Can Catfish Aquaculture be Profitable in Farm Ponds?

Siddhartha Dasgupta, William Wurts, and Robert Durborow

Aquaculture Research Center

Kentucky State University

Frankfort, KY 40601

Conference name, place, and date:

Selected Paper prepared for presentation at the

Southern Agricultural Economics Association Annual Meetings

Mobile, Alabama, February 4-7, 2007

Can Catfish Aquaculture be Profitable in Farm Ponds?

Abstract

Extensive channel catfish farming is a means of utilizing farm ponds for aquaculture production for either supplementary income or home use. This involves stocking catfish at sufficiently low densities such that a pond is able to assimilate excess feed and fish wastes without needing supplemental aeration or chemicals to keep water quality from reaching toxic levels. This is "low-tech" aquaculture and requires little producer labor/management inputs.

A mathematical model of extensive catfish culture in farm ponds is presented in this paper. This model used data from Kentucky where part-time producers, with a minimum of aquaculture experience and time for pond management, are involved in culturing catfish for retail/live markets. Results of this model showed that the optimal strategy would be to stock fish at densities up to 3,000/ha/yr (1,200/ac/yr). Other results showed that breakeven prices were less than $2.20/kg ($1.00/lb), a popular retail price for whole catfish. Hence, this paper concludes that small-scale aquaculture is both feasible and profitable in farm ponds, provided the producer had access to retail markets for the product.

Keywords: Mathematical programming, catfish, aquaculture, farm ponds

Introduction

Technological, economical, and logistical barriers make commercial catfish farming beyond the reach of many small-scale producers in the United States. Most commercial catfish farms are heavy on pond and equipment investment. For example, a farm with 40 ha (100 ac) of ponds requires an investment of at least $500,000 in land, ponds and equipment (Engle and Stone, 2002). Such financial demands are typically satisfied through bank financing; an option not available to small-scale farmers in states where aquaculture is not a major industry.

Most commercial catfish farms stock fingerlings at intensive densities, i.e., from 12,500-17,500/ha (5,000-7,000/ac) twice or more per year. At these stocking densities, both technology requirements and operating costs are high. For example, the annual feeding rate for 12,500-17,500 catfish per hectare can easily be 5-7 MT, which translates to a feed cost of $1,925-$2,695/ha/year (assuming a feed price of $385/MT or $350/ton). Intensive production also results in large output volumes (4,000-5,000 kg/ha/yr or 3,500-4,400 lb/ac/yr), which create marketing problems in regions where large volume buyers, such as processing plants, are unavailable. Intensive culture needs significant technological assistance such as aeration and water quality monitoring equipment, disease control measures, and management expertise.

Extensive or low-density catfish culture is a low-tech way for small-scale farmers to enter the catfish industry. In essence, extensive catfish farming involves stocking fingerlings at such low densities that the feeding rates will be sufficiently limited to allow the pond ecosystem to naturally process the fish wastes without supplemental aeration or chemical use. In a sense, the pond 'takes care of itself' with respect to assimilating organic matter and maintains sufficiently high water quality to keep fish alive, without the assistance of supplemental aeration. Extensive catfish farming needs little technology/management assistance that is essential for intensive systems. Morris (1993) reported that for extensive culture methods to work, farmers should limit the catfish biomass to a maximum of 1,705 kg/ha (1,500 lb/ac). Since catfish are typically harvested when they reach 568 g (1.25 lb), extensive producers should limit stocking densities to 2,500-3,000 per hectare (1,000 –1,200/ac).

Tucker et al. (1979) reported that the pond ecosystem will naturally process feed and catfish wastes without allowing the water quality to reach toxic levels for catfish, provided the feeding rate did not exceed 34 kg/ha/day (30 lb/ac/day). In contrast, intensive catfish farming features feeding rates as high as 114 kg/ha/day (100 lb/ac/day) during the summer months. Feeding rates for extensive catfish production were available from Dupree (1984) and Wurts and Wynne (1995).

This paper presents economics and pond management results associated with extensive catfish production. A mathematical model was developed for a hypothetical catfish farm in order to evaluate the optimal stocking and harvesting strategies and the corresponding economic parameters for a typical producer. The aquaculture economics literature has witnessed some examples of mathematical modeling that is similar to our application. Engle and Pounds (1993) investigated the economics underlying single and multiple-batch stocking of catfish using a linear programming (LP) model. Their study indicated that single-batch was more profitable in situations where off -flavor of catfish did not exist; however, multi-batch stocking was a practical necessity for producers experiencing off-flavor problems, in order to have a steady supply of on-flavor fish. Cerezo-Casado (1993) used mathematical programming to determine profit maximizing pollution control methods for pond effluent control. Kouka and Engle (1996) also used LP models to investigate the most profitable effluent control options available to catfish farmers.

Background

As mentioned above, management of extensive catfish ponds could be as simple as stocking and feeding catfish at pre-specified intensities, and harvesting at appropriate future dates. However, the realities of catfish farming in Kentucky impose additional qualifications, which are discussed in this section. Most small scale aquaculture farmers in Kentucky use small ponds (0.4 ha or less). Farm ponds, converted from livestock watering reservoirs, are often converted for such low-intensity aquaculture. Catfish are usually stocked during Spring or Fall months. We assumed that the stocking months were April and October. Fish are harvested when their average size exceeds 568 g (1.25 lb). Since extensive catfish farms have limited output volume, most fish are sold in retail markets, i.e., at the pond bank and/or sales to local pay lakes, restaurants, or fish markets.

Equipment needs for extensive catfish farming are very modest: a water pump, a truck (required for transportation, feeding and harvesting activities), and a mower are essential. Harvesting equipment such as a seine and livecars are useful because harvested fish can be temporarily held in livecars, via a water exchange mechanism with pond water, while awaiting sales. A cool, dry storage space is important for keeping 30-60 days worth of feed.

Extensive catfish farmers typically do not use a line of credit to finance their enterprise. The trend is for farmers to make an initial investment in land, ponds, equipment, and operating supplies (i.e., fingerlings, feed, etc.) during the first year of operations and use the income from fish sales to meet future cash flow demands. The initial investment is usually made with personal savings, or money borrowed from family members. Hence, farmers interested in extensive catfish farming are usually individuals with existing farm ponds that can be converted for aquaculture at a minimum expense, instead of building new ponds.

Data

Data on fixed resources necessary for an extensive catfish farm came from a survey of small-scale aquaculture producers in Kentucky. Land was valued at $2,500/ha, which is representative of the value of agricultural land in rural Kentucky. New pond construction cost was assumed to be $3,000/0.4 ha pond and renovation cost for farm ponds was $1,000/0.4 ha pond, which is typical of central/western Kentucky, where the catfish industry is concentrated. Ponds are typically used for 10 consecutive years, after which they are drained and renovated.

Such ponds can be restocked with catfish, and the whole process of renovation and restocking takes less than a month, resulting in minimal disruption to a pond's production schedule.

Cost of equipment including a pickup truck, a feed storage area, a seine, two live cars, a mower, and water pump, are listed in Table 1. We assumed that the truck and mower were used only 10% of their operational time on catfish culture.

Table 2 lists operating costs of an extensive catfish farm. Fingerling catfish prices were obtained from the Purchase Area Aquaculture Cooperative (PAAC), a Kentucky based catfish producer cooperative. Price of 45 g (0.1 lb) fingerlings have varied from \$0.15 - \$0.25, depending upon availability and volume of purchase (PAAC). We adopted Wurts and Wynne's (1995) observed fingerling survival rate (90%) in extensively stocked catfish ponds in Kentucky.

Catfish were fed a 32% crude protein catfish diet. In Kentucky, catfish feed is usually purchased from neighboring states of Arkansas and Mississippi. A time series (1986-2003) of catfish feed prices was obtained from Hanson and Sites (2004), and information on feed transportation cost from Arkansas to Kentucky was obtained from ARKAT Feed Mill (2004). The minimum, average**,** and maximum catfish feed prices, including transportation costs, from 1993 – 2003 were \$263/MT (\$239/ton), \$315/MT (\$286/ton), and \$397/MT (\$361/ton), respectively (Hanson and Sites, 2004). Feeding rates, as a function of water temperature, were available in Tucker et al. (1979) and Dupree (1984). Winter feeding practices were based on Tidwell and Mims (1991) and Mims and Tidwell (1989), which reported that channel catfish in Kentucky should not be fed at water temperatures less than 7.2°C (for fingerlings) and 10°C (for adult fish). For water temperatures between 10-13°C, the daily feeding rate should be 2% of the catfish biomass, every other day. Water temperature data from Kentucky (Onders, 1994) deemed the months between November and February to be too cold for feeding catfish.

Chemical applications, such as agricultural lime, were also an operating cost. Kentucky Cooperative Extension Service reported that lime should be applied to ponds at the rate of 1.8 MT/0.4 ha/ 3 years, at a cost of $13/MT. Labor and management costs were modeled by assuming an average requirement of 1 man-hour/day at $8/hour. Other operating costs included fuel, telephone, maintenance and miscellaneous costs, which were available in Dasgupta and Tidwell (2003). All price data were deflated using the producer price index and reported based on 2003 U. S. dollars. Dasgupta (2003) provided data on catfish demand and prices paid by Kentucky's pay lakes.

Catfish prices were obtained from various issues of the Aquaculture Situation and Outlook Reports (USDA). The minimum, average**,** and maximum catfish prices paid by processors to producers from 1993 – 2003 were $1.17/kg ($0.53/lb), $1.58/kg ($0.72/lb), and $2.07/kg ($0.94/lb), respectively. All prices were in 2003 U. S. dollars.

Catfish growth rates, under extensive stocking conditions, were available from Tucker et al (1979), and Wurts and Wynne (1995). These data were used to plot Figure 1, which depicts growth curves for catfish stocked in April and October. These growth curves were an approximation of actual catfish growth, and represent the currently available growth data for channel catfish in low density pond rearing conditions.

Model description

A LP model of an extensive catfish farm was developed with maximizing the net present value of returns above cash costs (RCC) as the objective function, subject to technical and financial constraints. We modeled a hypothetical catfish operation with 4, 0.4 ha farm ponds. A 10-year operating horizon was selected for the model, which reflected the working lifespan of a catfish pond between renovation activities.

Since ponds could be stocked twice a year (April and October), the 10-year operational period for a catfish pond featured a maximum of 17 stockings. Odd-numbered batches 1 - 17 were stocked in April of Year 1 - 9, respectively. Even-numbered batches 2 - 16 were stocked in October of Year 1 - 8, respectively. Fingerling catfish belonging to batch 17 reached food size by Year 10, after which the ponds were drained and renovated. Following Figure 1, fish stocked in Spring of Year t, were available for harvest by Fall of Year t, and was likely to be completely harvested by Fall of Year t+1. Similarly, fish stocked in Fall of Year t, were harvest-ready by Fall of Year t+1, and was likely to be completely harvested Fall of Year t+2.

Parameters and variables in this model were affected by the batch of catfish 'b'($1 \leq b \leq 17$), the number of ponds 'p' ($1 \leq p \leq 4$), and/or month of operations 'm' ($1 \leq m \leq 120$). Decision variables for this model included the number of fish available per batch, per pond of fish, during month m (i.e., N(b,p,m)); the amount of fish harvested per batch, per pond, per month (H(b,p,m)), and the volume of fish sold in a food market (Output(m)) and a pay lake market (PylkOutput(m)) in a given month. The model's objective was maximizing the net present value of the returns above all cash costs (RCC) computed for each month m:

(1) Objective $\equiv$ Maximize $\sum_{m} \frac{1}{(1+r_1)^{m-1}}\left[\text{RCC (m)} + r_2 * \text{Savings(m)}\right]$, where returns above cash costs $\equiv$ RCC(m) = Revenue for month m – Operating and Fixed cash costs during month m, r_1 and r_2 were interest rates, and Savings(m) was the cash left over at the end of a month, after all costs were met, and available to the producer during the following month.

Revenue was generated by selling fish to food markets and/or the pay lake stocking markets, i.e., Revenue(m) = p_1 * Output(m) + p_2 * PylkOutput(m). Operating costs included costs of stocking

N(b,m,p) amount of catfish: $\sum_p \sum_b \left[w_s * N(b,p,m) * \text{StockIndex}(b,m) \right]$, where StockIndex(b,m) was a "0/1" binary parameter which was 1 if batch b was to be stocked during month m. Feed costs were: w_f (m) * $\sum_p \sum_b \left[N(b,p,m) * wt(b,m) * F\%(b,m) * T(m) \right]$, where the feed price w_f (m) varied with the month, wt(b,m) was the size of catfish in batch b during month m, F%(b,m) was the feeding rate of batch b in month m as a percentage of catfish body mass, and T(m) were the number of feeding days in month m. Other operating costs included fuel costs for a truck and a water pump, legal fees, chemical application costs, labor and management costs, maintenance costs, telephone and advertisement costs, etc. (Table 2). Annual fixed cash costs included the cost of purchasing all equipment during the first year of operations, followed by equipment replacement costs for that equipment with lifespan of less than 10 years (Table 1).

Biology and management issues of extensive catfish farming demand certain conditions to be imposed on the decision variables. These conditions formulate a set of constraints which are expressed mathematically in equations (2) to (9). Stocking density was affected by constraints (2) and (3) that restricted the total catfish biomass per pond to a maximum of 1,704 kg/ha, and the maximum daily feeding rate to 34 kg/ha, respectively.

(2) $$\sum_b \left[N(b,p,m) * wt(b,m) \right] \leq 1{,}705 \text{ kg/ha, for all m and p.}$$

(3) $$\sum_b \left[N(b,p,m) * wt(b,m) * F\%(b,m) \right] \leq 34 \text{ kg/ha/day, for all m and p.}$$

The total number of fish available per batch, per pond, during any month (i.e., N(b,p,m)), was dependent on the number of fish stocked in the batch, survival rate of fish, and the number of fish harvested from the batch H(b,p,m) (constraint (4)).

(4) $N(b,p,m+1) \leq \{N(b,p,m) - H(b,p,m)\} *$ Survival Rate, for all b, p, and m.

The harvest volume from a given batch, during any month, was bounded by the amount of harvest-sized (≥ 568 g) fish available in that batch (constraint 5).

(5) $H(b,p,m)*wt(b,m) \leq 98\% * N(b,p,m) *wt(b,m)*\text{Harvest Index}(b,m)$, for all b, p, and m; where, 98% is the percentage of harvest-ready fish caught after repeated seining, and Harvest Index(b,m) is a "0/1" binary parameter which is equal to 1 provided catfish from batch b were harvest-ready by month m.

The total amount of catfish sold in month m was limited by the harvest volume, and output was allocated to food or pay-lake markets depending on relative returns from the two outlets:

(6) $$\text{Output}(m) + \text{PylkOutput}(m) \leq \sum_{p}\sum_{b}\left[H(b,p,m) * wt(b,m)\right],$$ for each month m.

However, the institutional requirements of having a pay lake contract forced producers to consistently supply a minimum quantity of fish per month during the pay lake season (i.e., March to October) of each year, i.e., PylkOutput(PylkM) ≥ Minimum supply, for all months during the pay lake season, i.e., PylkM.

The model also included financial constraints faced by small-scale farmers in Kentucky. At startup (Year 1), farmers needed a cash investment to cover the costs of pond construction/renovation, equipment, and operating costs for the first stocking period:

(7) $$\text{Cash costs of month 4} = \sum_{p}\sum_{b}\left[w_s * N(b,p,m=4) * \text{StockIndex}(b,m=4)\right] + w_f(m=4) *$$

$$\sum_{p}\sum_{b}\left[N(b,p,m=4) * wt(b,m=4) * F\%(b,m=4) * T(m=4)\right] + OCC(m=4) +$$

$FCC(m=4) + Savings(m=4) \leq$ Initial investment, where "m=4" represents the starting month (April, Year 1), OCC was other operating costs, and FCC was fixed cash costs.

In subsequent months, expenses were paid from revenue from fish sales and savings from with past revenues and any leftovers from the initial investment:

(8) $\text{Revenue}(m) + (1+r_2)*\text{Savings}(m-1) - \text{Savings}(m) \geq$

$$\sum_p \sum_b \left[w_s * N(b,p,m) * \text{StockIndex}(b,m) \right] + w_f(m) *$$

$$\sum_p \sum_b \left[N(b,p,m) * wt(b,m) * F\%(b,m) * T(m) \right] + OCC(m) + FCC(m).$$

Finally, a payback constraint ensured that a feasible solution accumulated sufficient income to payback the initial investment with interest compounded over 10 years:

(9) $\text{Savings}\ (m = 120) \geq (1+r_1)^9 * \text{Initial investment}.$

The model was optimized using GAMS solvers (GAMS Inc.).

Results

Base scenario

In the base scenario, we assumed that the producer used 4 farm ponds, and that the fingerling price was \$0.20/head (w_s) and catfish output price was \$2.20/kg (\$1.00/lb) (p_1). The model's results indicated a minimum initial investment of \$12,500 was necessary to start the catfish farm. The optimal stocking density varied from 2,770-2,953/ha (1,108-1,181/ac) during every spring and an additional 375-450/ha (150-180/ac) during fall, resulting in annual yield varying from of 1,362 kg/ha (1,198 lb/ac) of catfish to 1,918 kg/ha (1,688 lb/ac) of catfish with harvests starting in November, Year 1, followed by July-November of Year 2-Year 10. Fish sales to retail food markets resulted in a net present value of RCC of \$3,225 (or \$2,016 /ha; \$806 /ac), and internal rate of return (IRR) of 28.93% and a breakeven price of \$1.80/kg (\$0.82/lb).

If producers used 4 new ponds, an initial investment of $23,611 was required, resulting in optimal stocking densities and yields identical to the above values. The IRR was 8.00% and the breakeven price increased to $2.11/kg ($0.96/lb).

Consistent supply scenario

The base scenario assumed that a producer was able to sell all of the harvested catfish. In the real world, however, there are limits as to how catfish could be marketed. For example, if a producer were to supply a local retail or restaurant market, it might be necessary to have a consistent volume of fish available each month. In this scenario, we evaluated the maximum volume of catfish that our hypothetical farm could supply every month from the second year of production. Results of this model indicated that, when input and output prices were held the base scenario levels, the catfish farm, using renovated farm ponds, could supply a maximum of 87 kg/ha (77 lb/ac) of food fish per month at a breakeven price of $1.85/kg ($0.84/lb).

Pay lake sales scenario

In Kentucky, many catfish farmers had shown interest in supplying fee-fishing lakes or pay lakes with live fish. Pay lakes demand fish between March and October, and pay $1.93-$2.75/kg ($0.88-$1.25/lb) (Dasgupta, 2003). If our representative farm were to sell fish only to pay lakes, the breakeven price would be $1.95/kg ($0.89/lb), which is within the range of prices that pay lakes typically pay for live catfish. However, since the producer was no longer selling fish all year round, successful pay lake sales demanded a higher initial investment of $14,028. This increase in minimum initial investment was necessary to cover cash-flow scarcities during months without revenue from pay lake sales, but with the usual costs of operations.

Assuming that pay lakes were paying $2.34/kg ($1.07/lb) for catfish, i.e., average of the minimum and maximum pay lake prices, the maximum monthly volume of fish that the extensive catfish farm could supply to pay lakes was 236 kg/ha (208 lb/ac). To reach this goal, the optimal stocking density was 2,750-3,000 /ha/year (1,100-1,200 /ac/year), with most fish stocked in spring and a few stocked in fall in order to meet a maximum stocking density of 3,000/ha. The resulting net present value of RCC was $1,435/ 0.4ha.

Conclusions

The reality of catfish farming involves producers using rules-of-thumb, observations of fish behavior, and marketing opportunities to make the correct management decisions. Farmers, particularly in extensive aquaculture, generally do not calculate catfish biomass, feeding rates, and harvesting strategies in order to seek economically optimal solutions. The model in this paper generates guidelines for profit maximizing stocking, harvesting, and marketing strategies, subject to biological and economic constraints, that farmers could easily adopt.

The salient points in the results were 1) annual stocking densities should be at most 3,000 /ha/year (1,200 /ac/year), 2) large (45 g) fingerling catfish should be stocked primarily during spring, with some additional stocking allowed in fall to account for loss due to mortality and harvest, 3) if fish were fed according to the feeding table in Wurts and Wynne (1995), a first harvest could be scheduled in fall of Year 1, followed by consistent harvest of 87 kg/ha, every month for the remaining 9 years, and 4) breakeven price of whole catfish were less than $2.20/kg ($1.00/lb) making retail market and pay lake sales profitable.

The breakeven prices were mostly above the price paid by large-scale catfish processors, making sales to processors impossible for extensive catfish producers. However, our results showed that sale of live fish to pay lakes were profitable at the prices that pay lakes typically paid to producers. Since supply consistency is important for pay lake buyers; our results indicated that the hypothetical extensive catfish farm could deliver up to 236 kg/ha of catfish every month during pay lake season from Year 2- Year 10. Although, the limited production made such a small operation unlikely to be a major pay lake supplier, the catfish farm could be a source of fish for replenishing pay lakes during the busiest part of their season (i.e., summer months).

One caveat in our analyses was the exclusion of disease and off-flavor related factors in our model. While both these factors could affect a farm's management decisions, they are less likely to occur in extensive catfish farming, when compared with intensive culture. In an extensive culture environment, fish are less stressed and thus are more capable of disease resistance, if fed a nutritionally complete diet. The low feeding rates allow ponds to assimilate uneaten feed and fish wastes effectively to reduce the nutrient loads in the pond water in order to preclude the algal growth necessary for off-flavor to occur.

In conclusion, low-tech catfish farming in farm ponds is both technologically and economically feasible for small scale producers provided they have access to retail markets that pay a premium for fresh/live product. With output prices in excess of \$2.20/kg (\$1.00/lb), extensive catfish production could generate returns to investment in excess of 8%. This form of aquaculture is also suitable for part-time or hobby farmers with little expertise in pond management, who might want to produce limited quantity of catfish for home use.

References

ARKAT Feed Mill. 2004. Annual records. Dumas, AR.

Cerezo-Casado, G. A. 1993. Catfish pond effluent control: an economic analysis into wetlands, water recycling, and the effect of taxation of effluents. M. S. thesis. Auburn University, Auburn, AL.

Dasgupta, S., and J. H. Tidwell. 2003. A breakeven price analysis of four hypothetical freshwater prawn, Macrobrachium rosenbergii, farms using data from Kentucky. Journal of Applied Aquaculture, 14: 1--22.

Dasgupta, S. 2003. Marketing channel catfish in Kentucky: the promise of pay lakes. Aquaculture America 2003, Book of Abstracts, p. 72.

Dupree, H. K. 1984. Feeding practices. In: E. H. Robinson and R. T. Lovell (ed.), Nutrition and feeding of channel catfish (revised). Cooperative Series Bulleting 296, Texas A&M University, College Station, TX.

Engle, C. R. and N. Stone. 2002. Costs of small-scale catfish production. Southern Regional Aquaculture Center Publication Number 1800, Delta Research and Extension Center, Mississippi State University, 127 Experiment Station Road, Stoneville, MS.

Engle, C. R. and G. L. Pounds. 1993. Trade-offs between single- and multiple-batch production of channel catfish: an economics perspective. Journal of Applied Aquaculture 26(3):297-306.

GAMS Development Corporation. 1217 Potomac Street, NW, Washington, DC.

Hanson, T. and D. Sites. 2004. 2003 U. S. catfish database. Information report 2004-001. Department of Agricultural Economics, Mississippi State University, Mississippi State, MS.

Kay, R. D., and W. M. Edwards. 1999. Farm Management, 4th edition. McGraw-Hill Company, New York, New York.

Kouka, P. J., and C. R. Engle. 1996. Economic implications of treating effluents from catfish production. Aquaculture Engineering, 15: 273-290.

Mims, S. D. and J. H. Tidwell. 1989. Winter feeding of fingerling channel catfish in Kentucky. Transactions of the Kentucky Academy of Science. 50: 174-176.

Morris, J. E. 1993. Pond culture of channel catfish in the north central region. North Central Regional Extension Publication No. 444. North Central Regional Aquaculture Center, Iowa State University, Ames, IA.

Onders, R. J. 1994. Reservoir ranching of the paddlefish, Polyodon spathula. M.S. thesis, Department of Biology, University of Louisville, Louisville, KY.

Tidwell, J. H., and S. D. Mims. 1991. Effects of density and feeding regimen of the overwintering of channel catfish. Journal of Applied Aquaculture, 1: 103-111.

Tucker, L., C. E. Boyd, and E. W. McCoy. 1979. Effects of feeding rate on water quality, production of channel catfish, and economic returns. Transactions of the American Fisheries Society, 108: 389-396.

Wurts, W. A., and F. Wynne. 1995. Sustainable channel catfish farming: low management production through modified stocking and feeding practices. World Aquaculture 26: 54-59.

Table 1. Pond and equipment necessary for an extensive catfish farm. All prices are in 2003 U. S. dollars.

Item	Lifespan	Value	Annual depreciation[a]	Annual interest[a]
0.42 ha of land	_	$1,050	_	$105
0.4 ha pond	10 years	$3,000	$100	$250
Seine[b]	5 years	$450	$90	$23
Pickup truck[b, c]	10 years	$15,000	$150	$75
2 live cars[b]	5 years	$500	$100	$26
Feed storage area[b, c]	10 years	$3,000	$30	$15
Water pump[b]	5 years	$540	$54	$27
Mower[b, c]	5 years	$1,000	$20	$5
Total			$544	$526

[a]Annual depreciation was calculated by the straight line method, annual interest was calculated based on average investment (Kay and Edwards, 1999).

[b]Use of these equipment was shared among 4-10 ponds.

[c]Only 10% of these equipment was devoted to catfish farming.

Table 2. Estimated annual operating cash costs for a single 0.4 ha pond in an extensive catfish farm. All prices are in 2003 U. S. dollars.

Item	Unit	Quantity	Unit Cost	Cost
Fingerlings	Head	1,200.00	$0.20	$240.00
Feed	MT	1.34	_[a]	$317.00
Labor and management[b]	Man-hours	91.25	$8.00	$730.00
Chemicals[b]	Application	0.33	$24.00	$7.92
Fuel for truck and water pump	Liters	75.60	$0.40	$30.00
Harvesting and hauling	Kg	767.00[c]	$0.088	$67.50
Telephone, supplies, legal fees & maintenance[b,d]				$48.20
Total variable cost				$1,440.62

[a]Feed prices varied with time and were adopted from Hanson and Sites (2004).

[b]Costs were divided equally over 4, 0.4 ha ponds.

[c]Average catfish yield per pond, per year; yield per hectare per year = 1,918 kg.

[d]Annual maintenance was charged on 2% the value of truck, water pump, and mower. The truck and mower were used for catfish farming 10% of the total operation time. Annual legal fees consisted of a $50 propagation permit.

Figure 1. Growth of channel catfish stocked during October of Year t and April of Year t+1.