost per pond, exclusive of annual operating expenses. Since wetlands only remove about half of the BOD load, approximately 25-30 mg/L of BOD would remain after treatment and be subject to added taxation. Results of this study showed that under zero discharge conditions, forcing wetlands as the waste management technique caused income to fall by nearly $1,612 per pond, if ponds are drained every three years, and $1,742 if watershed ponds are drained annually, Appendix Table 1. Also, the added cost of wetlands would initiate a shift from watershed to levee ponds if watershed ponds are drained annually. This clearly shows that a wetland is the most expensive alternative.

Standards

Reduction in “legally”allowable BOD loads from pond waste discharges will force producers to either treat wastes or incur constraints in the form of taxation. Initially, zero discharge was assumed to be the norm. However, waste tolerance levels of 15 and 30 mg/L rather than the zero tolerance in the initial solutions were tested for impact. With increased amounts of acceptable waste loads, income rose as expected. However, the difference in income in situations with and without standards imposed was not significant, Appendix Tables 1 to 6.

Results showed that standards must be coupled with charges (tax) to have significant effects on waste reductions. Higher tax charges will be necessary to induce the desired effect. For example, when a standard of 15 mg/L of BOD was used in conjunction with a tax of $5 per unit of waste in excess of the standard, a farmer harvesting 3,500 pounds per acre could expect to pay a charge of $0.008 per pound. Increasing the standard to 30 mg/L would lower that cost to $0.005 per pound of harvested fish.

If the tax rate were increased to $10 per unit of waste, the same farmer could expect an increase in production costs of $0.016 and $0.015 under the 15 and 30 mg/L standards respectively. Income would be affected differently because the higher tax would make water recycling feasible, thus partially offsetting the added cost of the tax.

CONCLUSIONS

The fact that fish pond effluent controls are likely within some relatively near time period means that producers must begin thinking about the possibility of incurring additional costs to meet discharge requirements. Unfortunately, little direct information is available for fish producers. This simulation procedure was based on a compilation of data from several sources, including municipal waste disposal operations. However, the results do provide some fresh insights into the decision framework farmers may face.

Fish pond waste does represent a cost of production which currently is being passed on to other water users downstream. This externality has not been considered significant to date. However as production intensities continue to rise, the waste load on public waterways can be expected to rise.

Among the alternative evaluated, water recycling was shown to be the least-cost treatment method. However, producers would not decide to recycle water unless a tax of at least $10 per mg/L of BOD were levied. If this occurred, the optimum decision for profit maximization would be to stock fish at 4,000 per acre and grow them to two pounds harvest weight, which technically would be difficult, but possible.

Results further suggested that watershed pond production systems are preferred over levees. This conclusion portends a trend away from the present popular move towards levee ponds. If watershed pond systems do prove to be more feasible under increased environmental constraints, then Alabama as a state could gain a competitive advantage over the top catfish producing states of Mississippi and Arkansas. Reported ground water contamination and excessive water table drawdowns in those states could accelerate the move to watershed ponds and pond water recycling.

Designing watershed pond systems to accommodate water recycling technologies will not add greatly to the cost of production for new developments. Retrofitting existing ponds may be less efficient, but still should be cost-effective. Levee pond construction and recycling systems were relatively more expensive than watershed ponds. Part of the added cost is derived from the need to construct a separate pond(s) for water handling needs. While this study did not consider extra ponds as a production unit, it may be possible to incorporate such units into a production scheme. However, doing so would greatly complicate management of the system.

Pond drainage patterns and risk acceptance levels normally would be expected to further complicate the decision framework for producers. However, as the data indicated, differences in cost based on pond drainage dates were not significant, although, draining ponds annually did increase costs of production by about $130 per pond.

Finally, the more risk averse a producer is, the lower the income that may be expected. This observation is no different than is the case in any investment. Increased risks generally always are rewarded with greater incomes...if losses such as fish kills are not incurred. Individual farmers simply must decide the maximum losses they can afford and produce accordingly.

From a policy perspective, combining effluent standards with effluent charges (tax) appear to be the least costly alternatives to initiate internalization of catfish production effluents. Presently, estimated effluent loads based on stocking rates, feeding, and harvest weights seem to be sufficient for regulatory purposes. More direct restrictions such as metering pond outfalls may be cost prohibitive for state and federal regulatory agencies. Such expenses may exceed any revenues generated by effluent taxes.

The imposition of effluent taxation will cause an increase in the firm's variable cost, which in turn may force some smaller or more inefficient operations to exit the industry. This alone will reduce the aggregate effluent discharge from the industry in Alabama. More efficient producers likely will adopt waste control technologies. Thus, the results support the theoretical position that, in the long run, taxation may provide a reasonable incentive to internalize the externalities in the catfish industry.

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APPENDIX

APPENDIX TABLE 1
NET INCOME FOR RISK INTENSIVE CATFISH PRODUCTION, BY EFFLUENT STANDARD AND TAX CONSTRAINTS, WITH RESULTING POND AND EFFLUENT CONTROL SYSTEMS, ALABAMA, 1992*

Standard level	Tax per Mg/L	Stocking density	Ending weight	Pond system	Effluent control system[2]	Net income per 10-acre pond
Mg/L BOD	*Dol.*	*Fish/ac.*	*Lb.*	*No. & type*	*Type*	*Dol.*
0	5	4,000	2.00	12-watershed	tax	8,705
0	10	4,000	2.00	12-watershed	tax/recycle	8,360
15	5	4,000	2.00	12-watershed	tax	8,780
15	15	4,000	2.00	12-watershed	tax/recycle	8,340
30	20	4,000	2.00	12-watershed	tax/recycle	8,380
30	200	4,000	2.00	12-watershed	wetland	5,615
30	5	4,000	2.00	12-watershed	tax	8,860
0	185	4,000	2.00	12-levee	tax/wetland	7,370
30	700	4,000	2.00	12-levee	tax/wetland	5,255

[1] Risk neutral refers to operations for which there was an imposed 25% constraint on capital.

[2] Watershed ponds discharged annually and levee ponds discharged every three years.

APPENDIX TABLE 2

NET INCOME FOR RISK NEUTRAL[1] CATFISH PRODUCTION, BY EFFLUENT STANDARD AND TAX CONSTRAINTS WITH RESULTING POND AND EFFLUENT CONTROL SYSTEMS, ALABAMA 1992

Standard level	Tax per mg/L	Stocking density	Ending weight	Pond system	Effluent control system[2]	Net income per 10-acre pond
Mg/L	*Dol.*	*Fish/ac.*	*Lb.*	*No. & type*	*Type*	*Dol.*
0	5	4,000	2.00	10-watershed	tax	8,705
0	5	4,000	1.50	2-watershed	tax	6,010
15	5	4,000	1.50	2-watershed	tax	6,085
15	15	4,000	2.00	10-watershed	tax/recycle	8,340
15	15	4,000	1.50	2-watershed	tax/recycle	5,645
30	5	4,000	1.50	2-watershed	tax	6,160
30	15	4,000	2.00	10-watershed	tax/recycle	8,413
30	200	4,000	2.00	10-watershed	tax/wetland	8,115
30	200	4,000	1.50	2-watershed	tax/wetland	5,420
0	25	4,000	1.50	2-levee	tax/recycle	5,385
0	175	4,000	2.00	10-levee	tax/wetland	6,480
0	175	4,000	1.50	2-levee	tax/wetland	3,820
15	750	2,000	2.00	12-levee	tax/wetland	3,730

[1] Risk neutral refers to operations for which there was an imposed 25% constraint on capital.

[2] Watershed ponds discharged annually and levee ponds discharged every three years.

APPENDIX TABLE 3
NET INCOME FOR RISK AVERSE[1] CATFISH PRODUCTION, BY EFFLUENT STANDARD AND TAX CONSTRAINTS, WITH RESULTING POND AND EFFLUENT CONTROL SYSTEMS, ALABAMA, 1992

Standard level	Tax per mg/L	Stocking density	Ending weight	Pond system	Effluent control system[2]	Net income per 10-acre pond
Mg/L	*Dol.*	*Fish/ac.*	*Lb.*	*No. & type*	*Type*	*Dol.*
0	5	2,000	2.00	2-watershed	tax	2,200
0	5	4,000	1.50	6-watershed	tax	6,010
0	5	2,000	1.00	4-watershed	tax	850
0	15	2,000	2.00	2-watershed	tax/recycle	2,000
0	15	4,000	1.50	6-levee	tax	5,317
0	15	2,000	1.00	4-watershed	tax/recycle	
0	25	2,000	2.00	2-watershed	tax/wetland	1,205
0	25	4,000	1,50	6-levee	tax/wetland	4,770
0	25	2,000	1,00	4-watershed	tax/wetland	
15	5	2,000	2.00	2-watershed	tax/recycle	2,195
15	5	4,000	1.50	6-watershed	tax	6,110
15	5	2,000	1.00	4-watershed	tax	920
15	75	2,000	2.00	2-watershed	tax/recycle	1,377
15	75	4,000	1.50	6-levee	tax/recycle	4,650
15	75	2,000	1.00	4-watershed	tax/recycle	
15	150	4,000	1.50	7-levee	tax/wetland	3,950
15	150	2,000	1.00	5-levee	tax/wetland	
30	5	4,000	1.50	7-levee	tax	6,160
30	5	2,000	1.00	5-watershed	tax	775
30	20	2,000	2.00	2-watershed	wetland	1,830
30	20	6,000	1.50	6-levee	tax	1,450
30	20	2,000	1.00	4-watershed	wetland	258

[1] Risk averse refers to operations for which there was an imposed 50% capital constraint.

[2] Watershed ponds discharged annually and levee ponds discharged every three years.

APPENDIX TABLE 4
NET INCOME FOR RISK INTENSIVE[1] CATFISH PRODUCTION, BY EFFLUENT STANDARD AND TAX CONSTRAINTS, WITH RESULTING POND AND EFFLUENT CONTROL SYSTEMS, ALABAMA 1992

Standard level	Tax per mg/L	Stocking density	Fish ending weight	Pond system	Effluent control system[2]	Net income per 10-acre pond
Mg/L	*Dol.*	*Fish/ac.*	*Lb.*	*No. & type*	*Type*	*Dol.*
0	5	4,000	2.00	12-watershed	tax	8,890
0	30	4,000	2.00	12-watershed	tax/recycle	7,990
0	190	4,000	2.00	12-watershed	tax/wetland	7,240
15	5	4,000	2.00	12-watershed	tax	8,920
15	35	4,000	2.00	12-watershed	tax/recycle	8,190
15	200	4,000	2.00	12-watershed	tax/wetland	7,320
30	5	4,000	2.00	12-watershed	tax	8,940
30	45	4,000	2.00	12-watershed	tax/recycle	8,165
30	250	4,000	2.00	12-watershed	tax/wetland	7,870

[1] Risk intensive refers to operations for which there was no imposed capital constraint.

[2] Watershed and levee ponds discharged every three years.

Appendix Table 5
Net Income for Risk Neutral[1] Catfish Production, with Taxation and Effluent Standard Constraints on Production and Resulting Effluent Control Systems. Watershed and Levee Ponds Discharged Every Three Years, Alabama, 1992[1]

Standard level	Tax per mg/L	Stocking density	Ending weight	Pond system	Effluent control system[2]	Net income per 10-acre pond
M/gL BOC	*Dol.*	*No. & type*	*Fish/ac.*	*Lb.*	*Type*	*Dol.*
0	5	4,000	2.00	10-watershed	tax	8,890
0	5	4,000	1.50	2-watershed	tax	6,195
0	40	4,000	2.00	10-watershed	tax/recycle	7,805
0	40	4,000	1.50	2-watershed	tax/recycle	5,110
0	195	4,000	2.00	10-watershed	tax/wetland	6,365
0	195	4,000	1.50	2-watershed	tax/wetland	3,670
15	5	4,000	2.00	10-watershed	tax	8,920
15	5	4,000	1.50	2-watershed	tax	6,240
15	30	4,000	2.00	10-watershed	tax/recycle	8,140
15	30	4,000	1.50	2-watershed	tax/recycle	5,445
15	250	4,000	2.00	10-watershed	tax/wetland	7,120
15	250	4,000	1.50	2-watershed	tax/wetland	4,420
30	5	4,000	2.00	10-watershed	tax	8,940
30	5	4,000	1.50	2-watershed	tax	6,245
30	50	4,000	2.00	10-watershed	tax/recycle	8,123
30	50	4,000	1.50	2-watershed	tax	5,870
30	250	4,000	2.00	10-watershed	tax/wetland	7,868
30	250	4,000	1.50	2-watershed	tax/wetland	5,172

[1] Risk neutral refers to operations for which there was an imposed 25% constraint on capital.

[2] Watershed and levee ponds discharged every three years.

APPENDIX TABLE 6

NET INCOME FOR RISK AVERSE[1] CATFISH PRODUCTION, WITH TAXATION AND EFFLUENT STANDARD CONSTRAINTS ON PRODUCTION AND RESULTING EFFLUENT CONTROL SYSTEMS. WATERSHED AND LEVEE PONDS DISCHARGED EVERY THREE YEARS, ALABAMA, 1992

Standard level	Tax mg/L	Stocking density	Fish ending weight	Pond system	Effluent control system[2]	Net income per 10-acre pond
Mg/L BOD	*Dol.*	*Fish/ac.*	*Lb.*	*No. & type*	*Type*	*Dol.*
0	5	4,000	1.50	5-watershed	tax	6,195
0	5	4,000	1.50	2-levee	tax	5,975
0	5	2,000	1.00	5-watershed	tax	1,040
0	50	2,000	2.00	2-watershed	tax/recycle	7,620
0	50	4,000	1.50	6-levee	tax/recycle	4,610
0	50	2,000	1.00	4-watershed	tax/recycle	
0	75	2,000	2.00	2-watershed	tax/wetland	6,960
0	75	4,000	1.50	6-levee	tax/wetland	4,720
0	75	2,000	1.00	4-watershed	tax/wetland	500
15	5	4,000	1.50	7-watershed	tax	8,920
15	5	2,000	1.00	5-watershed	tax	1,072
15	30	2,000	2.00	2-watershed	tax/recycle	1,902
15	30	4,000	1.50	6-watershed	tax	5,890
15	30	2,000	1.00	4-watershed	tax/recycle	380
15	75	2,000	2.00	2-watershed	tax/wetland	1,580
15	75	4,000	1.50	6-levee	tax/wetland	5,095
15	75	2,000	1.00	4-watershed	tax/wetland	10
30	5	4,000	1.50	5-watershed	tax	6,245
30	5	2,000	1.00	7-watershed	tax	1,090
30	50	2,000	2.00	2-watershed	tax/wetland	1,561
30	50	4,000	1.50	6-levee	tax	5,735
30	50	2,000	1.00	4-watershed	tax/wetland	208

[1] Risk averse refers to operations for which there was an imposed 50% capital constraint.

[2] Watershed and levee ponds discharged every three years.

APPENDIX TABLE 7

CATFISH BUDGET. ESTIMATED COSTS AND RETURNS FOR A 10-ACRE LEVEE POND FOR A GROWING SEASON OF 270 DAYS WITH A STOCKING DENSITY OF 4,000 FISH PER ACRE, SIX PERCENT MORTALITY RATE, AND ONE AND A HALF POUND ENDING WEIGHT. ALABAMA, 1992

Item	Size	Unit	Quantity	Price or cost/unit	Value or cost
				Dol.	*Dol.*
Gross receipts:					
Catfish	1.50	lbs.	53,865	0.65	35,012.15
Variable cost:					
Fingerlings	5-inch	each	40,000	0.075	3,000.00
Feed		ton	51.48	265.00	13,642.00
Chemicals		appl.	22	70.00	1,540.00
Labor		hr.	376	5.00	1,880.00
Electricity		kwh	19,800	0.075	1,485.00
Equipment maintenance		hr.	110	4.50	495.00
Machinery and equipment		dol.	1.2	463.50	556.40
Miscellaneous		acre	15	5.00	75.00
Overwintering		dol.	1	2,320.00	2,320.00
Pond refilling		m/gal.	5.2	41.00	231.20
Interest on operating capital		dol.	8,318.20	0.09	748.64
Total variable cost					25,955.24
Income above variable cost					9,057.01
Fixed cost:					
General overhead		acre	10	5	50.00
Interest on building and equipment		dol.	10,780	0.09	970.20
Depreciation		dol.			1,820.00
Other fixed cost		dol.			150.00
Total fixed cost					2,990.20
Total of all specified expenses					28,945.44
Net returns above specified expenses[1]					6,066.81

[1] Net returns to land, existing pond and management.

APPENDIX TABLE 8

CATFISH BUDGET. ESTIMATED COSTS AND RETURNS FOR A 10-ACRE WATERSHED POND FOR A GROWING SEASON OF 270 DAYS WITH A STOCKING DENSITY OF 4,000 FISH PER ACRE, SIX PERCENT MORTALITY RATE, AND ONE AND A HALF POUND ENDING WEIGHT. ALABAMA, 1992

Item	Each	Unit	Quantity	Price or cost/ unit	Value or cost
Gross receipts:					
Catfish	1.50	lbs.	53,865	0.65	35,012
Variable cost:					
Fingerlings	5-inch	each	40,000	0.075	3,000.00
Feed		ton	51.48	265.00	13,642.00
Chemicals		appl.	22	70.00	1,540.00
Labor		hr.	376	5.00	1,880.00
Electricity		kwh	19,800	0.075	1,485.00
Tractor maintenance		hr.	110	4.50	495.00
Machinery and equipment		dol.	1.2	463.50	556.40
Miscellaneous		acre	15	5.00	75.00
Overwintering		dol.	1	2,320.00	2,320.00
Pond refilling		dol.	0	0.00	0.00
Interest on operating capital		dol.	8,248	0.09	742.30
Total variable cost					25,735.70
Income above variable cost					9,274.55
Fixed cost:					
General overhead		acre	10	5	50.00
Interest on building and equipment		dol.	10,780	0.09	970.00
Depreciation		dol.			1,820.00
Other fixed costs					150.00
Total fixed cost					2,990.20
Total of all specified expenses					28,725.90
Net returns above specified expenses[1]					6,286.35

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[1] Net returns to land, existing ponds and management.

APPENDIX TABLE 9

CATFISH BUDGET. ESTIMATED COSTS AND RETURNS FOR A 10-ACRE LEVEE POND FOR A GROWING SEASON OF 330 DAYS WITH A STOCKING DENSITY OF 4,000 FISH PER ACRE, 13 PERCENT MORTALITY RATE, AND TWO POUNDS ENDING WEIGHT. ALABAMA, 1992

Item	Each	Unit	Quantity	Price or cost/unit	Value or cost
				Dol.	*Dol.*
Gross receipts:					
Catfish	2.00	lbs.	69,600	0.65	45,240.00
Variable cost:					
Fingerlings	5-inch	each	40,000	0.075	3,000.00
Feed		ton	75.18	265.00	19,922.00
Chemicals		appl.	24	70.00	1,680.00
Labor		hr.	376	5.00	1,880.00
Electricity		kwh	24,750	0.075	1,856.25
Tractor maintenance		hr.	130	4.50	585.00
Machinery and equipment		dol.	1.2	463.50	556.40
Miscellaneous		acre	20	5.00	100.00
Overwintering		dol.	1	2,380.00	2,380.00
Pond refilling		m/gal.	5.2	41.00	213.20
Interest on operating capital		dol.	10,617.04	0.09	955.53
Total variable cost:					33,128.38
Income above variable cost					12,112.00
Fixed cost:					
General overhead		acre	10	5	50.00
Interest on building and equipment		dol.	11,430	0.09	1,028.70
Depreciation		dol.			2,100.00
Other fixed costs		dol.			170.00
Total fixed cost:					3,348.70
Total of all specified expenses					36,477.08
Net returns above all specified expenses[1]					8,726.90

[1] Net returns to land, existing pond and management.

APPENDIX TABLE 10

CATFISH BUDGET. ESTIMATED COSTS AND RETURNS FOR A 10-ACRE WATERSHED POND FOR A GROWING SEASON OF 330 DAYS WITH A STOCKING DENSITY OF 4,000 FISH PER ACRE, 13 PERCENT MORTALITY RATE, AND TWO POUND ENDING WEIGHT. ALABAMA, 1992

Item	Each	Unit	Quantity	Price or cost/unit	Value or cost
				Dol.	*Dol.*
Gross receipts:					
Catfish	2.00	lbs.	69,600	0.65	45,240.00
Variable cost:					
Fingerlings	5-inch	each	40,000	0.075	3,000.00
Feed		ton	75.18	265.00	19,922.00
Chemicals		appl.	24	70.00	1,680.00
Labor		hr.	376	5.00	1,880.00
Electricity		kwh	24,750	0.075	1,856.25
Tractor maintenance		hr.	130	4.50	585.00
Machinery and equipment		dol.	1.2	463.50	556.40
Miscellaneous		acre	20	5.00	100.00
Overwintering		dol.	1	2,380.00	2,380.00
Pond refilling		dol.	0	0.00	0.00
Interest on operating capital		dol.	10,546.70	0.09	949.20
Total variable cost					32,908.85
Income above variable costs					12,331.15
Fixed cost:					
General overhead		acre	10	5	50.00
Interests on building and equipment		dol.	11,430	0.09	1,028.70
Depreciation		dol.			2,100.00
Other fixed cost		dol.			170.00
Total fixed cost					3,348.70
Total of all specified expenses					36,257.55
Net returns above specified expenses[1]					8,982.45

[1] Net returns to land, existing ponds and management.

APPENDIX TABLE 11
CATFISH BUDGET. ESTIMATED COSTS AND RETURNS FOR A 10-ACRE WATERSHED POND FOR A GROWING SEASON OF 300 DAYS WITH A STOCKING DENSITY OF 2,000 FISH PER ACRE, SIX PERCENT MORTALITY RATE, AND TWO POUND ENDING WEIGHT. ALABAMA, 1992

Item	Each	Unit	Quantity	Price or cost/unit	Value or cost
				Dol.	*Dol.*
Gross receipts:					
Catfish	2.00	lbs.	38,620	0.65	25,103.00
Variable cost:					
Fingerlings	5-inch	each	20,000	0.075	1,500.00
Feed		ton	42.12	265.00	11,162.00
Chemicals		appl.	14	70.00	980.00
Labor		hr.	250	5.00	1,250.00
Electricity		kwh	22,500	0.075	1,687.50
Tractor maintenance		hr.	120	4.50	540.00
Machinery and equipment		dol.	1.2	463.50	540.00
Miscellaneous		acre	17	5.00	80.00
Overwintering		dol.	1	1,600.00	1,600.00
Pond refilling		dol.	0	0.00	0.00
Interest on operating capital		dol.	6,382.00	0.09	574.40
Total variable cost					19,913.90
Income above variable cost					5,189.10
Fixed cost:					
General overhead		acre	10	5	50.00
Interest on building and equipment		dol.	8,430	0.09	758.70
Depreciation		dol.			1,536.00
Other fixed cost		dol.			150.00
Total fixed cost					2,494.70
Total of all specified expenses					22,408.60
Net returns above specified expenses[1]					2,694.40

[1] Net returns to land, existing ponds and management.

APPENDIX TABLE 12

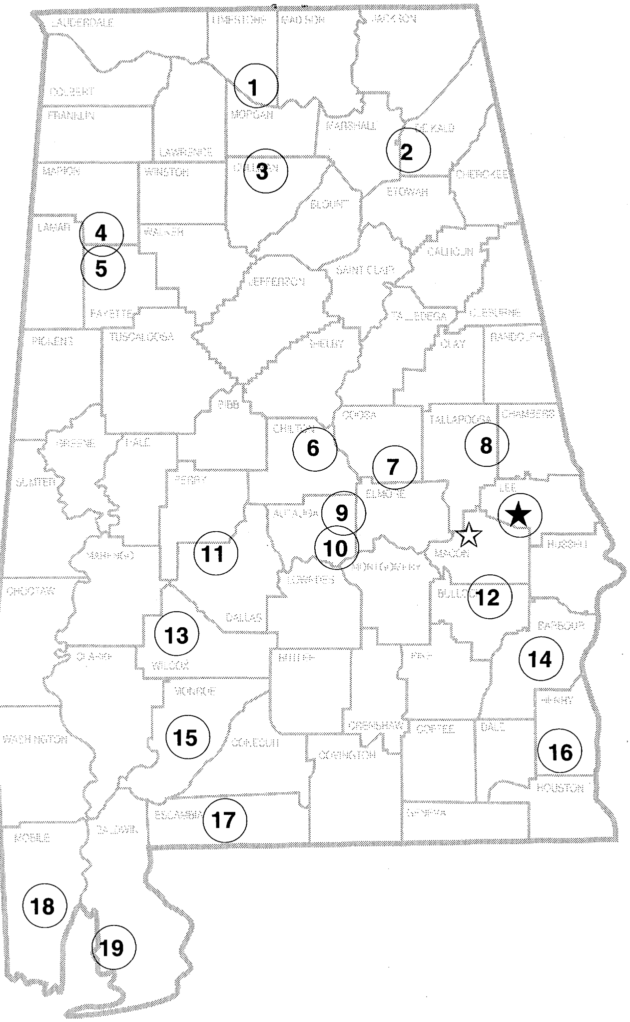
CATFISH BUDGET. ESTIMATED COSTS AND RETURNS FOR A 10-ACRE LEVEE POND FOR A GROWING SEASON OF 300 DAYS WITH A STOCKING DENSITY OF 2,000 FISH PER ACRE, SIX PERCENT MORTALITY RATE, AND TWO POUNDS ENDING WEIGHT. ALABAMA, 1992

Item	Each	Unit	Quantity	Price or cost/unit	Value or cost
				Dol.	*Dol.*
Gross receipts:					
Catfish	2.00	lb.	38,620	0.65	25,103.00
Variable cost:					
Fingerlings	5 inch	each	20,000	0.075	1,500.00
Feed		ton	42.12	265.00	11,162.00
Chemicals		appl.	14	70.00	980.00
Labor		hr.	250	5.00	1,250.00
Electricity		kwh	22,500	0.075	1,687.50
Tractor maintenance		hr.	120	4.50	540.00
Machinery and equipment		dol.	1.2	463.50	540.00
Miscellaneous		acre	17	5.00	80.00
Overwintering		dol.	1	1,600.00	1,600.00
Pond refilling		m/gal.	5.2	41.00	213.20
Interest on operating capital		dol.	6,452.40	0.09	580.72
Total variable cost					20,133.42
Income above variable cost					4,969.58
Fixed cost:					
General overhead		acre	10	5	50.00
Interest on building and equipment		dol.	8,430	0.09	758.70
Depreciation		dol.			1,536.00
Other fixed costs		dol.			150.00
Total fixed cost					2,494.70
Total of all specified expenses					22,628.12
Net returns above all specified expenses[1]					2,474.88

[1] Net returns to land, existing pond and management.

Alabama's Agricultural Experiment Station System
AUBURN UNIVERSITY

With an agricultural research unit in every major soil area, Auburn University serves the needs of field crop, livestock, forestry, and horticultural producers in each region in Alabama. Every citizen of the state has a stake in this research program, since any advantage from new and more economical ways of producing and handling farm products directly benefits the consuming public.



Research Unit Identification

★ Main Agricultural Experiment Station, Auburn.

☆ E. V. Smith Research Center, Shorter.

1. Tennessee Valley Substation, Belle Mina.
2. Sand Mountain Substation, Crossville.
3. North Alabama Horticulture Substation, Cullman.
4. Upper Coastal Plain Substation, Winfield.
5. Forestry Unit, Fayette County.
6. Chilton Area Horticulture Substation, Clanton.
7. Forestry Unit, Coosa County.
8. Piedmont Substation, Camp Hill.
9. Foresty Unit, Autauga County.
10. Prattville Experiment Field, Prattville.
11. Black Belt Substation, Marion Junction.
12. The Turnipseed-Ikenberry Place, Union Springs.
13. Lower Coastal Plain Substation, Camden.
14. Forestry Unit, Barbour County.
15. Monroeville Experiment Field, Monroeville.
16. Wiregrass Substation, Headland.
17. Brewton Experiment Field, Brewton.
18. Ornamental Horticulture Substation, Spring Hill.
19. Gulf Coast Substation, Fairhope.