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

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Abstract

Cost, returns, and economies of scale for small, medium and large catfish farms with recirculating ponds are presented for the upper Texas coast. Internal rates of return are 0.150, 0.183 and 0.219, respectively. Total investment is higher than farms with static ponds but investment per unit production capacity is 7 percent to 16 percent lower. Average total cost per pound is between $0.565 and $0.541, (11 percent-20 percent lower than farms using current technology). These results have implications for regional comparative advantage of catfish production as well as incentive for adoption of new technology in conventional ponds.

Key Words: aquaculture, catfish, economics, off-flavor

Introduction

Farm-raised catfish has become a substantial part of the U.S. seafood market in the last decade. Per capita consumption of catfish is now more than one pound annually (USDAa). Most production technologies for catfish production have been solved except off-flavor. This problem has plagued the industry since its inception. Pond organisms produce flavor compounds, which when absorbed by the catfish produce off-flavor. The catfish are unmarketable as long as the off-flavor exist (Lovell). Kinnucan, et al. (page 81) state, "Off-flavor is serious because it affects, depending on the season, up to 45 percent of the food size fish held in farmers' ponds; delays harvesting up to eight months; undermines consumers' confidence in the retail product; and at present, cannot be controlled cost effectively." Elimination of off-flavor is estimated to have short-run social welfare gains equal to 12 percent of catfish farm revenues (Kinnucan, et al.).

A modified recirculating system, developed by a Texas catfish production firm, has reduced the incidence of off-flavor to virtually zero.[1] The occurrence of off-flavor can be reduced significantly or even eliminated when pond water is circulated through noncatfish producing ponds. This technology requires a significantly larger capital investment, but it also increases production. Since 8 percent of the industry's ponds are either built new or renovated (USDAb), there is sufficient opportunity to incorporate this new technology

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across the southeastern U. S. For this type of facility to be accepted, however, it must compete favorably with the traditional method of producing catfish.

Several economic analyses have been conducted on catfish using the traditional method of production (Burtle et al.; Dellenbarger and Vandeveer; Hatch et al.; Sindelar et al.). This study developed enterprise budgets for a modified recirculating system and compared the results to Keenum and Waldrop because it is the most recent study and it examines three different farm sizes.[2] Farm size is important because the modified recirculating system examined herein requires eight catfish and one noncatfish pond as a production unit. Thus, there is a question as to level of economies of scale with these fixed units. The objectives of this study were: 1) investigate the economic returns of catfish farms with recirculating ponds; 2) evaluate the economies of scale in catfish farming; and 3) compare the costs and returns of recirculating ponds with those in other states (Lambregts, et al.). Texas was used as a case study for establishing cost and returns of recirculating ponds.

Methods

An economic engineering approach is used to evaluate farms of the same three sizes, 163, 323, and 643 acres, as in the Keenum and Waldrop study. The economic engineering approach requires a complete cash flow for an operation, including investments, operating costs, and returns. The three farms are referred to as small, medium, and large. The importance of economies of scale in aquaculture is well established (Lambregts, Thacker and Griffin; Adams, Griffin, Nichols and Brick; and Keenum and Waldrop). It is important to use farms of equal sizes to provide relative measures of performance. These farm sizes allow for direct comparisons to the Keenum and Waldrop estimates for Mississippi. Calculations are made by the firm-level economic engineering program for catfish, CATSIM.

CATSIM, which can run deterministically or stochastically, simulates catfish production on a weekly, monthly, and annual basis. This computer program is based on the program MARSIM (Hanson et al.). CATSIM has a biological submodel that generates stocking, feed, energy, and harvesting cost. The economic submodel calculates annual income statements, monthly and annual cash flows, and other financial information for the 10-year planning horizon including net present value (NPV) and internal rate of return (IRR).

Each of the three farms is assumed to be located along the upper Texas coast as 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 in the area. For this analysis, custom services are incorporated which allow the farms to operate without harvesting and hauling equipment, thereby reducing the investment needed, especially for the smaller farms. 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 a catfish producer and processor in Texas. This production method has a number of distinguishing features, particularly recirculation pumps, treatment ponds, and canals. In a recirculating system, several catfish ponds are connected to inflow and outflow canals which are, in turn, connected to a treatment pond. A pump station pumps water from the treatment pond to the inflow canal, where it circulates, by gravity, through the catfish ponds and the outflow canals back to the treatment ponds. The maximum daily water recirculation is 20 percent of the catfish pond volume. Because of evaporation and seepage water is periodically added to the pond. Treatment ponds contain filter feeding fish[3], 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 percent 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 15,000 pounds/acre annually.

Basic assumptions underlying this analysis are as follows:

1. Ponds are harvested selectively with larger fish gathered and sold;
2. Restocking occurs after each harvest;
3. Off-flavor is handled as a stochastic occurrence related to water temperature and season, and, if evident, that pond is not harvested until the fish are on-flavor;
4. Production parameters are held constant over time;
5. Growth and feeding rates are based on water temperature;
6. Risk is not considered beyond the attention given to off-flavor;
7. Profitability is measured by the IRR (Brealey and Meyers) generated over a 10-year planning horizon of the firm.

CATSIM calculates a modified IRR.[4] All values are measured in 1991 dollars. The returns are before income taxes, an appropriate assumption, because most catfish farmers operate with Subchapter S statutes.

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 and constructed facilities. All depreciation schedules are straight line.

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 trom suppliers and industry members. Details are presented in Lambregts, et al. (1992).

Systems in this study are engineered to be approximately 160 acres and contain 8 catfish ponds of 14.5 surface acres each, and one 17-acre 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 and carp (table 1) are based on commercial production records and work with producers, extension, and university personnel. Because the catfish is a cold blooded animal, its metabolism and growth rate slow down with colder temperatures and feeding rates and frequency of feedings are adjusted accordingly. According to producers and extension specialists, off-flavor is negligible in well-managed ponds. However, in this analysis, the probability of off-flavor is set at 10 percent, which is low compared to other production areas (Sindelar, Kinnucan and Hatch). Off-flavor is determined randomly (based on the 10 percent probability) the week before a pond is ready to be harvested. If a pond is found to be off-flavor, it has a 60 percent chance of being off-flavor the next week also. The survival rate for catfish is assumed to be 90 percent annually and includes mortality and bird predation. The feed conversion ratio (feed fed/weight gain) is assumed to be 2 to 1. Ponds are treated twice a year with a two ppm potassium permanganate ($KMnO_4$) solution. No other chemical treatments are used.

The size of the harvested fish is an essential part of a cost analysis. Processors consider marketable size for catfish to be from 20 to 45 ounces. After discussions with producers and processors, several assumptions were made on the population dynamics. 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. Annual production levels for catfish are set at 10,000 pounds/acre, and the minimum harvest size is 1.2 pounds. After harvesting fish which are 1.2 pounds or greater, fingerlings are added to the pond to bring the population in the pond to 9,000 fish per acre. The amount of fingerlings stocked is equal to the number of fish harvested plus mortality and bird predation. Fingerlings are delivered to the pond by the seller, and the hauling charge is included in the fingerling price of $0.015/inch.

Table 1. Biological Parameters for Catfish and Carp on the Upper Texas Coast, 1991

Parameter	Unit	Value	
		Catfish	Carp[a]
Growth	grams/week	0-24	0-30
Feed Conversion	kg feed/kg body mass	2.0	n.a.
Feeding Rate	percent biomass/day	0-2.8	0
Mortality	percent of population/year	10	10
Max. Pond Popu/acre	thousand/acre	9	4
Stocking Size			
Length	inches	7	6
Weight	ounces	1.8	1.4
Harvest Size			
Minimum	pounds	>1.1	>1.43
Average	pounds	1.3	1.6
Parasite Occurrence	times/year/pond	2	2
Annual Production	pounds/acre	10,000	5,000
Off-flavor Probability			
First week before scheduled harvest	percent	10	none
Given off-flavor occurred previous week	percent	60	none

[a]Carp in treatment ponds on catfish farms.

Based on these assumptions, CATSIM calculates the sizes of the fish harvested. The average size of fish in ponds about to be harvested is approximately 1.05 pounds. The average size of catfish harvested is 1.28 pounds, whereas the average size of the fish in the pond after harvest and restocking is 0.54 pounds.

Production levels for carp in the treatment pond are set at 5,000 pound/acre. The treatment pond fish are not fed. The target population is 4,000/acre, and fish over 1.5 pounds are harvested. The average size of fish in a pond about to be harvested is approximately 1.41 pounds. The average size of the fish harvested is 1.60 pounds, while the average size of the fish in the pond after harvest and restocking is 0.85 pounds.

Operations

Parameters used for the operations on the three farms are set to reflect the production activities required (table 2). Due to the seasonal nature of catfish, activities are highest during the summer months and decrease in frequency in the cool winter months. This analysis is based on the assumption that noncritical items, such as pond and machinery maintenance, take place during the slow periods to even out the demands on labor and equipment.

Harvesting and hauling charges are obtained from CATSIM calculations. It was assumed that each pond is harvested when the minimum harvest quantity (one truckload, approximately 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. Harvests are performed by custom operators, and hauling is performed by the processor. Charges for these services are $0.02/pound for the harvest crew and $0.02/pound for the hauler.

All farms start operations with $100,000 cash on hand (considered as part of the investment). 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 percent annual interest rate), but any outstanding operating loans are converted to 5-year level amortization intermediate term loans (12 percent annual interest rate) at the end of the year. The owners/investors receive all cash on hand

Table 2. Operational Parameters for Catfish Farms With Recirculating Ponds on the Upper Texas Coast, 1991

Parameter	Unit	Value
Feeding Frequency	lbs./week	1-14
Harvest Costs	$/pound	0.02
Hauling Costs	$/pound	0.02
Min. Harvest Quantity (1000's)	pounds	40
Internal Water Exchange	percent/day	0-20
Water addition (annual)	feet/acre	1
Pumping Time	hours/day	0-24
Aeration Time	hours/day	0-8
Aeration	h.p./pond	10
Rebuilding		
Period Between Reconstruction	years	7
Downtime for Reconstruction	weeks	16
Maintenance (Annual)		
Machinery	percent new value	3-8
Ponds	percent of construction cost	1
Insurance		
Liability	percent of investment	1
Crop	$/pound harvested	0.0072

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.

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 levels (figure 1). Clearly, future prices for catfish are highly uncertain. This analysis assumes a constant catfish price of $0.70/pound throughout the 10-year planning horizon. This is a limitation, particularly when considering risk exposure.

The price for carp is assumed to be $0.50/pound. The market for carp is thin, and the amount of fish that can be sold at this price is presently limited. If a market cannot be developed for carp at sufficient volume with an acceptable price, other species[5] are available for use in the treatment pond.

Investment

A detailed investment listing for each farm appears in Lambregts et al. (1992). Total investment is $764, $1,433, and $2,695 thousand for the small, medium and large farms, respectively (table 3). The required investment per catfish surface acre decreases as farms become larger (table 4). 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 due to economies of scale. Economies of scale have been found to be larger in other aquaculture operations (Keenum and Waldrop, Lambregts et al., 1992), because recirculating systems have unique construction features and pump stations which incur capital costs that vary less disproportionately with scale than do traditional systems.

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

Figure 1

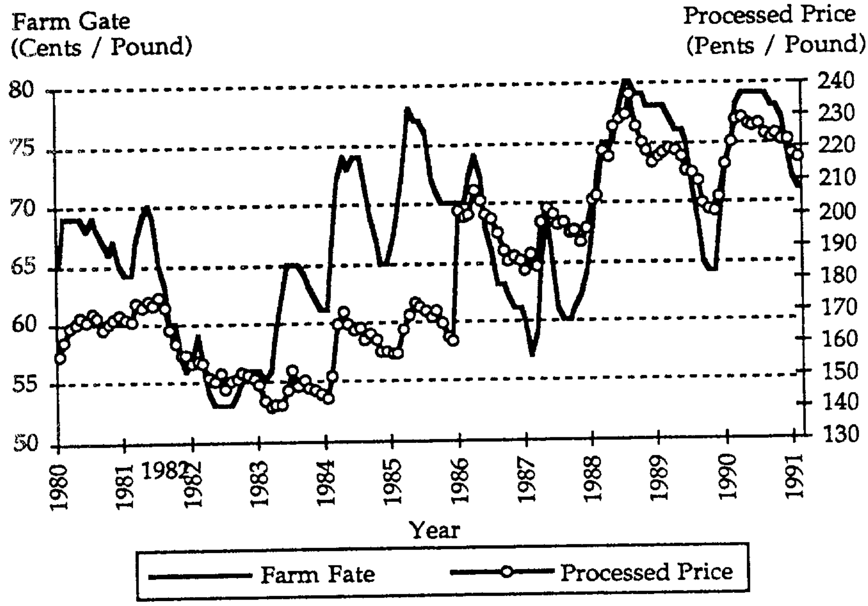


Table 3. Total Investments in Small, Medium and Large Catfish Farms[a] on the Upper Texas Coast, 1991

Category	Farm Size Small	Medium	Large
	---------------------$1,000---------------------		
Land and Water	193	382	761
Pond Construction	347	671	1,317
Pond Pumps	33	67	100
Buildings	32	43	58
Start-up Costs	41	71	113
Vehicles and Equipment	102	171	309
Tools, Furniture and Miscellaneous	16	27	36
TOTAL	764	1,433	2,695

[a]Sizes are 163 (133 in ponds), 323 (266 in ponds) and 643 (266 in ponds) acres, respectively.

Table 4. Total Investment per Acre and per Annual Unit Production Capacity in Small, Medium and Large Catfish Farms[a] on the Upper Texas Coast, 1991

Category	Farm Size		
	Small	Medium	Large
$/acre for catfish ponds	6,582	6,177	5,807
$/acre for all fish ponds	5,741	5,388	5,065
$/pound of catfish produced	0.66	0.62	0.58
$/pound for all fish produced	0.61	0.58	0.54

[a]Sizes are 163 (133 in ponds), 323 (266 in ponds) and 643 (266 in ponds) acres, respectively.

found in the buildings, start-up, and vehicles and equipment categories.

The investment required for these farms is between 56 percent and 70 percent higher than the identical size farms with static ponds analyzed by Keenum and Waldrop in Mississippi ($488, $840 and $1,588 thousand, respectively). However, farms with recirculating ponds in this analysis produce nearly twice as many pounds of catfish than farms in Mississippi (i.e., 1.16 v.s. 0.63 million pounds for the small farm). Investment per unit of production capacity for recirculating farms located in the study area is between $0.66 and $0.58/pound (table 4). This is 7 percent to 16 percent lower than 1988 estimates for static ponds in Mississippi, which were $0.77, $0.66 and $0.62/pound 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 percent to 20 percent lower than competitive southeastern operations.

Results

Based on the operational assumptions and investments, economic implications for the aquaculture system were estimated. This includes costs, revenues, cash flow, and sensitivity analysis.

Average costs and returns

Relative costs over ten years of operation for three farm sizes are compared in table 5. 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 cost categories account for more than 50 percent of average total costs. The most important costs are feed, fingerlings, and labor. The cost/pound of catfish produced ranges from $0.602 on the small farm to $0.574 on the large farm. The average total cost per pound of all fish (catfish and non-catfish) produced varies from $0.565 for the small farm to $0.541 for the large farm, a reduction of 7 percent (table 6). Most scale economies lie in depreciation, fixed costs, and labor, although some savings exist in other categories.

These costs compare favorably to the per pound costs of $0.677, $0.630 and $0.599 for the small, medium, and large farms, respectively, in Mississippi (Keenum and Waldrop). If the secondary species are 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 percent to 20 percent lower for recirculating systems located along the upper Texas coast.

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 $0.70/pound for all three farms (table 6). Average revenue for all fish on the farms is estimated to be $0.689. Although costs decrease with farm size by 7 percent, the margin between

Table 5. Relative Cost by Category for a 10 Year Period for Small, Medium and Large Catfish Farms[a] on the Upper Texas Coast, 1991

Category	percent of 10 year Total Cost		
	Small	Medium	Large
Stocking	16.1	16.7	17.2
Feed	40.9	42.3	43.8
Fuel	5.2	4.4	3.2
Harvest Costs	7.0	7.2	7.5
Labor	11.6	11.2	10.2
Repairs	2.2	2.1	2.0
Fixed Costs	4.7	4.5	3.7
Interest pmt.	2.4	2.6	2.7
Depreciation	8.0	7.3	8.2
Miscellaneous	1.9	1.6	1.5

[a]Sizes are 163 (133 in ponds), 323 (266 in ponds) and 643 (266 in ponds) acres, respectively.

Table 6. Total Costs and Total Revenue per pound by Category for a 10 Year Period for Small, Medium and Large Catfish Farms[a] on the Upper Texas Coast, 1991

Category	Catfish			All Fish		
	Small	Medium	Large	Small	Medium	Large
	$/pound					
Total	0.602	0.582	0.574	0.565	0.547	0.541
Revenue	0.700	0.700	0.700	0.689	0.689	0.689

[a]Sizes are 163 (133 in ponds), 323 (266 in ponds) and 643 (266 in ponds) acres, respectively.

average revenue (all fish) and average costs (all fish) increases with farm size from 22 percent to 27 percent, an increase of 25 percent.

Cash Flows

A second method to evaluate investments is cash flow analysis. 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.

Consolidated cash flows for the three farms appear in table 7 [detailed cash flows are presented in Lambregts et al. (1992)]. 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 "debt service" category includes both the original operating loan and intermediate term loans.

Catfish farms generally reach full production two 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 in the second year of operation, in this analysis year three is the first year of full production. The smallest

Table 7. Net Investor Cash flows and Internal Rates of Return (IRR) for Small, Medium and Large Catfish Farms on the Upper Texas Coast, 1991, for a 10-year Planning Horizon

Date	Farm Size[a] Small	Medium	Large
	----------------------------$1,000----------------------------		
Jan. yr. 0	-764	-1,433	-2,695
Jan. yr. 1	-100	-100	-100
Dec. yr. 1	0	0	0
Dec. yr. 2	0	0	31
Dec. yr. 3	87	274	798
Dec. yr. 4	234	416	951
Dec. yr. 5	139	343	929
Dec. yr. 6	164	291	776
Dec. yr. 7	101	500	923
Dec. yr. 8	0	0	0
Dec. yr. 9	154	395	884
Dec. yr.10	197	456	1,040
IRR	0.150	0.183	0.219

[a]Sizes are 163 (133 in ponds), 323 (266 in ponds) and 643 (266 in ponds) acres, respectively.

farm does not have a positive cash flow until year three. The medium sized farm has a positive cash flow by the end of year two, and the largest farm has enough funds to issue a small dividend by December of year two. Scheduled rebuilding and restocking the ponds occurred in year eight.

In the first year, the principal cost on the farms is stocking, but 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. All farms are able to issue dividends in the third year of operation.

The IRRs are provided in table 7 along 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 (investments 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 0. 150, 0.183, and 0.219, for the small, medium and large farms, respectively. These represent rates of return to the investor and do not include risk and inflation.

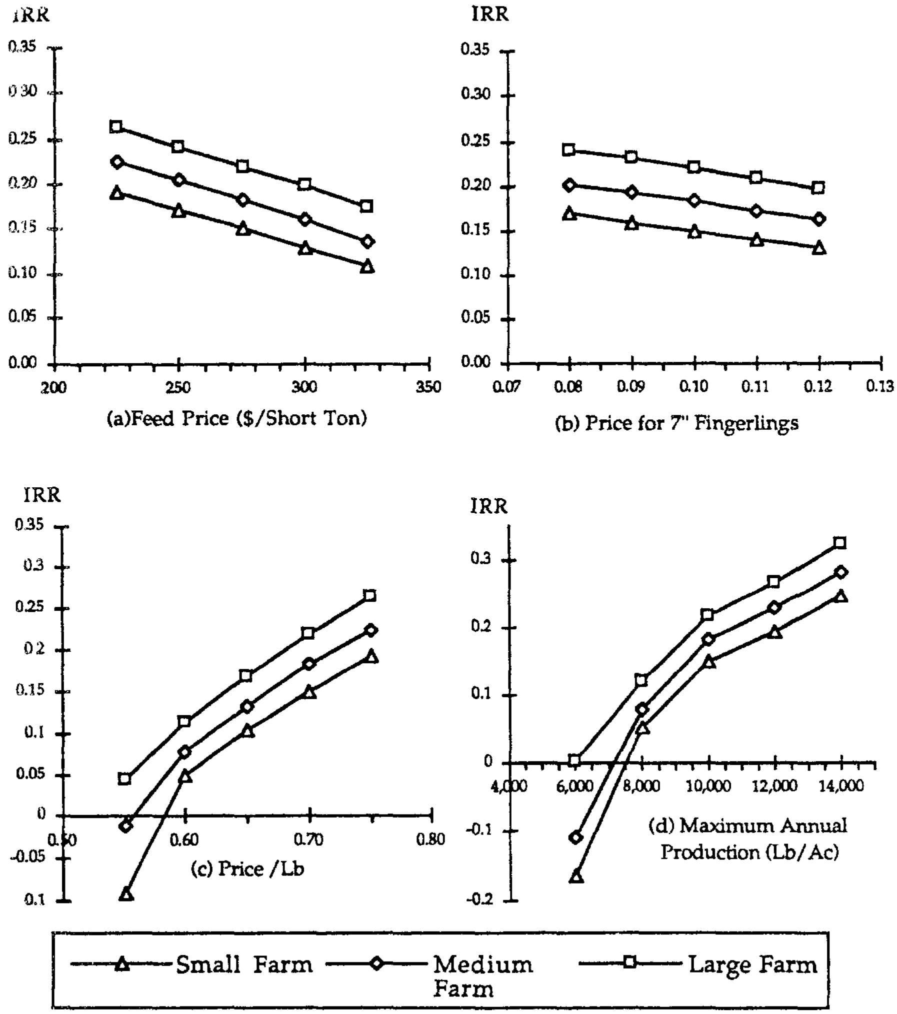
Sensitivity Analysis

Results of evaluating the sensitivity of the three farms to fluctuating prices and yields are shown in figure 2. The unit price of feed, the largest production cost, is varied from $225 to $325/short ton. The farms have returns greater than 10 percent for all feed price levels analyzed. Nevertheless, a feed price increase to $325 (18 percent) results in a decrease in the IRR between 21 percent 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 percent), the IRR of the farms increases between 9 percent and 13 percent. As the price of fingerlings increases from $0.08 to $0.12, the IRR's decrease from 15 percent, 18 percent, and 22 percent to 13 percent, 16 percent, 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 $0.70 to $0.55/pound results in a negative return for the small and medium size

Figure 2



farms. The largest farm still generates a 4 percent IRR at this price. An increase of 5 cents/pound to $0.75 increases the IRR between 25 percent and 28 percent for the farms. Price fluctuations affect the returns of small farms more than larger farms, indicating they are subject to more risk from price changes.

The annual production yield per acre, adjusted by varying growth rate (CATSIM automatically adjusts feed consumption), strongly influences the returns. A drop in maximum production by 20 percent decreases the IRR between 45 percent and 64 percent. On the up side, increasing production by 40 percent increases the IRR between 48 percent and 64 percent. Clearly, the production yield will be one of the most important determinants of a farm's success. It also suggests that farm managers need to evaluate the trade-offs between mechanical aeration (paddle wheel aeration and water flow-through) and production yield.

The relationship between a catfish farm's IRR and the price of feed, fingerlings, and production is remarkably linear. Only in the lower regions, where the IRR becomes negative, is the relationship curvilinear. Rates of return for the farms at other prices may be easily obtained from figure 2 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.

Conclusions

Results of the study indicate that the IRR's of catfish farms along the upper Texas coast would vary from 15 percent to 22 percent. The total investment required for the small, medium and large farms is $764, $1,433, and $2,695 thousand, respectively, resulting in economies of scale. Pond construction accounts for 45 percent to 49 percent of investment. The investments necessary for farms using recirculating ponds are nearly double those of equal sized farms with static ponds in Mississippi; however, the investment per unit production capacity is lower.

In the Texas upper coast region, average total costs for catfish farms are generally lower than those for farms with static ponds in Mississippi. This suggests the recirculating ponds technology is effective in reducing costs and solving the off-flavor problem that has plagued catfish production. Adoption of the technology addressed in this study is an opportunity to reduce cost of production and deliver a consistent high-quality product. This may have long term positive effects on the market and industry.

This analysis suggests that returns to catfish 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 $0.60/pound. The medium and large farms achieve a positive rate of return for catfish prices as low as $0.55/pound. However, there is a substantial start-up period which 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.

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USDAb. National Agricultural Statistical Service. Catfish Production. Washington, D.C., February 1990, 1991, 1992.

Endnotes

1. In three years of production, only one pond has had off-flavor that is attributed to the recirculating system being off. When the recirculating system was turned on the pond cleared up within ten days. Ponds that do not have the recirculating system installed have as high as 40 percent off-flavor which is equivalent to Mississippi. (Personal communication, Steve Rawls, Extension Associate in Aquacultural Production, Agricultural Research Station, Angleton, Texas)

2. While these studies can be compared as competing in the same regional market, this study does not imply that Mississippi would have the same cost of production. One difference is that Texas' growing season is two months longer than Mississippi's.

3. Filter feeding fish include silver carp (Hypophthalmichthys molitrix), and bighead carp (H. nobilis).

4. The modified IRR used the discount rate to inflate the initial investment (year 0 in table 7) to the first year production begins (year 1 in table 7). This gives year one as the base year in 1991 dollars. The discount rate for the investment is assumed to be 15 percent since it includes a risk free rate representing the time value of money, a risk premium reflecting the uncertainty of future cash flows, and an inflation premium equal to the expected rate of inflation. See Brealey and Meyers for a detailed description of this modified method.

5. Other species include mullet, tilapia, and paddlefish. Mullet requires 3 to 4 ppt of salt water, tilapia cannot tolerate winter weather and paddlefish are just now being experimented with in the market place.