PRODUCTION, PRICE AND RISK FACTORS IN CHANNEL CATFISH FARMING

Gregory D. Hanson, Neil R. Martin, Jr. and John B. Flynn

Abstract

The effects of several production/management, price and risk factors upon channel catfish profitability are analyzed with a multiperiod mixed-integer linear programming model. Factors analyzed include pond size and optimal stocking rates, alternate levels and trends in catfish prices, pond production losses and level of family consumption withdrawals. Model results indicate that channel catfish offer the potential to significantly increase farm rates of return while providing an avenue of intensive farm growth, without expanding the land base of the farm. However, the long range financial success of the firm was very sensitive to several of the management and risk factors examined.

Key words: channel catfish, risk, linear programming, growth model, aquaculture.

Pond production of channel catfish is a relatively new farm enterprise in the United States, with current production concentrated in Mississippi, Alabama and Arkansas, supplying 94% of foodsize catfish sales in 1981 (USDA 1982). Catfish production has also been one of the fastest growing enterprises in these states during recent years. Between 1963 and 1981, total pond acreage increased from about 2,000 to more than 70,000 (USDA, 1982). This study analyzed several catfish production growth process issues at the firm level.

Objectives of this study were to explore the effects upon growth in farm net worth of: (a) production factors including pond size and stocking rates, (b) alternative price levels and (c) risk and consumption factors including alternative rates of declining real catfish prices, loss of a pond's production and alternative levels of family consumption. Operationally, the primary objective was to develop with multiperiod mathematical programming a growth model of a diversified family-sized farm with which to explore the above objectives.

ASPECTS OF CHANNEL CATFISH FARMING

The decision to produce catfish presents several unique problems; for example, raising catfish usually requires construction of ponds to impound water. Pond construction requires capital investment that frequently exceeds the value of the land on which ponds are built (Waldrop and Smith). Because of the expense involved in removing dams, levees and draining structures once they have been established and because the former fertility levels of the topsoil have been seriously depleted in the earth-moving process, pond construction can be viewed to permanently alter previous land use patterns. This aspect of catfish production irreversibly commits the farm firm to a long-term investment project with very restricted capital mobility.

Pond construction offers distinct economies of size in earth moving and operating economies in the production process (Crews et al.; Waldrop and Smith; Adrian). Also, with the exception of a few very large firms that raise fingerlings, grow-out and market the fish, catfish production usually represents a diversification of existing farm firms. The economic implications of alternative transition strategies to include the catfish enterprise in the organization of an existing farm (along with row crop and livestock enterprises) is not well understood. For example,

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farm land on which ponds are constructed is taken out of production for up to one and one-half years before a cash return from sale of fish is realized. The income foregone from this land during the initial fish production period, combined with the relatively large capital outlay for pond construction can be substantial obstacles to entry into commercial catfish production.

Technology for catfish farming has developed rapidly (Lovell), and nutritionally "complete" catfish rations are now available from commercial sources. Techniques for managing water quality have been developed as well as methods and drugs for disease treatment. These technological advances have made possible the use of higher stocking and feeding rates. Production intensification based on very high stocking rates leads to greater returns to the pond resource (Crews et al.); however, it is also associated with increased risk of losing the fish crop, primarily because of the increased frequency of drastically depressed dissolved oxygen levels (Boyd et al.) and stress induced disease problems.

Unique production constraints, the highly fixed character of pond investment, increased biological risks of large operations and rapidly advancing technologies have resulted in serious gaps in producer knowledge of management practices which can be expected to maximize profits. Catfish enterprise budgets provide useful information but do not adequately address cashflow and capital budgeting costs, as well as the effects of competition for resources between the catfish enterprise and other existing or potential farm activities. In this respect, additional knowledge is needed regarding the sequence of activities or conditions necessary for catfish production to become a profitable part of the farm organization.

METHOD OF STUDY

A multiperiod linear programming (MLP) model was developed to evaluate catfish production as an intensive farm growth (internal expansion rather than acquiring control of additional land) alternative. The measure of growth was change in farm net worth, a growth criterion frequently used in farm firm modeling, and one based on a well-established tradition in the economics literature.[1] Machinery and equipment depreciation and family living expenses effects are included in the net worth criterion, while land values were maintained constant in real terms. The MLP model was applied to a 10-year planning period for a representative farm situation in the Western Black Belt of Alabama, the area of concentrated catfish production in the state. Enterprises included on the representative farm are a beef brood cow herd, cotton, soybeans and catfish. The representative farm was endowed with 440 acres of land of which 124 acres were suitable for row crops (the enterprise combination and asset base correspond to typical farm situations in the Western Black Belt region, U.S. Department of Commerce). As indicated above, leasing or renting of land was not permitted in the model.

The representative farm possessed machinery and equipment compatible with the enterprise mix in the study area. The major pieces of machinery were tractor, chisel, disc, planter, cultivator, mower and ripper/bedder. Asset depreciation was based on a 10-year straight-line schedule with no salvage value.[2] Initial farm assets thus consisted of 440 acres of land of which 124 were tillable (value $163,492), a complement of row-crop equipment (value $43,146) and a 250 cow/calf herd (value $129,417). Total beginning farm assets were $336,055. The farm operator was assumed to provide 2,500 hours per year which could be used as direct labor or for supervision of hired labor. Each hour of hired labor was assumed to require 0.1 hour of supervisory labor. The operator was allocated 12,000 dollars annually for family living expenses. This allocation is in constant dollars, so that consumption expenditures are not reduced by inflation. It is recognized that this is a minimal consumption

[1] This measure has become known as the Haig-Simons "accretion" approach defined to be the algebraic sum of the market value of consumption with-drawals plus the change in firm value between the beginning and end of the time period studied (Simons). There are numerous alternatives to this growth measure such as changes in gross sales, acres farmed, assets controlled, etc. However, the Haig-Simons definition applies to the observed firm-household behavior of many farmers to reinvest available cash surpluses in the farming operation after meeting family living expenses.

[2] This study was begun in 1980 and completed in 1981, when the Economic Recovery Tax Act (ERTA) was passed. Thus the 10 year straight line depreciation assumed does not correspond closely to accelerated cost recovery (although it is much more similar to optional cost recovery that the ERTA method also permits). The effect of this study's depreciation assumptions is thought to be minimal for three reasons. First, new depreciable investment in aquacultural equipment is relatively small (compared to pond investment) consisting primarily of a feed wagon, aerator, small feed storage facility and a share of a 40 hp. tractor. Second, the study permitted rather broad tax management flexibility through a very liberal catfish stock carryover provision. Third, the conservation tax deduction permitting pond construction costs to be deducted from gross income (the deduction may not exceed 25% of gross farm income, deduction carry-over permitted) was also included in the model. It may be noted that in many instances it is unclear whether catfish pond construction fulfills the conservation criteria of this last deduction. Finally, the investment credit and income averaging alternatives were not modeled. Comprehensive modeling of not only federal tax provisions, but also state income and self-employment tax provisions is a needed future research task.

level, one that may be appropriate only during periods of firm expansion when cashflow constraints often require restriction of family expense outlays (this assumption is relaxed in the final section of this paper).

Specification of the MLP model was organized around the standard definition of a linear programming problem:

$$\text{Maximize } f = TX$$
$$\text{subject to } AX = B$$
$$X > 0$$

where f is the objective function, T is a 1 x n matrix of coefficients of the objective function, X is a n x 1 matrix of variables or activities, A is a m x n matrix of constraint coefficients and B is a m x 1 matrix of constraint levels. The objective function used in this analysis is maximization of whole farm net worth at the end of the planning period. Firm net worth is the sum of all farm assets less farm liabilities. A principal component of 'change in net worth' is comprised of commodity sales less cash production expenses. The undepreciated value of machinery and equipment, stored production, cash accounts and interest income on excess cash (10% rate of interest assumed) add to ending net worth while unpaid loan balances and family expense withdrawals decrease net worth. Also, net worth increases by less than the cost of pond construction because soil productivity has been depleted and alternative pond uses are not feasible. Additional information on model product prices, costs and investment levels is provided in the Appendix.

Row-crop activities and constraints in the MLP model provided for the production of soybeans and cotton in each growing season of the 10-year planning period. The representative farm was assumed to be an operating business with an initial endowment of machinery and equipment that could be liquidated at market value or used in a given production period and transferred to the next year. A minimum production level of 30 brood cows was imposed on the model to represent observed personal preferences of many Black Belt farmers and long-term use of marginal land resources. No assets included in the initial period of the model were specifically designed for catfish production. The major feeding, harvesting, construction and management advantages associated with ponds of uniform length, depth, and shape suggested that only row-crop land be utilized for pond

TABLE 1. SUBMATRIX OF SELECTED CATFISH ACTIVITIES IN MULTIPERIOD LINEAR PROGRAMMING MODEL

	BPOND2	BPONDM2	BPONDS2	GCFH3	GCFHM3	GCFHS3	BCFEQ3	BCFEQM3	BCFEQS3	SCFH3	XCFH34	LIMITS
PNUCAP3	−1			1								< 0
.	.											.
PNDCAP10	−1											< 0
PNDCAPM3		−1			1							< 0
.		.										.
PNDCAP10		−1										< 0
PNDCAPS3			−1			1						< 0
.			.									.
PNDCAPS10			−1									< 0
RCLAND2	22	11.5	6									< 124
.	.	.	.									.
RCLAND10	22	11.5	6									< 124
HLBR3				600	310	255						< 2500
CMCY3				1			−1					< 0
.							.					.
CMCY10							−1					< 0
CMCYM3					1			−1				< 0
.								.				.
CMCYM10								−1				< 0
CMCYS3						1			−1			< 0
.									.			< 0
.									.			< 0
.									.			< 0
CMCYS10									−1			< 0
OCA3				20240	10800	5365						< 0
OCB3				20240	10800	5365						< 0
SCF3				−90000	−45000	−22500					1	< 0
SCF4										1	−1	< 0
SCFL34				−90000	−45000	−22500					1	< 0

construction.[3] The indivisible nature of fish-pond construction and use, the irreversibility of changes in land resources and pronounced economies of size were conditions included in the constraints and activities of the MLP model.

Specification of pond construction activities in the MLP model is shown in Table 1. For brevity, only production periods 2 and 3 are shown. Pond construction activities of 20 acres (BPOND2), 10-acres (BPONDM2) and 5 acres (BPONDS2) are included in the model as integer activities. Catfish production activities (GCFH3, GCHM3 and GCFHS3) are linked in the model to the pond construction activities according to unit size by pond capacity rows (PNDCAP3, PNDCAPM3, PNDCAPS3). Pond capacity for catfish production is created only in years succeeding the year pond construction occurred. Land requirements for pond construction are larger than the surface area of the ponds by 10 to 20 percent depending on size of pond. Thus, the 20 acre pond construction activity in year 2 (BPOND2) requires "withdrawal" of 22 acres of row-cropland in periods 2 through 10 (RCLAND2, RCLAND3 ... RCLAND10).

Grow catfish activities (GCFH3, GCFHM3 and GCFHS3) require labor (HLBR3), pond capacity (PNDCAP3, PNDCAPM3 and PNDCAPS3), catfish equipment (CMCY3, CMCYM3 and CMCYS3) and operating capital (OCA3 and OCB3). Catfish equipment must be purchased (BCFEQ3, BCFEQM3 and BCFEQS3) to fit the pond size constructed. Catfish production (SCF3) may be sold in the year produced (SCFH3) or over-wintered and transferred to the next year (XCFH34). Transfer of catfish production (SCF3) was restricted to one year after production by a row constraint (SCFL34). Capital expenditures and income tax activities with the exception of the conservation tax deduction associated with pond construction were adapted from matrix structures presented by Reid et al. Tax treatment of conservation expense as well as other model features are discussed in Flynn.

PRODUCTION AND PRICE LEVEL EFFECTS ON PROFITABILITY

Small vs. Large Ponds. From a cost perspective, large ponds are more efficient than small ponds. However, sites suitable for building large ponds may be limited on many farms, restricting pond building alternatives. This situation was explored by restricting the model to only 10-acre pond building activities in one case, and 5-acre pond activities in another. Other assumptions were: total debt was restricted to 30% of the current market value of total assets (including market value of land), no initial farm debt existed and the high catfish stocking rate of 4,500 fish per acre was maintained.

The assumption of no initial debt was intended to permit model results to be applicable to well established small farmers with limited cropland resources. For this farm situation, with resource levels based on census data for the region studied, channel catfish presents an opportunity to intensify production with debt financing. Limiting debt to 30% of the market value of assets allows model results to be reasonable for farmers with low to moderate debt. A producer with 15% original debt (to assets) could add an additional 25-35% debt and still be acceptable to many agricultural lenders (provided cashflow is acceptable). The major difference is that model results would consist of a reduced end-period net worth and lower rate of growth in net worth because of higher interest payments.[4]

When pond construction was restricted to 5-acre sites, no pond building occurred. Higher pond construction costs along with higher operating costs made 5-acre ponds an unattrac-

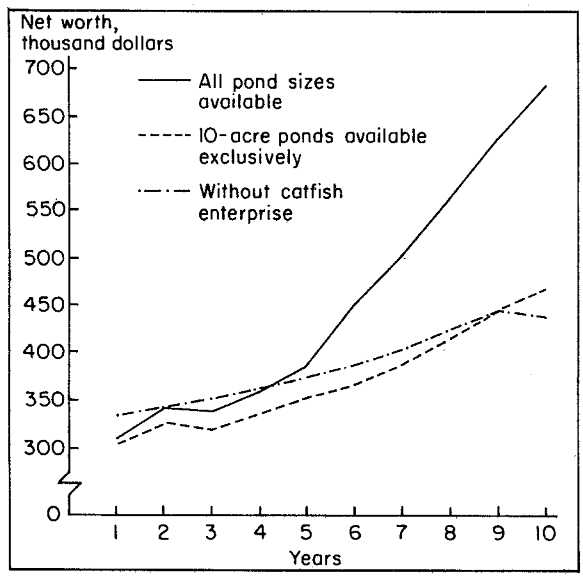

Figure 1. Growth in farm net worth with and without the catfish enterprise.[a]

[a] No initial debt, 30% debt limit and high catfish stocking rate.

[3] The suitability of non row-cropland for pond construction and management depends upon drainage, slope, soil type and accessibility characteristics. Additional research is needed to determine the prevalence and relative profitability of investment in this type of ponds.

[4] As an example, presence of an initial debt of $40,000, decreased the annual growth rate in net worth by 2% and the total growth in net worth by $142,474 during the 10 year study period. In a firm growth study with a limited time horizon, the presence of initial debt not only increases interest expense, capital investment is delayed and this can have a noticeable effect upon accumulation of net worth.

tive avenue for intensive farm growth (Table 2, Case 1). In this case, the catfish enterprise was not included in the farm operation, and total net worth increased $101,410 during the study period (contributed by beef, cotton and soybean production). With only 10-acre pond sites available, optimal organization of the farm limited pond construction to four units (40 acres), of which three were constructed in the first year and the remaining pond was built in the third year. Also, the catfish enterprise contributed $29,924 to net worth growth (Table 2, Case 2). The ability to construct 20-acre units resulted in 100 acres (five 20-acre units) of ponds, providing a marked contrast with the much lower levels of pond building when only 5- and 10-acre units were permitted. The catfish contribution to net worth was much higher, $246,386 (Table 2, Case 3). The financial significance of the size restrictions was that ending net worth was substantially less where only 5- or 10-acre sites were available. The yearly pattern in growth of net worth with alternative pond size restrictions is shown in Figure 1. The large difference in net worth levels at the end of year 10 points out the importance of the application of capital budgeting techniques, or the capital investment structure to the success of a decision to add a catfish enterprise.

Alternative Stocking Rate Levels. The high fixed costs of pond construction suggest at the outset that profits will decline if fewer fish are marketed from each acre of water (although feed and other variable costs also decline with the per acre marketing rate). In this respect, a low catfish management intensity can be equated to a stocking rate of 2,500 fish per acre. This rate may be preferred by less experienced fish farmers or those with more limited management capabilities, particularly in view of heightened disease and oxygen inversion problems related to intensive stocking rates. (The costs of preventing oxygen inversion are included in the model since use of aerators is required only for the high stocking rate.) While the fixed-cost relationship clearly ensures lower returns for the 2,500 fish/acre rate, quantification of the stocking rate effect provides useful information to producers considering a low stocking rate with a reduced management option.

With the low stocking rate, the process of building ponds and growing catfish continued to be an optimal part of the farm organization, Table 3. Net worth increased to $474,005 by year 10 from $324,481 at the end of year 1.

TABLE 2. SUMMARY OF POND CONSTRUCTION, CHANGES IN NET WORTH AND ANNUAL RATE OF CHANGE IN NET WORTH FOR THE CHANNEL CATFISH ENTERPRISE[a]

Case	Item	Size ponds built	Increased net worth due to catfish production	Annual "catfish" rate of change in net worth[b]	Whole farm change in net worth
		Acres	($)	(%)	($)
	Pond sizes available:				
1	5 acres	0	0	0.0	101,410
2	10 acres or less	40	29,924	0.9	131,334
3	20 acres or less	100	246,386	5.7	347,796
	Catfish stocking rate:				
4	2,500 fish/acre	80	36,540	1.0	137,950
5	4,500 fish/acre	100	246,386	5.7	347,796
	Alternative price levels:				
6	Very low 0.55	0	0	0.0	101,410
7	low 0.60	80	67,527	1.8	168,937
8	Base 0.65	100	246,386	5.7	347,796
9	High 0.70	110	396,702	8.1	498,112
10	Very high 0.75	110	545,178	10.1	646,588
	Risk factors analyzed:				
	Real price annual decline				
11	Moderate rate 0.01	80	92,049	2.5	193,459
12	High rate 0.02	40	15,465	0.5	116,875
	Loss of pond in year 3:				
13	Total loss	60	------------------Solution Infeasible------------------		
14	Partial loss (64%)	100	239,605	5.5	341,015
	Alternative annual family living expense levels:				
15	Minimum 12,000	100	246,385	5.7	347,797
16	Moderate 18,000	100	120,421	3.1	221,831
17	High 24,000	60	−40,187	−1.1	61,223
18	Very high 30,000	20	−202,561	−4.8	−101,151
19	Very high 31,000	0	------------------Solution Infeasible------------------		

[a] Unless otherwise indicated, above results are based on optimal conditions which include high stocking rate, conservation tax deduction taken, all pond sizes available, $.65 catfish price, zero initial debt and debt not permitted to exceed 30% of total farm assets.

[b] The first 3 results columns must be interpreted as "marginal" or incremental growth compared to growth associated with the beginning farm organization (over the 10 year modeling period). Annual farm growth in net worth without catfish was 2.6% and the increase in net worth was $101,410 (far right column). Thus, in case 3, total growth was $347,796; however $101,410 would have occurred without the addition of the catfish enterprise.

TABLE 3. FINANCIAL AND PRODUCTION EFFECTS OF ALTERNATIVE STOCKING RATES, MAXIMUM DEBT LIMITED TO 30% OF ASSETS, ZERO INITIAL DEBT

Item Period:	1	2	3	4	5	6	7	8	9	10
				A. Low catfish stocking rate						
1 Net worth ($)[a]	324,481	337,108	348,795	364,959	302,265	363,917	385,266	412,547	443,524	474,005
2 Adjusted gross income ($)	5,400	26,004	22,200	13,334	5,400	14,062	24,123	13,900	5,400	18,000
3 Income tax ($)	0	4,338	3,273	1,336	0	2,189	5,537	1,404	0	6,201
4 Pond tax deduction Current year ($)	18,434	1,566	0	0	33,857	26,143	0	0	0	0
5 20-acre ponds	1	0	0	0	3	0	0	0	0	0
6 Catfish sold (lb.)	0	50,000	45,000	23,093	81,367	200,000	182,381	161,230	144,632	117,755
7 Catfish carry forward (lb.)[b]	0	0	4,460	31,367	0	0	17,619	56,388	111,755	200,000
				B. High catfish stocking rate (base case)						
8 Net worth ($)[a]	310,438	342,740	340,400	361,306	387,610	449,727	501,672	560,423	623,069	683,851
9 Adjusted gross income ($)	5,400	22,200	17,822	24,210	32,282	22,200	31,900	13,900	5,400	5,400
10 Income tax ($)	0	3,273	2,228	3,836	6,242	3,273	6,201	1,404	0	0
11 Pond tax deduction Current year ($)	25,997	14,002	20,000	20,000	20,000	0	0	0	0	0
12 20-acre ponds	2	0	1	1	1	0	0	0	0	0
13 Catfish sold (lb)	0	170,650	189,349	270,000	360,000	395,430	379,493	362,080	345,174	317,821
14 Catfish carry forward (lb)[b]	0	9,349	0	0	0	54,569	125,076	212,995	317,821	450,000

[a] Net worth measured at year end. Net worth at the beginning of period 1 was $336,055.

[b] The model permitted up to one year's production to be carried forward. This markedly decreased tax liabilities since production expenses could be claimed when incurred, usually one tax year prior to the sales revenue associated with this expense. Cashflow, marketing and production constraints may not permit sales to be delayed in a typical farm situation.

While fish sales generally follow a strong upward trend, the concentrated pond building activity in year 5 and large conservation tax deductions in years 5 and 6, result in maximum sales in year 6. After year 6, increasing quantities of fish are carried forward in successive years (Table 3, line 7). The large fluctuations in adjusted gross income (calculated for the Federal Income Tax Form 1040) are due to the complex interplay of income taxes, conservation tax deductions and the ability to over-winter the catfish. Although additional land was available for pond sites, returns from the catfish enterprise were insufficient to warrant building more than 4 ponds. Finally, the rate of increase in net worth with the 2,500 stocking rate was only 1.0% higher than the farm would have generated without addition of the catfish enterprise, and terminal net worth increased only $36,540 more than with the non-catfish option (Table 2 case 4 vs. case 1).

The high stocking rate permitted 100 acres of ponds to be built during periods 1, 3, 4, and 5 (Table 3, line 12). Production levels are much higher than with the low stocking rate, and ending in net worth is also correspondingly higher, $683,851 vs. $474,005 (Table 3, lines 8 vs. 1). Note that the decline in net worth with the high stocking rate in year 1 is largely the result of valuing ponds at considerably less than their construction cost.

Alternative Price Levels. Very rapid expansion in production of channel catfish (e.g. a five-fold increase between 1973-82) has led to recent weakening in prices (Giachelli et al., 1982). During the years 1970-80, average nominal prices increased every year with only 2 exceptions. However, real prices have declined markedly since 1977 and nominal prices have also declined in recent years (Crop Reporting Board). The average nominal price received in 1982 of $.55 was very near the low-end of a range of cash break-even prices computed for alternative financial situations in a recent Mississippi study (Giachelli et al., 1983).

The "borderline profitability" (Giachelli et al., 1983) of the channel catfish enterprise was examined with a sensitivity test of alternative price levels ranging from $.55-$.75, Table 2, cases 6-10. As shown in case 6, a price level of $.55 or lower prevents the catfish enterprise from entering the model solution (the minimum price for production to occur is $.57, providing a cumulative profit of $11,475 at the end of year 10). The $.60 price/lb. level contributed only modestly to net worth (an average of $6,753 per year); this is evidenced by the low 1.8% rate of increase. The rate of growth in net worth attributable to catfish production increased from 1.8% to 5.7% as real prices increased to $.65/lb., the base case study price. Price levels exceeding $.65 yielded very substantial increases in net worth and annual growth rates (cases 9 and 10). A similar effect to be noted is that quality control in the catfish enterprise is critical since problems such as "off-flavor," a common little-understood "fish taste" phenomenon, can result in severe price markdowns. Thus, not only is it important to have favorable market prices, it is essential to produce a product meeting stringent quality guidelines that captures the highest available price.

RISK RELATED FACTORS AFFECTING FARM SUCCESS

Knowledge of risk factors affecting the financial success of the channel catfish enterprise are not well known. Probabilities associated with disease, oxygen deficiency, nutrition problems and price fluctuations have not been estimated. Further, the parameters associated with farmer attitudes toward risk have not been rigorously analyzed or quantified (e.g. producer risk preferences).[5] Risk issues are quite important in this enterprise because it is a nascent, rapidly changing industry with added risk management problems associated with the water medium where the fish are not visible unless caught and their behavior is difficult to observe. Several variable, risk-related factors that can affect the financial success of the catfish enterprise are examined in the following sections.

Changes in fish price trends. The downward trend in real catfish prices (when prices are deflated by the Producer Price Index) that has occurred since the early 1970's is quite sensitive to the selection of beginning and ending years. For example, the annual average decrease in liveweight deflated catfish prices paid by processors is $.0131, $.0271 and $.0222, respectively, for the periods 1972-81, 1973-82, and 1970-82 (Crop Reporting Board). Cases 11 and 12, Table 2, examine the effects of $.01 and $.02 average annual decreases in deflated prices paid to producers.[6] (Again, all prices in this study are in constant dollars.)

An average $.01 decline in deflated liveweight prices per lb. (from the base case level of $.65) results in a decline in the growth in net worth attributable to catfish to 2.5% from the base case rate of 5.7%. The growth in net worth due to catfish, $92,049, is only 37% of the base case amount, $246,386, and pond construction declines to 80 acres from the base case of 100 acres. The effects of a $.02 average decline in deflated liveweight prices per lb. are only 40 acres of ponds built, a net worth growth rate of 0.5% and a real increase in net worth of only $15,465 over the 10 year planning horizon. These results warrant cautious interpretation since there may likely occur offsetting productivity gains in the future. However, they do point out the greatly diminished financial attractiveness of continued real price declines (such as those experienced recently) for chan-

Loss of ponds. Many producers have suffered partial or complete losses of fish in particular ponds, a problem exacerbated by "stress" from the high stocking rates that are popular with good managers. For example, most producers do not own pond aerators (or for that matter sufficient tractors to drive them) for each pond in production. A precipitous decline in oxygen levels during summer months can result in a difficult management decision about which ponds to "save" and which to "sacrifice." To analyze the economic effects of possible pond losses, a financially vulnerable year was selected in the growth process (year 3) when both current production and pond investment are increasing, and the economic benefits of catfish production are to a large extent yet to be realized. To explore this issue, base case investment and production results were frozen through year 3 with the exception of the amount of fish marketed at year-end.

At the beginning of year 3, production is occurring in two 20-acre ponds and a third 20 acre pond is under construction. The loss of one pond's production at this critical juncture in the growth process renders the model solution infeasible, Table 2, case 13. For the producer to survive, model debt constraints would be exceeded. The maximum debt ratio (debt/assets) limit of 30% is stringent. However, the model farm's growth in debt is entirely associated with expansion of the channel catfish enterprise. (This conservative attitude towards debt use is also consistent with the farm's debt-free initial status.) The loss of more than 64% of one pond's production in year 3 resulted in violation of the debt limit constraint. Loss of less than 64% permitted the farm to meet all financial obligations and to continue growth in the catfish enterprise (case 14). The ending increase in net worth due to catfish production of $239,605 is only slightly less than in the base case, indicating the importance of the ability to survive shortrun financial stress. (Model behavior to offset pond losses consisted primarily of a modest delay in pond building activity and lowered income taxes.)

Living Expense Levels. Controlling living expenses has long been recognized to be an important factor in firm-household decision making and farm survival (Brake). Large changes in family consumption expense have been shown to affect the probability of survival of the farm business in whole-farm stochastic models (Condra and Richardson). Financial lenders are also typically concerned that farmers control living expenses and do not increase consumption with the proceeds of production loans or mortgages. In a recent study of farm conditions, $12,000 annual real consumption was *"considered the* minimum *level of expenditures necessary if the family restricted its consumption for the purpose of weathering a period of adverse prices and incomes"* (Jensen et al., footnote 2,

[5] A recent study conducted at Mississippi State University briefly discusses the current lack of knowledge concerning risk issues in catfish production. (Giachelli et al., 1982).

[6] The motivation for this analysis is that in view of recent downward price trends, producers or investors may want to consider the economic impact of continuation of these trends prior to undertaking new investment in ponds.

p. 7, their emphasis). This assumption may not be appropriate for many farm families, and also for the duration of a 10-year planning horizon. In a firm household context, there is the risk that consumption can not be strictly controlled at a low budgeted level. This issue is examined in cases 15-19, Table 2.

Case 15 illustrates base case model results with consumption at the \$12,000 minimum annual level. The incremental growth rate of annual net worth is 5.7% indicating a substantial degree of economic success. A consumption level of \$18,000 reduced the growth rate to 3.1% and the incremental increase in net worth to \$120,421 (case 16). Thus, the economic gains from catfish production were substantially less with a more moderate living expense level. A "high" level of living costs, \$24,000 resulted in a negative (compared to initial model results without catfish) growth in net worth of -1.1%. The catfish enterprise did not contribute sufficient profits to fund the high rate of consumption withdrawals and maintain the growth rate that would have occurred without the aquaculture enterprise. In other words, the increased farm profitability due to catfish production was unable to both maintain the pre-catfish expansion rate of growth in farm net worth and also to fund a much higher standard of living for the farm family.[7] A consumption level of \$30,000 depleted the farm's capital base to the extent that only 20 acres of ponds could be financed and also whole farm net worth declined \$101,151 (case 18). Finally, case 19 indicates that a consumption level of \$31,000 annually provides an "infeasible" model solution as the profitable catfish enterprise is unable to satisfy financial constraints and net worth decreases dramatically.

SUMMARY AND CONCLUSIONS

Conversion of land to fishponds is an avenue for intensive farm growth in the Southeast. However, investment in fishponds is often an irreversible decision, and this raises questions about the long-run ramifications of pond construction. Farmers, lending institutions and economists have had relatively few economic studies to guide decision making.

The catfish enterprise exhibited a strong tendency to enter the optimal farm organization when the 20-acre pond building alternative was available, a high management intensity was employed and catfish price levels were \$.60 or higher. The review of cases in Table 2 shows that the catfish enterprise generally increased incremental net worth (compared to farm growth without a catfish production option) by approximately 1-6% annually for most cases. Exceptions were high catfish prices (cases 9 and 10 with net worth growth rates from 8.1-10.1%), only 5-acre ponds permitted (case 1, no fish produced), a rapid decline in price levels averaging \$.02 annually (case 12 resulting in a 0.5% net worth growth rate) and high consumption levels (cases 17-19 with negative growth in net worth compared to the base farm projected performance without catfish). Several specific comments can be made based on the findings.

1. The analysis indicated that profitable production is most critically dependent on high stocking rates and the operating and construction economies of size associated with 20-acre ponds. The additional risks of high stocking rates in particular heighten the importance of adequate equipment and sound management ability.
2. Profitability is especially sensitive to breakeven catfish prices in the \$.55-\$.60 range (prices have fluctuated in this range recently) suggesting caution in future expansion plans unless expectations are for strengthening catfish prices.
3. The loss of one large pond's production (or a large fraction of it) for a season during an active expansion phase can be critical for prospects of firm growth and survival for the moderate size operation depicted in this study. While the limited risk analysis showed this issue to be very important, the reader is cautioned that little is known about sources of risks and their empirical effects in catfish production.
4. While catfish production was quite profitable given base assumptions, growth in net worth was very sensitive to moderate or high family living expenses. This is a point that producers need to recognize clearly, especially in low income years.

This study provides one of the first mixed-integer, multi-period linear programming studies of firm growth relating to adoption and expansion of the channel catfish enterprise. Additional studies are needed based on sound knowledge of empirical behavior and accurate cost, production and consumption data gathered from a wide range of producers. In addition, the results of future modeling attempts

[7] Frequently, farmers and their families dramatically increase their living standard as farm profitability grows. This consumption behavior is quite understandable; however, model consumption level results indicate the adverse effects for firm growth that can occur in this firm household tradeoff. The family living expenses for this study are perhaps more typical of small farmers who place a higher priority on increasing net worth through intensive farm growth than on increasing their living standard. Since living expenses are in constant dollars, the nominal level would be much higher at the end of the 10 year study period given annual inflation rates in the 4-8% range.

will be enhanced with a more formal treatment of risk and financial leverage factors, and comprehensive treatment of state and federal income and conservation tax issues. In this regard, quantification of probabilities associated with pond losses and price changes would be particularly useful. Also, the issues of optimal stocking rates and pond sizes need to be researched in the context of more numerous alternatives than in the present study. While sound empirical work is essential for all commodities, it is especially useful for a new, unique and rapidly expanding enterprise such as channel catfish.

APPENDIX

Cost and receipt model assumptions for the 4,500 and 2,500 fish per acre stocking rates are shown in Table 4 for 20-acre pond units. Although not shown below, labor and interest costs of variable inputs are included in the model. Note that total variable cost as a percent of gross receipts is slightly less for the 2,500 compared to the 4,500 stocking rate (respectively 68.2% vs. 70.1%). This is due to lower per fish chemical and fuel, oil and lube costs with the 2,500 per acre stocking rate. However, the 4,500 stocking rate saves 35.2 hours of labor compared to an equal amount of fish production with the low stocking rate. Another important source of model efficiency concerns construction cost assumptions. The per acre costs were $1,000, $1,500 and $2,000, respectively, for 20-, 10- and 5-acre pond units. Land requirements were 1.1, 1.15, and 1.2 acres of land for each acre of water with, respectively, 20-, 10- and 5-acre pond sizes (Kelley).

Equipment and machinery requirements were $19,793, $16,347 and $12,793 for, respectively, 20-, 10- and 5-acre pond units given the 4,500 fish per acre stocking rate. Aeration equipment for high stocking rates is included in these costs ($2,400 for 20-acre and $1,200 for smaller ponds). These values were less where machinery was shared among other enterprises or additional ponds.

Commodity prices for cotton lint, cotton seed, soybeans and steers were, respectively, $0.75/lb., $125/ton, $7.50/bu. and $0.65/lb. These prices were not varied. Total variable costs excluding labor and interest on variable inputs (although included in model) were $295.61 per acre for cotton, $117.76 per acre for soybeans and $6,458.26 per 30-cow herd of beef cattle. Additional information on enterprise costs, returns and investment requirements is provided in Flynn. Finally, model short- and long-term interest rates were .14 and .12, respectively.

TABLE 4. ESTIMATED VARIABLE COSTS AND RETURNS FOR CATFISH PRODUCTION IN 20-ACRE "HILL" PONDS USING: A) HIGH MANAGEMENT INTENSITY AND B) LOW MANAGEMENT INTENSITY

Item	Weight each	Unit	Price or cost/unit	Quantity	Value or cost
A. Gross receipts					
Catfish	1.0	lb	0.65	90000.00	58500.00
Total					58500.00
Variable cost					
Fingerlings		each	0.12	95400.00	11448.00
Floating feed		tons	310.00	81.00	25110.00
Chemicals		appl.	1351.00	2.00	2702.00
Fuel, oil & lube		hr.	2.16	444.00	959.04
Equipment (repair)		dol.			275.69
Total variable cost					40995.73
B. Gross receipts					
Catfish	1.0	lb	0.65	50000.00	32500.00
Total					32500.00
Variable costs					
Fingerlings		each	0.12	53000.00	6360.00
Floating feed		tons	310.00	45.00	13950.00
Chemicals		appl.	1351.00	1.00	1351.00
Fuel, oil & lube		hr.	1.58	226.00	357.08
Equipment (repair)		dol.			147.88
Total variable Costs					22165.96

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