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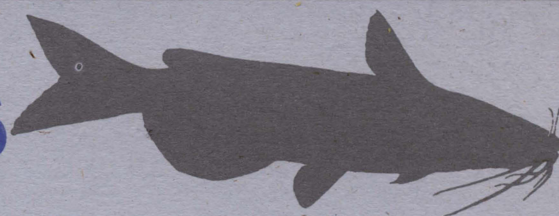

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Estimated Costs and Returns for Catfish Farms with Recirculating Ponds Along the Upper Texas Coast

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Executive Summary

Interest from investors in catfish farming in Texas is increasing. Natural resources, climate, and production methods used along the upper Texas coast are sufficiently different from those in traditional production areas to require a separate economic evaluation of catfish farming in Texas. The objectives set for this study are to investigate catfish farming along the upper Texas Coast with respect to: 1) economic returns, 2) economies of scale, and 3) costs compared with those in other catfish production areas.

Hypothetical farms using the modified recirculating system are studied. Three farm sizes are cost engineered and evaluated, a small farm with 66 (163) total land ha (ac), a medium farm with 132 (323), and a large farm with 264 (643). The farms are analyzed with a farm-level simulation program (CATSIM) to determine costs, returns, and economies of scale of catfish farming. Production of the catfish ponds is set at 11,227 kg per ha (10,000 lb per ac) when the ponds are in full production, with an annual mortality of 10 percent and a feed conversion ratio of 2.0. After harvest, the ponds are restocked to maintain a population of 22,230 fish per ha (9,000 per ac). Ponds are dried up and rebuilt in the seventh year of operation. The feed cost is $303 per metric ton ($275 per short ton), and the price of catfish is $1.54 per kg ($0.70 per lb).

Results of the study are: first, that the internal rate of return (IRR) of catfish farms along the upper Texas coast varied from 15 to 22 percent (0.150, 0.183, and 0.219, for the small, medium, and large farms, respectively.) These rates compare favorably with traditional returns in the United States stock market, and suggest that catfish farming along the upper Texas coast provides attractive returns compared with other agricultural enterprises.

Second, the total investment required for the small, medium, and large farms is $763,526, $1,433,088, and $2,694,680, respectively, resulting in economies of scale of 12 percent. Pond construction accounts for between 45 and 49 percent of investment. Most economies of scale are gained in the buildings, start-up, and vehicles and equipment categories. The investments necessary for the farms analyzed here are nearly double those of equal size farms with static ponds in Mississippi; however, the investment per unit production capacity is lower.

Third, in the Texas upper coast region, average total costs for catfish farms are generally lower than those for farms with static ponds in Mississippi (11-20%). The most important costs on a catfish farm are feed, stocking, and labor. The average total cost per kg (lb) is between $1.245 ($0.565) and $1.193 ($0.541). Economies of scale in production costs are about 7 percent. Most scale economies lie in depreciation, fixed costs, and labor.

A number of conclusions are appropriate based on the work presented. First, returns to the farms are highly sensitive to production yields, the price of catfish, cost of feed, and, to a lesser extent, the price of fingerlings. All farms are expected to generate a positive return to the investor when the price of catfish is at least $1.32 ($0.60) per kg (lb). The medium and large farms achieve a positive rate of return for catfish prices as low as $1.19 ($0.55) per kg (lb).

Second, the high investment required in the three catfish farms suggests that catfish farming is a capital intensive venture. However, it appears that the recirculating production method used in Texas reduces the investment in the per unit production capacity by between 16 and 7 percent. On the other hand, the recirculating system also raises the threshold for total investment required (capital investment and initial operating costs) to over $1,000,000; a farmer must operate a complete system to achieve the savings associated with this production method.

Third, the extreme sensitivity of farm returns to production levels implies that the trade-off between levels of aeration and water exchange on one side and the level of biological performance in the ponds on the other should be given close attention. Because energy is one of the least important cost categories, the known benefits of added aeration and mixing (including improved feed conversion, growth, and survival) may far outweigh the added costs, even in recirculating systems.

Fourth, there is a substantial start-up period that requires careful cash flow planning by management. This is especially true for the small farm, which does not generate a positive cash flow until the end of the second year of operation. The large farm is able to issue a dividend in the second year.

Introduction

Farm raised catfish has become a substantial part of the United States (U.S). seafood market during the past decade. Per capita consumption of catfish is now more than 450 grams (1 pound) annually (USDA). Growth of the industry has taken place almost completely outside Texas, despite the availability of land and water (Steinbach and Boettcher).

Early research showed the economic viability of catfish farming in the state (Lacewell et al.), yet a lack of suppliers and processing facilities hindered large scale production. Recently, two processing facilities have been constructed in Texas and a number of farms are under construction. Production is expanding substantially along the upper Texas coast, in and surrounding Brazoria county. The basic technology used for catfish production in Texas is identical to that used in other areas, but several parameters are significantly different, including off-flavor, capital investment, marketing constraints, water supply, and climate.

Off-flavor has been a bane of catfish farmers in the South. In Texas, experience has shown that the occurrence of off-flavor can be reduced significantly or even eliminated when pond water is circulated through non-catfish producing ponds. This technology, used by the major producer in the state, requires a significantly larger capital investment, but it also increases production. Almost no marketing constraints exist in Texas since the existing processing capacity is substantially greater than the production capacity in the area, and farms can market the fish when they reach optimal size. Water is an essential factor that is different from Mississippi and other major production areas, both in quality and in quantity. Due to the salt content of the local surface water, catfish disease incidence is comparatively lower, and the availability of surface water eliminates the need for wells. Finally, the geographic location of many of the production areas in Texas implies a growing season for catfish that is nearly two months longer than in other southern states.

Therefore, economic analysis such as those by Hatch et al.(1989); Sindelar et al.; Hatch et al.(1987); Keenum; Fuller and Dillard; Keenum and Waldrop; Burtle et al; Dellenbarger and Vandeveer; and others, are not accurate in a Texas setting, and a study of the economic viability of this industry is needed. The objectives of this study are: 1) Investigate the economic returns of catfish farms with recirculating ponds in Texas; 2) Evaluate the economies of scale in catfish farming in Texas; 3) Compare the costs and returns of catfish farming in Texas with those in other states.

Estimates in this work are based in part on actual data and in part on estimates and extrapolation. Assumptions made here do not necessarily apply to all situations. No limitations on availability of water are considered. No marketing limitations are imposed. It is assumed that farmers can obtain financing for operating loans and that qualified management is available. Effects of hurricanes and other natural disasters are ignored. The limited experience with recirculation systems suggests that production estimates should be evaluated carefully in light of each producer's individual situation.

Methods

Following Keenum and Waldrop, an economic engineering approach is used to evaluate farms of three sizes: 66 (163), 131 (323), and 260 (643) hectares (acres). The economic engineering approach requires a complete cash flow for an operation, including investments, operating costs, and returns. The three farms will be referred to as small, medium, and large, respectively, throughout this paper. Because in aquaculture the importance of economies of scale is well established (Lambregts et al.: Adams et al., Keenum and Wal drop), it is important to use farms of identical sizes for comparison purposes. These farm sizes allow for direct comparisons with the Keenum and Waldrop estimates for Mississippi. Calculations are made by the firm-level economic engineering program for catfish, CATSIM. This computer program is based on the program MARSIM (Hanson et al.). Modifications to the program are extensive; however, the basic flow of the data is identical.

Simulation Assumptions

Each of the three farms is assumed to be an independently operating venture, with a full-time staff and dedicated equipment. It is also assumed that each farm is a grow-out operation only: fingerlings are purchased and food size fish are sold to a processor. The farms are presumed to be located along the upper Texas coast, in or adjacent to Brazoria county. The use of custom services allows the farms to operate without harvesting and hauling equipment. Especially for the smaller farms, this reduces the investment needed. Each farm is equipped with adequate hardware to feed, sample, control diseases, monitor water quality, and perform other necessary tasks.

The production facilities are designed as a "modified recirculating system". This system was originally developed by Naiad, currently the largest catfish producer and processor in Texas. A sample layout of a recirculating system is shown in Figure 1. This production method has a number of distinguishing features, particularly recirculation pumps, treatment ponds, and canals. In a recirculating system, a number of catfish ponds are connected to inflow and outflow canals. The canals are connected in turn to a treatment pond. A pump station pumps water from the treatment pond to the inflow canal, from where it circulates by gravity through the catfish ponds and the outflow canals back

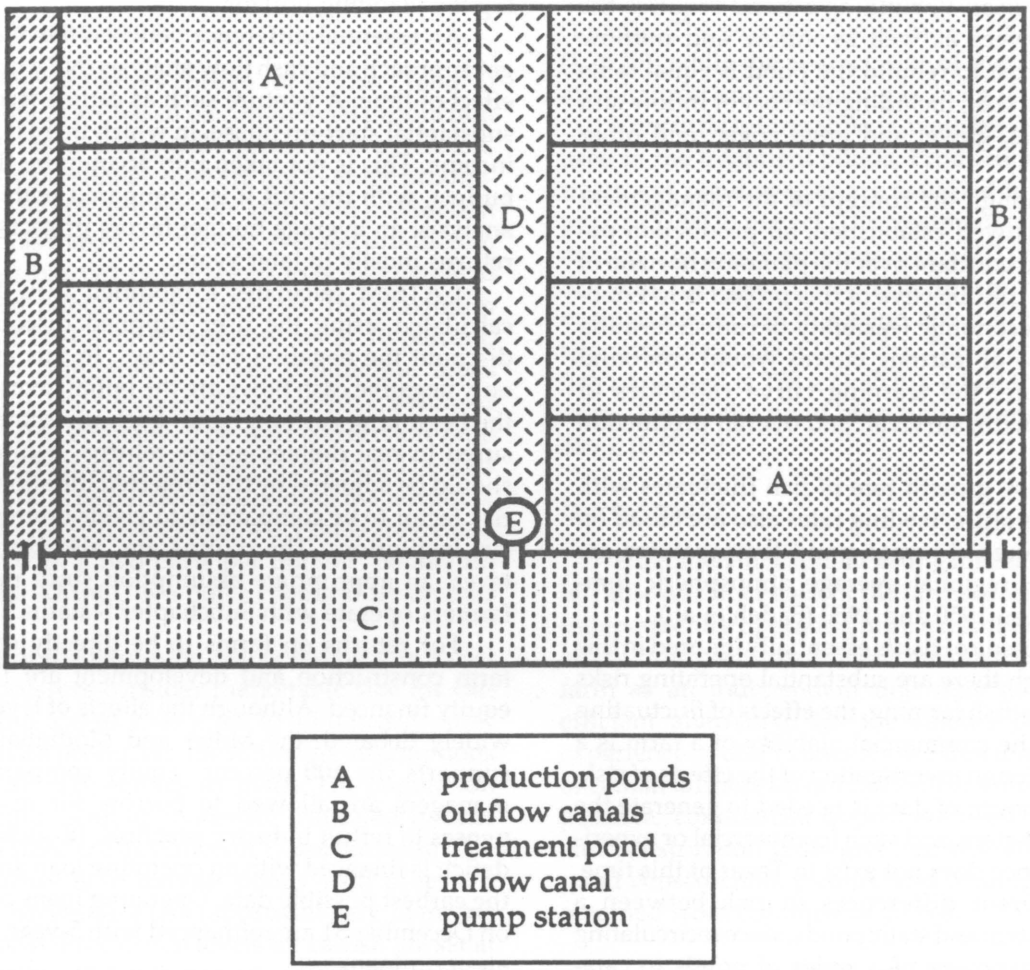

Figure 1. Schematic of a single recirculating pond system.

to the treatment ponds. The maximum daily water exchange is 20 percent of the catfish pond volume. Treatment ponds contain filter feeding fish, which eat zooplankton, phytoplankton, and particulate waste, thus reducing the biological oxygen demand and waste accumulation in the system. The area of the treatment pond is between 10 and 20 percent of the total area of the catfish ponds. By reducing the accumulation of by-products in the ponds, annual production in catfish ponds can be increased substantially. Proprietary data show that some commercial systems have produced in excess of of 16,840 kg per ha (15,000 lb per ac) annually.

CATSIM follows the basic production schedule used for catfish farming. There are several assumpti ons that are critical to this analysis. First, ponds are harvested selectively. Much like enterprises such as cattle, the larger animals that are ready for market are gathered and sold. Harvesting takes place with a large seine, which traps larger fish but lets the smaller fish escape. Restocking takes place after each harvest. A pond is stocked and restocked to maintain the target population based on the number of fish harvested, mortality, and predation.

Second, CATSIM simulates the off-flavor problem as follows: when the catfish in a pond are ready for harvest, a random number routine, using maximum probabilities supplied by the user of the software, determines if the fish in a pond are on- or off-flavor. Ponds with off-flavor fish are not harvested. A different user-supplied probability value is then used with the random number routine to determine if the fish will be off-flavor the following week. This is repeated until the fish are again on-flavor, at which time they are harvested. The model manipulates the probabilities related to off-flavor based on the water temperature to model seasonal fluctuations in off-flavor occurrence (Sindelar et al.).

Third, given the lack of marketing constraints in Texas, no limitations are set on harvest timing. Each pond is harvested when the target weight of harvestable catfish is reached, provided, of course, that the pond is on-flavor. After a number of years, as specified by the user, each pond is completely harvested, rebuilt, and restocked. The time required to rebuild the pond is specified by the user. Rebuilding a pond requires the renovation of levees as well as inflow and outflow structures. The cost to rebuild the pond is equal to its original building cost, including the cost of inflow and outflow structure, gravel and grass cover, and other factors.

Fourth, although the concept of the management learning curve is well established, all production parameters are held constant over the planning horizon of the farms. Since the objective of this project is to establish the current economic feasibility of catfish farming in Texas, the use of learning curves would confound results. Therefore, the learning curve capacities of CATSIM for growth, survival, and overall production are not used.

Fifth, because growth rate of fish fluctuates with the water temperature, feeding rates also are based on water temperatures. Average pond temperatures are calculated from regional average atmospheric temperatures between 1950 and 1980 (Sadeh et al.).

Finally, the issue of risk is essentially ignored in this project. Although there are substantial operating risks involved with catfish farming, the effects of fluctuating production on the commercial viability of a farm is a separate issue. For an investigation of the effects of risk, a substantial amount of data is needed to generate the necessary parameters, and such (commercial or experimental) experience does not exist in Texas at this time. There are inherent differences in risk between a recirculating system and static ponds, since recirculating systems allow exposure of a series of ponds to catastrophic biological events. Also, the risk of relying on a key processor or feed manufacturer should be considered.

Financial Evaluation

The profitability of each farm is measured by the Internal Rate of Return (IRR; Brealey and Meyers) generated over a 10 year planning horizon of the firm. Although the average budget is the tool used most often in the analysis of catfish farmers, it is not the most appropriate one. The Net Present Value (NPV) is usually presented as the most appropriate measurement of financial success. However, the difference in investment among the three farms makes the related measure, the IRR, more desirable.

The NPV uses a rate to discount the cash flows to the investor, usually the investor's next best use for funds. Essentially, the NPV is the additional amount of cash, in current value, that the project will produce over the best available alternative. By comparing the NPV of a project, an investor compares the project's cash value, at that moment, with the alternative. The internal rate of return (IRR) is a related measure. The IRR is that discount rate at which the NPV of the investment equals zero. The IRR measure, in principal, reflects the rate of return, or "interest", the investment will generate during the planning horizon.

An essential difference between the average budget approach and cash flow analysis (NPV or IRR) is the effect of time. A venture such as catfish farming has a substantial start-up phase, in which there is little or no income. This is not taken into account by the average budget, with the IRR it is. Compared with cash flow analysis, an average budget favors projects with cash returns mostly in later years.

CATSIM calculates a modified IRR. The IRR is calculated using the user supplied discount rate to discount the negative cash flows. In this analysis the only negative cash flows are the initial investment and the beginning cash on hand. Each investment is measured in real dollars, as are returns. Estimates made should be adjusted by the projected inflation rate and a risk factor to be comparable to yields offered by financial institutions. The returns are also before income taxes, an appropriate assumption since most catfish farmers operate with Subchapter S status.

For returns on farms to be directly comparable, farm construction and development are 100 percent equity financed. Although the effects of leveraging are widely debated, the Miller and Modigliani theorem supports the 100 percent equity comparison. Farm managers are allowed to borrow for operating expenses to reflect industry practices. In such a case, the deficit is financed with an operating loan and repaid at the earliest possible date. Operating loans outstanding on December 31 are refinanced with 5-year, intermediate-term loans.

Depreciation on farms is based on useful life of machinery or construction. Equipment is depreciated on a relatively fast schedule to reproduce accurately the wear and tear that occurs in a humid and slightly saline environment. All depreciation schedules are straight line. Since this analysis is on a before-tax basis, depreciation schedules accurately reflect the economic life of assets as opposed to using IRS guidelines.

Data

The equipment necessary on each farm was determined in cooperation with industry leaders and members of the Texas Agricultural Extension Service. Cost information was obtained from suppliers and industry members. Because of the lack of experience in Texas with state of the art technology in large scale production, judgment and expert opinion were used to set parameters in some cases.

System Dimensions

Systems in this study are engineered to be approximately 65 ha (160 ac) and contain 8 catfish ponds of 6 surface ha (14.5 ac) each, and one 6.9 ha (17 ac) treatment pond. Thus, the small farm has one system, the medium farm has two, and the large farm has four.

Biological Parameters

The biological figures chosen for catfish (Table 1) and carp (Table 2) are based on commercial production records and discussions with producers, extension, and university personnel; they are not average production figures. The lack of a reliable long term production history in Texas makes calculating average production values impossible. Off-flavor seems to be negligible in well managed ponds. In this analysis, the maximum probability of off-flavor is therefore set at 10 percent, which is low compared to other production areas (Sindelar et al.). The survival rate for catfish is assumed to be 90 percent annually. The feed conversion ratio (feed fed / weight gain) is assumed to be 2 to 1. The feed conversion ratio is calculated by dividing the weight of feed fed by the net fish weight gained. Ponds are treated twice a year with a two parts per million potassium permanganate $KMnO_4$. No other chemical treatments are used.

The size of the harvested fish is essential in a cost analysis. Processors consider marketable size for catfish to be from 550 to 1300 g (20 to 45 ounces). After discussions with producers, the following assumptions on the population dynamics are made: The population size distribution is an approximate truncated normal curve, with a standard deviation of 1/3 of the mean. The industry practice is to harvest ponds with at least a truckload of harvestable fish (approximately 18 metric or 20 short tons). Production levels for catfish are set at 11,227 kg per ha (10,000 lb per ac), and the minimum harvest size is 550 g (1.2 lb). After harvest, ponds are restocked with fingerlings to bring the population in the pond to 22,230 per ha (9,000 per ac).

Based on these assumptions, CATSIM calculates the sizes for the fish harvested. The average size of fish in ponds about to be harvested is approximately 470 g (1.05 lb). The average size of catfish harvested is 582 g (1.28 lb), while the average size of the fish in the pond after harvest and restocking is 243 g (0.54 lb).

Very little information is available concerning carp used in the treatment ponds. Production levels for the treatment pond species are assumed to be at 5,614 kg per ha (5,000 lb per ac). The treatment pond species are not fed. The target population is 9,880 per ha (4,000 per ac), and fish over 700 g (1.5 lb) are harvested. The average size of fish in a pond about to be harvested is approximately 639 g (1.41 lb). The average size of the fish harvested is 729 g (1.60 lb), while the average size of the fish in the pond after harvest and restocking is 386 g (0.85 lb).

Investment

A detailed investment listing for each farm appears in Table A1. Since each of the farms is assumed to be an independently operating unit, a number of items, such as a building with an office, is included. Operating each farm as an independent unit may not be the most efficient alternative for the smaller operations, but experience in other states shows that the large majority of catfish farmers do not have other enterprises. Where possible, commercial quotes are used for equipment and construction costs given in this analysis. Cost of pond construction, pumps, and feeding equipment is obtained from commercial farms.

Start-up Costs

Construction of the farms takes place in a one-year period under the supervision of a paid construction

Table 1. Biological parameters for catfish on the upper Texas coast, 1991.

Parameter	Unit	Value
Growth	Gram/week	0-24
Feed conversion	kg feed/kg body mass	2.0
Feeding rate	% biomass/day	0-2.8
Mortality	% of population /year	10
Max. pond population	1000's/ha (1000's/acre)	22 (9)
Stocking size		
length	cm (inch)	17.5 (7)
weight	grams (ounces)	50 (1.8)
Harvest size		
minimum	grams (lb)	>550 (>1.1)
average	grams (lb)	582 (1.3)
Parasite occurrence	times/year/pond	2
Annual production	kg/ha (lb/acre)	11,227 (10,000)
Off-flavor probability		
on-flavor week before	%	10
off flavor week before	%	60

Table 2. Biological parameters for carp in treatment ponds on catfish farms on the upper Texas coast, 1991.

Parameter	Unit	Value
Growth	Gram/week	0-30
Feed conversion	kg feed/kg body mass	n.a.
Feeding rate	% biomass/day	0
Mortality	% of population/year	10
Max. pond population	1000's/ha (1000's/acre)	10
Stocking size		
length	cm (inch)	15 (6)
weight	grams (ounces)	40 (1.4)
Harvest size		
minimum	grams (lb)	>650 (>1.43)
average	grams (lb)	729 (1.6)
Parasite occurrence	times/year/pond	2
Max. annual production	kg/ha (lb/acre)	5,614 (5,000)
Off-flavor probability		
on-flavor week before	%	none
off flavor week before	%	none

supervisor, with additional labor as necessary. Including the start-up costs is essential in a cash flow analysis as performed in this study to accurately estimate the returns to the farms. During this start-up period, costs such as utilities, fuel, telephone, and insurance are prorated according to the number of people employed and size of the farm.

Real Estate

Land for the farms is assumed to be a flat, contiguous area, easily adapted to a catfish production system as described earlier. Land is valued at the current market value in potential catfish production areas. The soil was assumed to have good water retention as well as adequate erosion characteristics. The volume of water needed and frequency of levee repair are dependent on these characteristics. The land parcels are assumed to have a connection to a commercial electric grid and adequate access to publicly maintained roads. The water supply to a farm is assumed to be gravity fed surface water. This is a major diversion from practices in Mississippi, but it is a justified assumption for the upper Texas coast. Pumps are still necessary to provide recirculation. Each farm manager purchases enough water rights in the start-up year for approximately 5 acre feet of water per pond acre (3,053 M^3 per pond ha). Although such volume is typically not necessary, a large volume of water is required in the start-up year for the initial filling of the ponds as well as to compensate for normal losses such as seepage and evaporation.

Buildings

The farms are supplied with buildings to house the offices, shops, and storage, according to size. It is assumed that one building includes all these functions. Since the farms are assumed to be independently operating units, each is equipped with a potable water and septic system.

Pond Construction

One of the largest investments on the farms is the cost of dirt moving. The costs and sizes are based on experiences of a local catfish farm and discussions with extension personnel. Although the advantage of multiple ponds has been established (Yates), the three farms here have the same per unit cost of earth moving. Justification for this diversion from traditional assumptions is the layout of the recirculating systems. Since each system is almost surrounded by canals few opportunities exist to share levees. Hence, the normal savings achieved by large facilities are reduced substantially. The levees are assumed to have a 6 m (19.7 foot) crown, a 3 to 1 slope for inside levee's, and a 3.5 to 1 slope for outside levees. The average depth of the ponds is 1.5 m (4.9 foot), with a 50 cm (1.6 foot) freeboard. The depth of the ponds allows for fluctuation in water levels inherent in the recirculating system. Pond and levee dimensions and characteristics can be found in Table 3.

Other important costs associated with construction of the ponds are the electric grid, engineering, land clearing and preparation, and inflow and outflow structures. The costs of a vegetative cover, such as grass, and gravel for roads depends largely on the type of soil on the farm, while the cost of electric wiring depends on the arrangement with the local utility supplier. In this analysis, the ponds have gravel on three of the four levees, all levees are seeded, and each pond has a simple inflow and outflow structure that can be screened if necessary.

Table 3. Pond and levee dimensions for catfish farms.

	Dimension			Dimension	
Levees	**m**	**feet**	**Ponds**	**m**	**feet**
Crown:			Growout:		
internal	6	19.7	Length	370	1214
external	8	26.2	width	185	607
Slope:			depth	1.5	4.9
internal	3:1	3:1	Treatment		
external	3.5:1	3.5:1	length	500	1640
Height:			width	123	405
internal	1.5	4.9	depth	1.5	4.9
external	1.5	4.9	Bottom Slope	<1%	
Freeboard:					
internal	0.5	1.6			
external	0.5	1.6			

Pond Pumps

Each system on the farms is equipped with a recirculating pump. Given the cost of electricity in the areas most suited for catfish farming, the recirculating pump is powered by a 74 kW (100 h.p.) air cooled diesel engine, rather than an electric motor. The pump capacity is 1.304 m^3/s (20,698 gpm). Pumps are placed on concrete mounts with a screened intake. Each pump station is equipped with a fuel tank and miscellaneous hardware, including timers. Because the situation requires low lift, pumps with an axial flow design are preferred. The low lift also allows large volumes of water to be moved with relatively low horsepower engines. Nevertheless, the capital investment in pumps is substantial.

Major Pond Equipment

Farms purchase one stationary floating 7.46 kW (10 h.p.) paddle wheel aerator for each catfish pond plus one backup per subsystem. The paddle wheels are included in the analysis as a risk reduction measure. Aside from the paddle wheels, substantial aeration and mixing are provided by the recirculating water in each system.

All farms are supplied with equipment to distribute bulk feeds to the grow-out ponds. A truck mounted feeder with computerized scales (to measure the amount fed to each pond) is assumed to be the basic feeding equipment for all three farms. Feed storage capacity is constructed to accommodate standard delivery trucks.

Each farm manager also invests in vehicles as necessary, including half ton pickups and four wheel ATV's (all terrain vehicles). All supplies necessary to control weeds and diseases also are included, notably boats and motors, chemical storage capacity, as well as tools to measure and distribute the necessary therapeutic chemicals.

As stated, farms are grow-out operations only and have no fingerling or brood stock ponds. On the assumption that custom harvesting services are available from either the processor or an independent contractor, farm managers do not invest in harvesting and hauling equipment. It is also assumed that the fingerling producer will be able to deliver the stocker fish to the ponds. Custom harvesting and hauling fees are incurred as an operational cost. These also represent limitations of the analysis since such services may or may not be readily available to a new producer.

Implements and Pond Equipment

Each farm is also outfitted with basic maintenance equipment for roads and levees, including a grader blade and a disk. The largest farm is outfitted with a mobile radio system. Basic pond necessities, such as screens, waders, and dip nets, are included on all farms in proportion to size. Additionally, all farms are assumed to have cutting seines and scales for taking sample counts.

Shop, Office Equipment, and Miscellaneous

All farms have shop equipment to be able to complete basic repairs to aerators and other hardware, including a welder and hand and power tools. The tools and equipment necessary for pond monitoring are also provided, including oxygen and pH meters, sampling scales, and the like. Offices are provided with sufficient equipment to monitor and record farm activities and meet all business responsibilities. Each office has a computer system and basic office supplies. Other items, such as furniture and software, are added as needed. A number of miscellaneous items to control birds, provide amenities, and laboratory equipment also are provided.

Product Prices

One of the most important and most difficult parameters to set in economic evaluations is the product price. Some industry members suggest that vertical integration of operations to include processing decreases the exposure to market price swings. There is considerable variation in prices at both the farm gate and processor level (Figure 2). Vertical integration of companies, therefore, appears to have had little effect on the exposure to price risk. Future prices for catfish are clearly highly uncertain. This analysis assumes a constant catfish price of $1.54 per kg ($0.70 per lb) throughout the 10 year planning horizon.

The price for carp is assumed to be $1.10 per kg ($0.50 per lb). The market for carp is thin, and the amount of fish that can be sold at this price is presently limited. Other species are available, however, if this market cannot be developed to accept sufficient volume at an acceptable price.

Operations

Parameters used for the operations on the three farms are set to reflect the production activities required (Table 4). Due to the seasonal nature of catfish farming, most activities, such as feeding and harvesting, occur more often during the summer months; while in the cool winter months, the necessary activities decrease in frequency. This analysis is based on the assumption that non-critical items, such as pond and machinery maintenance, take place during the slow periods to even out the demands on labor and equipment.

Feeding

Feeding takes place from twice daily to once weekly, depending on average water temperatures on the farms. The feed price of $303 per metric ton ($275 per short ton) is based on current feed prices in Texas, delivered to the farm. Fuel consumption and labor costs are calculated from feeding frequencies. It is assumed that the feed was distributed from the pond bank by a truck mounted feeder/blower apparatus. The hopper on the feeders has a capacity of 2 short tons of feed. The average time required to feed one pond is 30 minutes. The feed is assumed to be a standard 32 percent floating catfish ration, to be delivered to the 20 ton farm silos in bulk, ready for distribution. Each farm is provided with adequate equipment to complete the feeding task.

Harvesting and Hauling

Harvesting and hauling charges are obtained from the CATSIM calculations. It was assumed that each pond is harvested once the minimum harvest quantity [one truckload, approximately 18 metric tons (20 short tons)] is reached, given that it is not off-flavor. This assumption causes a significantly higher number of ponds to be harvested during summer and fall. In this study, for the case of the upper Texas coast, no market limitations are imposed. Given the over capacity in processing and freezing and the small number of producers in this region, it is assumed that the farms will be able to sell fish when they reach harvestable size. The

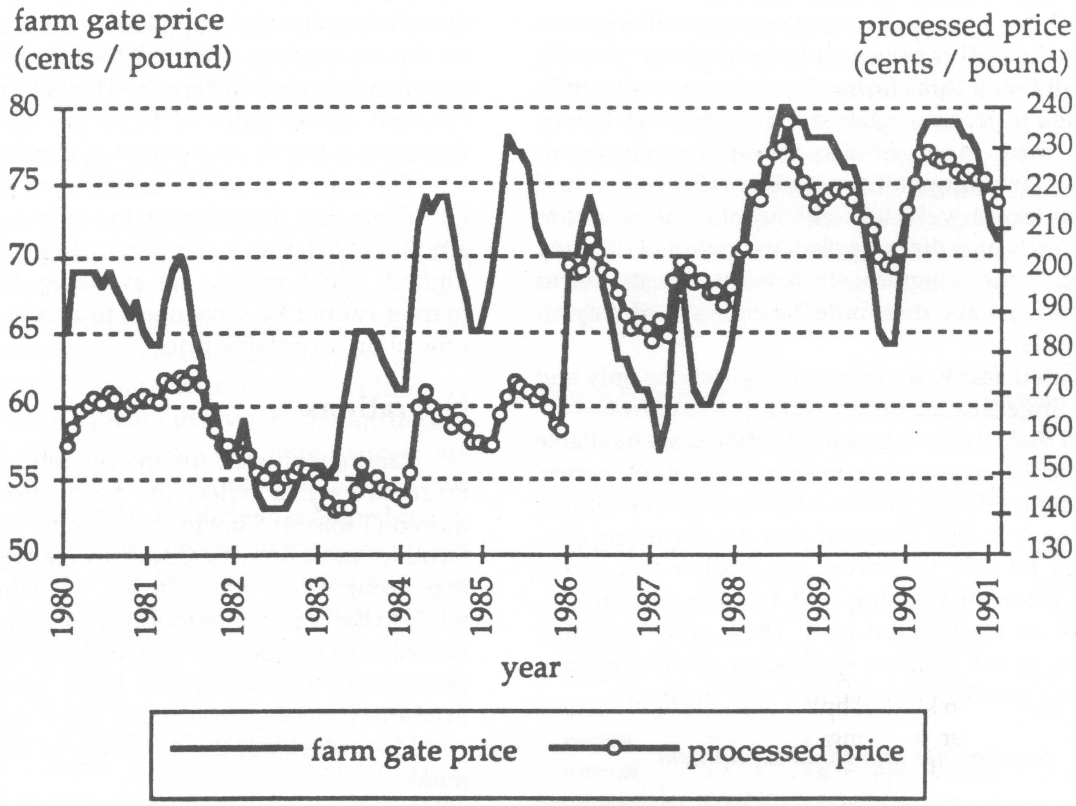

Figure 2. Average U.S. prices for food size catfish at the farm gate and processed catfish (all cuts) F.O.B plant from 1980 to 1991 (USDA).

effects of this "glut" can be counteracted by marketing strategies (Lambregts et al.), and by manipulating the average size harvested through the year. Harvests are performed by custom operators, and hauling is performed by the processor. Charges for these services are $0.044 per kg ($0.02 per lb) for the harvest crew and $0.044 per kg ($0.02 per lb) for the hauler.

Stocking

It is assumed that fingerlings are purchased from outside sources. Ponds are restocked after each harvest to maintain the pond target populations of 22,230 per ha (9,000 per ac). The number of fingerlings stocked is equal to the number of fish harvested plus mortality and bird predation. Fingerlings are delivered to the pond bank by the seller, and the hauling charge is included in the fingerling price of $0.006 per cm ($ 0.015 per inch). Treatment species are harvested using the same criteria, but are restocked once a year. The price for catfish and carp fingerlings is assumed to be identical.

Water Exchange and Supply

The average depth in the ponds is 1.5 m (4.9 feet). Effects of heavy rainfall or periods of drought are ignored since the water supply to the farms is assumed to be gravity fed. No fuel charge is made to the farms for adding water to the ponds. A total of 3,053 m^3 (one acre foot) of water per surface ha (ac) is purchased from the local water district to replace that lost through evaporation. This is approximately the amount of evaporation over rainfall [1,328 mm (52.28 inches)] in Brazoria

Table 4. Operational parameters for catfish farms with recirculating ponds on the upper Texas coast, 1991.

Parameter	Unit	Value
Feeding frequency	#/week	1-14
Harvest costs	$/kg($/lb)	0.044(0.02)
Hauling costs	$/kg($/lb)	0.044(0.02)
Min. harvest quantity (1,000's)	kg (lb)	18 (40)
Stocking quantity	#/ha (#/acre)	0 - 11,040 (0 - 9,000)
Internal water exchange	%/day	0-20
Water addition (annual)	m^3/ha (acrefeet)	3,053 (1)
Pumping time	hrs/day	0-24
Aeration time	hrs/day	0-8
Aeration	kw/pond (h.p./pond)	7.46 (10)
Rebuilding		
Period between reconstruction	years	7
Downtime for reconstruction	weeks	16
Maintenance (annual)		
Machinery	% new value	3-8
Ponds	% of construction cost	1
Insurance		
Liability	% of investment	1
Crop	$/kg harvested ($/lb)	0.0158 (0.0072)

County. The fuel charge for water recirculation in the systems is calculated by CATSIM based on standard engineering efficiency ratios and the hours pumped per day. The water recirculation rate is between 0 and 20 percent daily, depending on feeding rates and biomass in the ponds. The ponds start exchanging 1 percent of the pond volume daily when biomass in the pond exceeds 1,122 kg/ha (1,000 lb/ac). It then increases linearly with biomass until the maximum of 20 percent when 4,488 kg/ha (4,000 lb/ac) is reached. The dynamic head of the pumps is assumed to be 3.5 m (10.5 feet). The pumping rate varies linearly with feeding rate according to temperature.

Since the flow rate of each pond can be manipulated relative to the other ponds, an off-flavor pond is exchanged at 100% daily until the occurrence of off-flavor disappears. The cost of diesel delivered to the fuel tanks at the pumps is $0.317 per liter ($1.00 per U.S. gallon).

Aeration

Aeration strategies on the farms are determined by features of the recirculating system. Each pond is equipped with a 7.46 kW (10 hp) electric paddle wheel. During the summer growing season, all ponds are monitored daily for dissolved oxygen deficiency during the early morning hours. CATSIM applies aeration if pond biomass surpasses 1,704 kg per ha (1,500 lb per ac). Aeration time starts at 3 hr per day, and increases linearly with biomass until it reaches a maximum of 8 hr per day at 5,682 kg per ha (5,000 lb per ac). Standard engineering efficiency formulas are used to calculate the energy consumption of the paddle wheels in the ponds.

Pond Rebuilding

After a production period of 7 years, a pond is considered for rebuilding. After the next harvest, the undersized fish are transferred and the pond is dried in preparation for reconstruction. In a period of 16 weeks, the pond is dried, completely rebuilt, and restocked to resume production. The reconstruction cost is set equal to the original construction cost of the pond. Characteristics of the recirculating system are assumed to allow the operators to store 30 percent of the water from the ponds being rebuilt in other ponds so less water has to be added to the system after reconstruction.

Maintenance and Repairs

Labor, supplies, and equipment are included in the analysis for essential maintenance functions on the farm equipment and ponds. Aside from expenses on emergency repairs, the grounds and equipment are assumed to be maintained regularly, including feeders, pumps, vehicles, roads, ponds, and water intake and outflow structures. When possible, maintenance is scheduled during slow periods. Farms are charged a cost for repairs based on the new value of all equipment and ponds. This percentage was determined in discussions with suppliers and producers. For machinery, the annual repair cost is a function of the equipment cost and its age: it ranges from 3 percent in the first year to 10 percent from the 8th year on. The annual repair cost for ponds is 1 percent of the construction cost. This does not include the rebuilding charge in the seventh year of operation. The cost for maintenance materials, such as lubricants, is included.

Insurance and Miscellaneous Expenses

Cost for standard agricultural liability insurance is included at 1 percent of the original investment and included in the analysis. All farms carry crop insurance, which costs $0.0158 per kg ($0.0072 per lb) fish harvested. Estimates for administrative costs, such as legal fees, accounting costs, insurance, and property taxes are estimates from experiment station personnel or producers. Fuel, supplies, utilities, and other operational expenses are estimated based on the expected activities on the farms.

Financial Management

All farms start operations with $100,000 cash on hand. Farms may borrow when their cash on hand falls below the minimum amount of $50,000. During the year, operating deficits may be financed by operating loans (12% annual interest rate), but any outstanding operating loans are converted to 5-year, level amortization, intermediate-term loans (12% annual interest rate) at the end of the year. The owners/investors receive all cash on hand above $100,000 on December 31 as dividends. The farms are assumed to be managed by professional managers who are compensated by a fixed salary according to the level of skill required.

Labor

Labor requirements are calculated based on the tasks necessary on each farm and are verified by industry members (Table 5). It is assumed that the salaried labor force is flexible with respect to working hours during the busy summer and slack winter months. The single most time demanding activity is feeding. Other time demanding activities are, in order of importance, maintenance, supervision, bird control, and administrative. Miscellaneous pond activities, such as sampling, disease checks, and aeration management, require a substantial amount of time on all three size farms. It should be understood that these categories are highly dependent on the age of equipment used, quality of employees, soil and water characteristics, and other variables. Farms with more erodible soils, for example, can expect to spend considerably more labor and equipment time rebuilding roads and levees than producers

Table 5. Annual labor requirements (in hours) for small, medium, and large catfish farms* on the upper Texas coast, 1991, by activity.

	Farm size		
Category	Small	Medium	Large
Feeding	2,160	4,320	8,640
Maintenance	910	1,403	2,509
Supervision	619	1,306	2,651
Bird duty	900	1,300	2,200
Administrative	732	1,062	1,470
Disease checks	540	960	1,920
Repair	483	870	1,362
Rebuilding ponds	300	600	1,200
Water checks	264	528	1,056
Sampling	243	486	972
Aeration	240	480	960
Breaks	225	375	675
Removing dead fish	160	320	640
Record keeping	243	308	386
Water flow mgmt	150	150	150
Mowing	48	96	192
Disease treatment	32	64	128
Water weeds	32	64	128
TOTAL	8,281	14,692	27,238
Personnel Needed	4.31	7.65	14.19

*The total area in ha (ac) for the small farm is 66 (163), for the medium farm 132 (323), and for the large farm 264 (643).

with less erodible soils. Farms with PTO driven aerators can expect a considerable amount of additional labor for aeration activities.

Resources are allocated to record keeping and other administrative tasks as necessary. Growth, feed consumption, mortality, pH, dissolved oxygen levels, and water flows are recorded and analyzed at least weekly. Time is also allocated for disease and parasite checks and other essential biological control activities. Administrative time is allotted for activities like payroll, hiring and other personnel activities, banking, and harvest scheduling. This category also includes miscellaneous secretarial tasks such as accounts payable.

Farm managers are assumed to follow the weed control program developed by the Mississippi Cooperative Extension Service (Wellborn). Boats, motors, trailers, and water analysis equipment are provided as prescribed. The necessary operational costs for items like chemicals are included.

Recirculating systems appear to experience less frequent disease incidence than traditional production methods based on production records. This is partly attributable to the high salt content of the local water supply and partly to the improved water quality in a properly managed recirculating system. This analysis includes two pond treatments annually of potassium permanganate.

The prevention of bird predation is a major concern on catfish farms. During cormorant season, the small farm has one employee on full time "bird duty". Larger farms have similar allotments of time to prevent predatory losses. All farms are outfitted with standard bird gear, including shotguns with scare and shot shells, propane cannon, and other scare equipment. Predation on the farms is included in the mortality rate.

Results and Discussion

Investments

Total investment is $763,526, $1,433,088, and $2,694,680 for the small, medium and large farms, respectively (Table 6). The required investment per catfish surface ha (ac) decreases substantially as farms become larger (Table 7). There is a 6 percent saving in investment per unit production capacity between the small and medium farm and between the medium and large farm that is caused by economies of scale. Economies of scale have been found to be larger in other aquaculture operations (Keenum and Waldrop, Lambregts et al.), but the savings of scale in recirculating

Table 6. Total investments in small, medium, and large catfish farms* on the upper Texas coast, in 1991 dollars.

	Farm size		
Category	Small	Medium	Large
Land and water	192,600	382,200	761,400
Pond construction	346,612	671,420	1,316,675
Pond pumps	33,408	66,815	100,223
Buildings	32,230	42,680	57,530
Start-up costs	40,961	71,295	113,210
Vehicles and equipment	101,805	171,215	309,265
Tools, furniture and miscellaneous	15,910	27,463	36,377
TOTAL	763,526	1,433,088	2,694,680

*The total area in ha (ac) for the small farm is 66 (163), for the medium farm 132 (323), and for the large farm 264 (643).

Table 7. Total investment per area and per annual unit production capacity in small, medium, and large catfish farms* on the upper Texas coast, in 1991 dollars.

	Farm size		
Category	Small	Medium	Large
	Total per area		
Total per ha (catfish only)	16,258	15,257	14,345
Total per ha (all fish only)	14,180	13,307	12,511
Total per ac (catfish)	6,582	6,177	5,807
Total per ac (all fish)	5,741	5,388	5,065
	Total per unit production capacity		
Total per kg prod. capacity, catfish	1.45	1.36	1.28
Total per kg prod. capacity, all fish	1.35	1.27	1.19
Total per lb prod. capacity, catfish	0.66	0.62	0.58
Total per lb prod. capacity, all fish	0.61	0.58	0.54

*The total area in ha (ac) for the small farm is 66 (163), for the medium farm 132 (323), and for the large farm 264 (643).

systems are less because of unique construction features and the addition of pump stations.

Pond construction accounts for 45 to 49 percent of the total investment, while land and water account for 25 to 28 percent of the costs. Vehicles and equipment, start-up costs, pumps, buildings and tools together account for between 30 and 33 percent of the investment. The largest economies of scale are found in the buildings, start-up, and vehicles and equipment categories.

The investment required for these farms is between 56 and 70 percent higher than the identical size farms with static ponds analyzed by Keenum and Waldrop ($488,407, $840,348, and $1,587,795, respectively). However, farms with recirculating ponds in this analysis produce nearly twice as many pounds of catfish [527,273 (1,160,000 vs. 287,181 (631,800) kg (lb) for the small farms]. Investment per unit production capacity for recirculating farms located in the study area is between $1.45 ($0.66) and $1.28 ($0.58) per kg (lb) (Table 7). This is 7 to 16 percent lower than 1988 estimates for static ponds in Mississippi, which were $1.69 ($0.77), $1.45 ($0.66) and $1.36 ($0.62) per kg (lb) for small, medium, and large farms, respectively. If investment costs are compared on an "all fish" basis, the cost for farms with recirculating ponds along the upper Texas coast is 14 to 20 percent lower than competitive southeastern operations.

Costs and Revenues

Profitability of a farm can be described in different ways. One of the most common ways is the average budget (cash basis income statement), in which the average costs and revenues of farms are described either on a per unit weight or total cost and revenue basis. Such analyses are useful when comparing different production sites within the same industry or different methods of production.

Average Costs

Average costs over the ten years of operation for three farm sizes are compared in Table 8. The costs for any given year will depend on the inventory in the ponds, weather, rebuilding of ponds and other factors. Feed, stocking, and labor account for over 60 percent of the costs for the smallest system. Feed is a variable expense that remains constant between farms and is the most important cost factor. None of the categories account for more than 50 percent of total average costs.

The most important costs are feed, fingerlings, and labor. Other categories are of lesser importance. The average total cost per kg (lb) of all fish produced varies from $1.245 ($0.565) for the small farm to $1.193 ($0.541) for the large farm, a reduction of 7 percent (Table 9). The cost per kg (lb) catfish produced ranges from $1.327 ($0.602) to $1.265 ($0.574). Most scale economies lie in depreciation, fixed costs, and labor, although some savings exist in other categories.

Table 8. Relative cost (%) by category for a 10-year period for small, medium, and large catfish farms* on the upper Texas coast, 1991.

	% of 10 year total cost		
Category	Small	Medium	Large
Stocking	0.161	0.167	0.172
Feed	0.409	0.423	0.438
Fuel	0.052	0.044	0.032
Harvest Costs	0.070	0.072	0.075
Labor	0.116	0.112	0.102
Repairs	0.022	0.021	0.020
Fixed Costs	0.047	0.045	0.037
Interest pmt.	0.024	0.026	0.027
Depreciation	0.080	0.073	0.082
Miscellaneous	0.019	0.016	0.015

*The total area in ha (ac) for the small farm is 66 (163), for the medium farm 132 (323) and for the large farm 264 (643).

Table 9. Total costs and total revenue per kg (lb) by category for a 10 year period for small, medium, and large catfish farms* on the upper Texas coast, 1991.

	Catfish			All Fish		
Category	Small	Medium	Large	Small	Medium	Large
	$/kg					
Revenue	1.543	1.543	1.543	1.519	1.519	1.519
Total costs	1.327	1.284	1.265	1.245	1.206	1.193
	$/lb					
Total Costs	0.602	0.582	0.574	0.565	0.547	0.689
Revenue	0.700	0.700	0.700	0.689	0.689	0.541

*The total area in ha (ac) for the small farm is 66 (163), for the medium farm 132 (323), and for the large farm 264 (643).

These costs compare favorably to the per kg (lb) costs of $1.489 ($0.677), $1.386 ($0.630) and $1.318 ($0.599) for the small, medium, and large farms in Mississippi, respectively (Keenum and Waldrop). If the secondary species is ignored, average costs per unit of catfish is 4 to 12 percent lower for the farms with recirculating systems. If total production cost per unit (all fish) is compared, production costs appear to be 11 to 20 percent lower for recirculating systems located along the upper Texas coast.

Average Revenues

Farms are assumed to receive the same price for their products and to produce the same mix of carp and catfish. Therefore, average revenue for catfish is $1.543 ($0.70) per kg (lb) for all three farms (Tabl e 9). Average revenue for all fish on the farms is $1.519 ($0.689). Although costs decrease with farm size by 7 percent, the margin between average revenue (all fish) and average costs (all fish) increases with farm size from 22 to 27 percent, an increase of 25 percent.

Cash Flows

A second method to evaluate investments is cash flow analysis. For entrepreneurs, cash flow is important; timing of inflows and outflows of cash must be projected carefully. A manager of a start-up catfish farm must plan for the first 12 to 24 months when no fish are harvested and, therefore, no cash is generated. Managers must plan to ensure that economically profitable farms are not faced with bankruptcy because of poor cash flow planning. A company will not be able to sustain a 2-year period of no revenues without prior arrangements with investors or lenders.

Consolidated cash flows for the three farms appear in Table 10, while detailed cash flows appear in Tables A2, A3, and A4. Loan amounts in these cash flow statements should not be used to determine outstanding debt because outstanding operating loans are converted to intermediate loans annually on December 31. Therefore, the "loans" category includes both the original operating loan and intermediate term loans. The category "interest pmt." includes interest payments on intermediate- and short-term debt.

Catfish farms generally reach full production 2 years after the ponds are first stocked; the start-up period extends through the second year of operation. The start-up phase can be shortened by stocking larger animals in the ponds. Although the farms produce a substantial crop the second year of operation, in this analysis, year 3 is the first year of full production. The smallest farm does not have a positive cash flow until year 3. The medium sized farm has a positive cash flow by the end of year 2, and the largest farm has enough funds to issue a small dividend by December of year 2.

In the first year, the principal cost on the farms is stocking. Labor and feed are also important. In year 2, feed becomes relatively more important, as the fish in the ponds are increasing in size and require larger daily rations. Although the first fish are harvested, the farms have not yet reached full production. All farms are able to issue dividends in the third year of operation.

The IRRs are provided in Table 11 with the net cash flows of the three farms. The first two cash flows, the initial investment and the beginning cash on hand, are negative while the last 10 entries, dividends issued, are zero or positive. The IRRs are based on these cash flows (investme nts and dividends), as well as the net worth of the farms in the last year. If the net worth is not included, the IRR will be lower.

The IRRs are 15, 18.3, and 21.9 percent, for the small, medium, and large farms, respectively. These are real rates of return to the investor, unadjusted for risk and inflation. By comparison, the average real rates of return of U.S. stocks and treasury bills have been 8.3 and 0.1 percent, respectively, between 1926 and 1981 (Ibbotson and Sinquefield, 1982). The individual investor should adjust expected rates of return by expected

Table 10. Cash flows for small, medium, and large catfish farms on the upper Texas coast, 1991, for the first 3 years of operation. (May not add due to rounding.)

	Farm size*								
	163			323			643		
	yr. 1	yr. 2	yr.3	yr. 1	yr. 2	yr.3	yr. 1	yr. 2	yr.3
Beginning cash on hand	100,000	50,000	50,000	100,000	50,000	50,000	100,000	50,000	100,000
Revenues catfish	0	616,346	817,674	0	1,233,683	1,678,271	0	2,472,716	3,359,906
Revenues carp	0	17,094	34,540	0	38,941	50,275	0	77,882	133,476
Loans	544,532	195,347	74,833	1,164,970	334,774	141,294	2,281,676	541,015	172,133
Interest income	3,474	3,446	7,238	3,260	4,380	11,853	3,250	7,012	25,299
TOTAL	648,007	882,233	984,285	1,268,230	1,661,779	1,931,693	2,384,927	3,148,625	3,790,814
Stocking	111,200	84,584	106,633	222,400	169,109	215,699	444,800	338,790	437,553
Feed	68,544	287,691	308,414	137,087	574,991	610,054	274,174	1,148,919	1,232,963
Labor	75,860	75,860	75,860	143,700	143,700	143,700	251,490	251,490	251,490
Energy	18,546	35,192	36,579	34,963	59,016	60,587	59,373	82,870	82,641
Harvesting	0	38,509	52,086	0	77,476	105,170	0	155,273	213,313
Fixed Costs	35,612	37,433	43,227	65,094	68,361	81,522	102,389	107,772	127,390
Debt service	281,092	259,227	158,837	604,038	494,927	312,499	1,184,612	887,945	492,684
Other	7,153	13,739	16,061	10,948	24,198	28,934	18,088	44,643	54,569
Dividends	0	0	86,587	0	0	273,529	0	30,922	798,210
TOTAL	598,007	832,233	884,285	1,218,231	1,611,779	1,831,693	2,334,926	3,048,625	3,690,813
Ending cash	50,000	50,000	100,000	50,000	50,000	100,000	50,000	100,000	100,000
Beginning cash	100,000	50,000	50,000	100,000	50,000	75,281	100,000	50,000	100,000

*The total area in ha (ac) for the small farm is 66 (163), for the medium farm 132 (323), and for the large farm 264 (643).

Table 11. Net investor cash flows and internal rates of return (IRR) for small, medium, and large catfish farms on the upper Texas coast, in 1991 dollars, for a 10-year planning horizon.

	Farm size*		
Date	Small	Medium	Large
Jan. yr. 0	-763,526	-1,433,088	-2,694,680
Jan. yr. 1	-100,000	-100,000	-100,000
Dec. yr. 1	0	0	0
Dec. yr. 2	0	0	30,922
Dec. yr. 3	86,587	273,529	798,210
Dec. yr. 4	233,623	415,587	950,917
Dec. yr. 5	138,564	342,625	929,340
Dec. yr. 6	163,550	290,645	776,091
Dec. yr. 7	101,313	500,409	923,436
Dec. yr. 8	0	0	0
Dec. yr. 9	154,344	394,767	884,460
Dec. yr.10	196,522	456,462	1,039,880
IRR	0.150	0.183	0.219

*The total area in ha (ac) for the small farm is 66 (163), for the medium farm 132 (323), and for the large farm 264 (643).

inflation rates to generate nominal rates of return. These nominal rates of return can then be compared to rates investors expect to attain for investments with comparable risk.

Sensitivity

Results of evaluating the sensitivity of the three farms to fluctuating prices and yields are shown in Table 12. The unit price of feed, the largest production cost, is varied from $248 ($225) to $358 ($325) per metric ton (short ton). The farms have returns greater than 10 percent for all feed price levels analyzed. Nevertheless, a feed price increase to $358 ($325), 18 percent, results in a decrease in the IRR between 21 and 28 percent. Feed prices must nearly double before returns to the farms become negative.

The effect of fingerling price fluctuations is significantly smaller than for feed price swings. When the price of fingerlings decreases by $0.02 from $0.10 to $0.08 (20%), the IRR of the farms increases between 9 and 13 percent. As the price of fingerlings increases from $0.08 to $0.12, the IRR's decrease from 15, 18, and 22 percent to 13, 16, and 20 percent for the small, medium, and large farms, respectively. Although stocking is the second largest cost, the effect of price fluctuations on returns is relatively small.

Returns to the farms are very sensitive to fluctuations in the price of catfish. A decrease in the catfish price from $1.54 ($0.70) to $1.21 ($0.55) per kg (lb) results in a negative return for the smallest farm. The largest farm still generates a 4 percent IRR at this price, but the smaller two farms generate negative returns. An increase of 11 cents per kg (5 cents per lb) to $1.65 ($0.75) increases the IRR between 25 and 28 percent for the

Table 12. The Internal rates of return (IRR) for small, medium, and large catfish farms on the upper Texas coast, 1991, at selected prices for feed, fingerlings and catfish, and at selected yields.

		Farm Size*		
Item	Price	Small	Medium	Large
Feed, $/metric ton (short ton)				
	248 (225)	0.192	0.225	0.263
	275 (250)	0.171	0.204	0.241
	302 (275)	0.150	0.183	0.219
	330 (300)	0.129	0.159	0.197
	358 (325)	0.108	0.136	0.173
Fingerling price ($)				
	0.080	0.169	0.202	0.239
	0.090	0.159	0.192	0.230
	0.100	0.150	0.183	0.219
	0.110	0.141	0.172	0.209
	0.120	0.131	0.162	0.198
Catfish price, $/kg ($/lb)				
	1.21 (0.55)	-0.091	-0.011	0.044
	1.32 (0.60)	0.049	0.077	0.114
	1.43 (0.65)	0.103	0.134	0.170
	1.54 (0.70)	0.150	0.183	0.219
	1.65 (0.75)	0.192	0.225	0.265
Annual yield, kg/ha (lb/ac)				
	6,736 (6,000)	-0.166	-0.109	0.004
	8,982 (8,000)	0.054	0.080	0.121
	11,227 (10,000)	0.150	0.183	0.219
	13,473 (12,000)	0.196	0.231	0.269
	15,718 (14,000)	0.247	0.285	0.324

*The total area in ha (ac) for the small farm is 66 (163), for the medium farm 132 (323), and for the large farm 264 (643).

farms. Price fluctuations affect the returns of the small farm more than the larger farms, indicating that small farms are subject to more risk from price changes.

The annual production yield per area strongly influences the returns. A drop in maximum production by 20 percent decreases the IRR between 45 and 64 percent. On the up side, increasing production by 40 percent increases the IRR between 48 and 64 percent. Clearly, the production yield will be one of the most important determinants of the farm's success. It also suggests that farm managers evaluate the tradeoffs between mechanical aeration (paddle wheel aeration and water flow-through) and production yield.

The relationship between the IRR to the farms and the price of feed, fingerlings, and catfish is remarkably linear. Only in the lower regions, where the IRR becomes negative, is the relationship clearly curvilinear. Rates of return for the farms at other prices may be easily obtained from Figure 3 by interpolation. Such rates can be used to provide individual investors with approximate returns for their particular situation. Care should be taken when extrapolating these relationships outside the range of prices analyzed here.

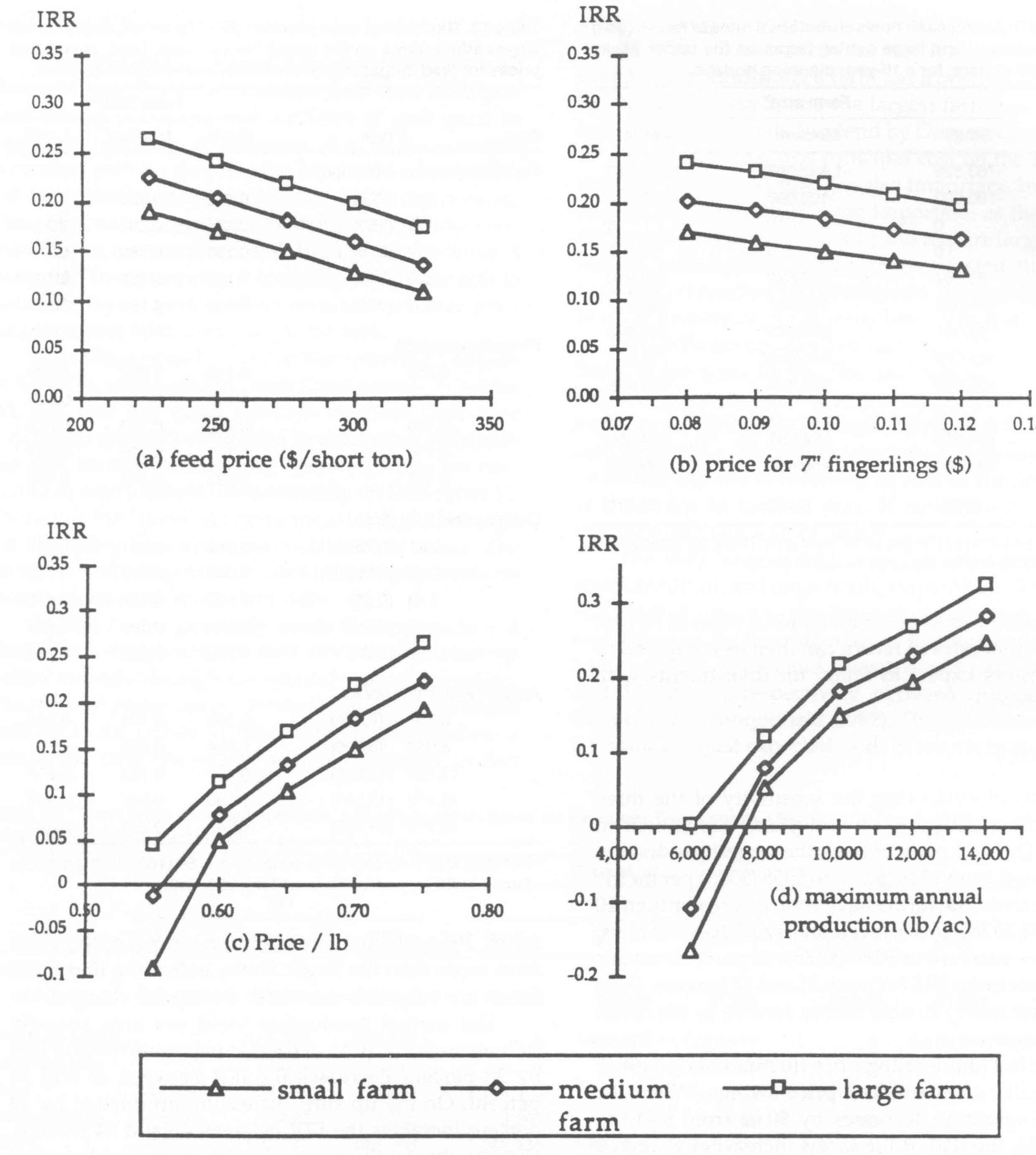

Figure 3. The internal rate of return (IRR) by (a) feed price, (b) fingerling price, (c) catfish price, (d) yield, for small (66 ha, 163 ac), medium (132 ha, 323 ac) and large (264 ha, 643 ac) catfish farms on the upper Texas Coast, 1991.

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Appendix

Table A1. Total investments in three catfish farms (small, medium,and large) on the upper Texas coast in 1991 dollars by size (may not add due to rounding).

	Farm size*									
	Small			Medium			Large			
Category	units	price	total	units	price	total	units	price	total	Eco. life
STARTUP COSTS										
Laborer	0.50	11,000	5,500	0.5	11,000	5,500	2	11,000	22,000	
General manager	0.50	35,000	17,500	1	35,000	35,000	1	35,000	35,000	
Assistant manager	0	0	0	0	0	0	0.2	22,000	4,400	
Accountant fees	40	40	1,600	63	40	2,500	87	40	3,480	
Legal fees	25	75	1,875	68	75	5,100	98	75	7,350	
Insurance (liability)	1	1,929	1,929	1	2,508	2,508	1	3,575	3,575	
Insurance (health)	1	3,216	3,216	1.5	3,216	4,824	3.2	3,216	10,291	
Insurance (auto)	1	1,406	1,406	1	1,406	1,406	2	1,406	2,812	
Repair nonmachine	40	20	800	80	20	1,600	160	20	3,200	
Repair machine	22	40	880	40	40	1,600	80	40	3,200	
Utilities (electricity)	4,500	0.07	315	8,500	0.07	595	12,000	0.07	840	
Utilities (phone)	6	75	450	12	75	900	12	95	1,140	
Supplies	1	500	500	2	500	1,000	3	500	1,500	
Fuel	400	1.19	476	600	1.19	714	850	1.19	1,012	
Property tax	163	4.85	791	323	4.85	1,567	643	4.85	3,119	
Miscellaneous	1	3,724	3,724	1	6,481	6,481	1	10,292	10,292	
SUBTOTAL			40,961			71,295			113,210	
REAL ESTATE										
Land	163	1,000	163,000	323	1,000	323,000	643	1,000	643,000	50
Water rights (acre feet)	800	37	29,600	1,600	37	59,200	3,200	37	118,400	50
SUBTOTAL			192,600			382,200			761,400	
BUILDINGS	0	0	0							
Buildings (shop/off)	1,200	15	18,000	1,500	15	22,500	2400	15	36,000	20
Well	1	5,000	5,000	1	5,000	5,000	1	5,000	5,000	20
Septic system	1	6,300	6,300	1	6,300	6,300	1	6,300	6,300	20
Architect fee	0	5,000	0	1	5,000	5,000	1	5,000	5,000	20
Miscellaneous	1	2,930	2,930	1	3,880	3,880	1	5,230	5,230	20
SUBTOTAL			32,230			42,680			57,530	
POND CONSTRUCTION										
Dirt moving	189,600	1	170,640	379,200	1	322,320	758,400	1	621,888	7
Gravel	2,285.714	14	32,000	4,571.429	14	64,000	9,142.86	14	128,000	7
System pipe and const.	160	165	26,400	320	165	52,800	640	165	105,600	7
Clearing and preparation	160	148	23,680	320	148	47,360	640	148	94,720	7
Grass	80	12	960	160	12	1,920	320	12	3,840	7
Survey (to permit)	1	4,800	4,800	1	9,600	9,600	1	19,200	19,200	7
Engineering design	1	30,400	30,400	1	60,800	60,800	1	121,600	121,600	7
Electric lines	8	1,800	14,400	16	1,800	28,800	32	1,800	57,600	7
Miscellaneous	1	43,332	43,332	1	83,820	83,820	1	164,227	164,227	7
SUBTOTAL			346,612			671,420			1,316,675	
POND PUMPS										
Pump mount	1	6,400	6,400	2	6,400	12,800	3	6,400	19,200	15
Hardware and installation	1	4,150	4,150	2	4,150	8,300	3	4,150	12,450	15
Fuel tank	1	1,500	1,500	2	1,500	3,000	3	1,500	4,500	7
Pump	1	8,600	8,600	2	8,600	17,200	3	8,600	25,800	7
Diesel engine	1	8,400	8,400	2	8,400	16,800	3	8,400	25,200	7
Miscellaneous	1	4,358	4,358	1	8,715	8,715	1	13,073	13,073	7
SUBTOTAL			33,408			66,815			100,223	
MAJOR POND EQUIP.										
Bulk feed silos (incl. pad)	1	9,500	9,500	2	9,500	19,000	2	9,500	19,000	15
1 ton Feed Pickup	1	13,200	13,200	2	13,200	26,400	4	13,200	52,800	7
Feeder with scales/printer	1	9,800	9,800	2	9,800	19,600	4	9,800	39,200	7
Tractor /45HP/used	1	10,000	10,000	1	10,000	10,000	2	10,000	20,000	7
Boat, motor and trailer	1	3,800	3,800	1	3,800	3,800	1	3,800	3,800	5
Stationary aerators	9	3,400	30,600	18	3,400	61,200	35	3,400	119,000	5
1/2 Ton pickup	1	8,500	8,500	1	8,500	8,500	2	8,500	17,000	5
Miscellaneous	1	8,540	8,540	1	14,850	14,850	1	27,080	27,080	5
SUBTOTAL			93,940			163,350			297,880	

Table A1. (continued)

Category	Small units	Small price	Small total	Medium units	Medium price	Medium total	Large units	Large price	Large total	Eco. life
IMPLEMENTS										
Mower	1	3,000	3,000	1	3,000	3,000	1	3,000	3,000	7
2-way radio system	0	3,200	0	0	3,200	0	1	3,200	3,200	7
Portable pump	1	650	650	1	650	650	1	650	650	7
Grader	1	1,500	1,500	1	1,500	1,500	1	1,500	1,500	7
Disk	1	2,000	2,000	1	2,000	2,000	1	2,000	2,000	7
Miscellaneous	1	715	715	1	715	715	1	1,035	1,035	7
SUBTOTAL			7,865			7,865			11,385	
POND EQUIP.										
Seine rods	10	20	200	10	20	200	10	20	200	3
Cutting seine	1	500	500	1	500	500	1	500	500	3
Pond screens	16	50	800	32	50	1,600	32	50	1,600	3
Four wheeler	0	3,600	0	1	3,600	3,600	2	3,600	7,200	3
Dip nets	2	50	100	2	50	100	2	50	100	3
Waders	4	80	320	6	80	480	8	80	640	3
Oxygen kits	1	1,490	1,490	1	1,490	1,490	2	1,490	2,980	3
Chemical kits	1	360	360	2	360	720	3	360	1,080	3
Miscellaneous	1	377	377	1	869	869	1	1,430	1,430	3
SUBTOTAL			4,147			9,559			15,730	
OFFICE										
Desk & chair	1	250	250	1	250	250	3	250	750	12
Blackboard	0	100	0	1	100	100	3	100	300	12
Bookshelves	1	150	150	2	150	300	2	150	300	12
Filing cabinet	1	150	150	2	150	300	2	150	300	12
Computer system	1	1,500	1,500	1	4,000	4,000	1	4,000	4,000	6
Typewriter	0	500	0	1	500	500	1	500	500	6
Telephone system	1	150	150	1	150	150	1	150	150	5
Light fixtures	1	200	200	3	200	600	3	200	600	5
Xerox machine	0	500	0	1	500	500	1	500	500	5
Calculator	1	75	75	1	75	75	1	75	75	5
Software	1	750	750	1	750	750	2	750	1,500	5
Miscellaneous	1	323	323	1	752.5	753	1	898	898	5
SUBTOTAL			3,548			8,278			9,873	
SHOP EQUIP.										
Drill press	0	400	0	1	400	400	1	400	400	10
Grinder	1	125	125	1	125	125	1	125	125	10
Welder	0	300	0	1	300	300	1	300	300	10
Torch	1	300	300	1	300	300	1	300	300	10
Work bench	1	60	60	1	60	60	1	60	60	10
Air compressor	1	400	400	1	400	400	1	400	400	7
Battery charger	1	50	50	1	50	50	1	50	50	7
Jack 12 Ton	1	400	400	1	400	400	1	400	400	7
Wheelbarrow	1	90	90	1	90	90	1	90	90	7
Hand truck	1	120	120	1	120	120	1	120	120	7
Hand tools	1	250	250	1	250	250	1	250	250	7
Gen supplies	1	250	250	1	250	250	1	250	250	7
Generator(small)	1	1,000	1,000	1	1,000	1,000	1	1,000	1,000	7
Hand drill 3/8	1	120	120	1	120	120	1	120	120	3
Sawtable	1	150	150	1	150	150	1	150	150	3
Jigsaw	1	100	100	1	100	100	1	100	100	3
Circular	1	150	150	1	150	150	1	150	150	3
Ladder	1	50	50	1	50	50	1	50	50	3
Miscellaneous	1	362	362	1	432	432	1	432	432	3
SUBTOTAL			3,977			4,747			4,747	
MISCELLANEOUS EQUIP.										
Binoculars	1	110	110	1	110	110	1	110	110	7
Propane cannon	2	250	500	2	250	500	4	250	1,000	7
Triple beam balance	1	90	90	1	90	90	2	90	180	7
Microscopes	1	300	300	1	300	300	1	300	300	7
Scare equipment	1	140	140	2	140	280	4	140	560	7
Sampling scales	1	114	114	2	128	256	2	215	430	7
Air conditioner	1	2,000	2,000	1	2,000	2,000	1	2,000	2,000	7
Refrigerator	1	300	300	1	300	300	1	300	300	5
PH meter	1	300	300	2	300	600	2	300	600	5
Miscellaneous	1	385	385	1	444	444	1	548	548	5
SUBTOTAL			4,239			4,880			6,028	
TOTAL			763,526			1,433,088			2,694,680	

Farm size* (Small, Medium, Large)

*The total area in ha (ac) for the small farm is 66 (163), for the medium farm 132 (323), and for the large farm 264 (643).

Table A2. Cash flow for a small (66 ha, 163 ac) catfish farm along the upper Texas coast during the first 5 operating years (in 1991 dollars).

	Year				
Category	1	2	3	4	5
Beginning cash	100,000	50,000	50,000	100,000	100,000
Plus:					
Revenues specie 1	0	616,346	817,674	930,797	843,121
Revenues specie 2	0	17,094	34,540	34,872	34,926
Interest inc.	3,474	3,446	7,238	11,102	8,619
Short term loan	272,266	174,763	74,833	848	24,110
Intermed. loan	272,266	20,584	0	0	0
Total	648,007	882,233	984,285	1,077,619	1,010,775
Minus:					
Stocking	111,200	84,584	106,633	120,549	108,933
Feed	68,544	287,691	308,414	310,020	292,449
Pumping energy	4,811	16,585	17,825	17,912	18,058
Aeration energy	1,735	6,607	6,754	6,754	6,754
Salt	0	915	1,237	1,399	1,274
Harvesting	0	18,294	24,744	27,989	25,486
Hauling	0	18,294	24,744	27,989	25,486
Crop insurance	0	6,586	8,908	10,076	9,175
Lab testing fees	0	1,006	1,361	1,539	1,402
Disease treatment	4,212	4,212	4,212	4,212	4,212
General manager	25,000	25,000	25,000	25,000	25,000
Pond mgr/feeder	16,000	16,000	16,000	16,000	16,000
Part time labor	23,100	23,100	23,100	23,100	23,100
Fringe & benefits	11,760	11,760	11,760	11,760	11,760
Prop. Tax(4.85)	790	790	790	790	790
Accountant fees	2,000	2,000	2,000	2,000	2,000
Legal fees	1,500	1,500	1,500	1,500	1,500
Water rights(1')	5,032	5,032	5,032	5,032	5,032
Insurance (1%)	7,635	7,635	7,635	7,635	7,635
Repair mach. & pond	8,929	10,750	12,570	14,278	16,025
Machine replacement	0	0	3,974	1,697	39,872
Epa lab fees	200	200	200	200	200
Test kits (k&w)	245	245	245	245	245
Fuel and lube	1,464	1,464	1,464	1,464	1,464
Fuel (feed: 5/hr)	12,000	12,000	12,000	12,000	12,000
Utilities	2,800	2,800	2,800	2,800	2,800
Travel & dues	1,250	1,250	1,250	1,250	1,250
Miscellaneous	6,708	6,708	6,708	6,708	6,708
Interest inter.	0	32,672	29,999	23,850	16,964
Interest short	8,826	8,935	2,765	8	251
Principal inter.	0	42,857	51,240	57,389	64,276
Principal short	272,266	174,763	74,833	848	24,110
Sub total	598,007	832,233	797698	743,997	772,212
Dividends paid	0	0	86,587	233,623	138,564
Total	598,007	832,233	884,285	977,619	910,775
Ending cash bal.	50,000	50,000	100,000	100,000	100,000

Table A3. Cash flow for a medium (132 ha, 323 ac) catfish farm along the upper Texas coast during the first 5 operating years (in 1991 dollars).

Category	Year 1	2	3	4	5
Beginning cash	100,000	50,000	50,000	100,000	100,000
Plus:					
Revenues specie 1	0	1,233,683	1,678,271	1,748,687	1,768,448
Revenues specie 2	0	38,941	50,275	88,802	64,276
Interest inc.	3,260	4,380	11,853	16,439	14,666
Short term loan	582,485	315,810	141,294	20,710	67,614
Intermed loan	582,485	18,964	0	0	0
Total	1,268,231	1,661,779	1,931,693	1,974,638	2,015,005
Minus:					
Stocking	222,400	169,109	215,699	229,592	229,594
Feed	137,087	574,991	610,054	617,107	618,419
Pumping energy	7,493	21,775	23,078	23,049	23,005
Aeration energy	3,470	13,241	13,509	13,509	13,509
Salt	0	1,840	2,498	2,676	2,655
Harvesting	0	36,806	49,962	53,515	53,098
Hauling	0	36,806	49,962	53,515	53,098
Crop insurance	0	13,250	17,986	19,265	19,115
Lab testing fees	0	2,024	2,748	2,943	2,920
Disease treatment	8,424	8,424	8,424	8,424	8,424
General manager	35,000	35,000	35,000	35,000	35,000
Pond mgr./feeder	32,000	32,000	32,000	32,000	32,000
Mechanic	14,000	14,000	14,000	14,000	14,000
Laborers	13,000	13,000	13,000	13,000	13,000
Seasonal labor	26,500	26,500	26,500	26,500	26,500
Fringe & benefits	23,200	23,200	23,200	23,200	23,200
Property taxes	1,567	1,567	1,567	1,567	1,567
Accountant fees	3,000	3,000	3,000	3,000	3,000
Legal fees	2,000	2,000	2,000	2,000	2,000
Water rights (1')	10,064	10,064	10,064	10,064	10,064
Insurance (liab.)	14,040	14,040	14,040	14,040	14,040
Repair mach. & pond	16,517	19,784	23,052	26,038	29,181
Machine replacement	0	0	9,893	2,852	64,687
Epa lab fees	300	300	300	300	300
Test kits (k&w)	490	490	490	490	490
Fuel and lube	2,432	2,432	2,432	2,432	2,432
Fuel (feed: 5/hr)	24,000	24,000	24,000	24,000	24,000
Utilities	4,800	4,800	4,800	4,800	4,800
Travel & dues	2,250	2,250	2,250	2,250	2,250
Miscellaneous	10,158	10,158	10,158	10,158	10,158
Interest inter.	0	69,898	61,171	48,490	34,287
Interest short	21,553	17,530	4,357	207	1,412
Principal inter.	0	91,689	105,677	118,358	132,561
Principal short	582,485	315,810	141,294	20,710	67,614
Sub total	1,218,231	1,611,779	1,558,165	1,459,051	1,572,380
Dividends paid	0	0	273,529	415,587	342,625
Total	1,218,231	1,611,779	1,831,693	1,874,638	1,915,005
Ending cash bal.	50,000	50,000	100,000	100,000	100,000

Table A4. Cash flow for a large (264 ha, 643 ac) catfish farm alongthe upper Texas coast during the first 5 operating years (in 1991 dollars).

Category	Year 1	2	3	4	5
Beginning cash	100,000	50,000	100,000	100,000	100,000
Plus:					
Revenues specie 1	0	2,472,716	3,359,906	3,521,265	3,531,996
Revenues specie 2	0	77,882	133,476	139,393	128,650
Interest inc.	3,250	7,012	25,299	29,763	26,077
Short term loan	1,140,838	541,015	172,133	110,361	150,060
Intermed loan	1,140,838	0	0	0	0
Total	2,384,927	3,148,625	3,790,814	3,900,782	3,936,783
Minus:					
Stocking	444,800	338,790	437,553	454,252	456,909
Feed	274,174	1,148,919	1,232,963	1,230,434	1,235,682
Pumping energy	9,232	13,189	12,424	12,374	12,394
Aeration energy	6,941	26,481	27,017	27,017	27,017
Salt	0	3,688	5,067	5,309	5,303
Harvesting	0	73,764	101,336	106,183	106,060
Hauling	0	73,764	101,336	106,183	106,060
Crop insurance	0	26,555	36,481	38,226	38,182
Lab testing fees	0	4,057	5,574	5,840	5,833
Disease treatment	16,848	16,848	16,848	16,848	16,848
General manager	35,000	35,000	35,000	35,000	35,000
Foreman	17,000	17,000	17,000	17,000	17,000
Feeder	64,000	64,000	64,000	64,000	64,000
Mechanic	14,000	14,000	14,000	14,000	14,000
Laborers	39,000	39,000	39,000	39,000	39,000
Seasonal labor	41,900	41,900	41,900	41,900	41,900
Fringe & benefits	40,590	40,590	40,590	40,590	40,590
Property taxes	3,119	3,119	3,119	3,119	3,119
Accountant fees	4,000	4,000	4,000	4,000	4,000
Legal fees	2,500	2,500	2,500	2,500	2,500
Water rights	20,128	20,128	20,128	20,128	20,128
Insurance (liab).	14,040	14,040	14,040	14,040	14,040
Repair mach. & pond	29,314	34,697	40,079	45,057	50,284
Machine replacement	0	0	14,236	3,535	7,654
Epa lab fees	400	400	400	400	400
Test kits (k&w)	980	980	980	980	980
Fuel and lube	3,165	31,65	3,165	3,165	3,165
Fuel(feed: 5/hr)	43,200	43,200	43,200	43,200	43,200
Utilities	6,400	6,400	6,400	6,400	6,400
Travel & dues	2,875	2,875	2,875	2,875	2,875
Miscellaneous	16,708	16,708	16,708	16,708	16,708
Interest inter.	0	136,901	115,351	91,216	64,184
Interest short	43,774	30,450	4,071	2,761	3,671
Principal inter.	0	179,579	201,129	225,264	252,296
Principal short	1,140,838	541,015	172,133	110,361	150,060
Sub total	2,334,926	3,017,703	2,892,604	2,849,865	2,907,443
Dividends paid	0	30,922	798,210	950,917	929,340
Total	2,334,926	3,048,625	3,690,813	3,800,782	3,836,783
Ending cash bal.	50,000	100,000	100,000	100,000	100,000

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