Enterprise Budget Analysis of Three Stocking Densities of Caged Florida Red Tilapia

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ABSTRACT

Enterprise budgets were prepared from growth and production data of Florida Red tilapia stocked in 1 m^3 cages at three densities (300, 400, and 600 fish/m^3). Fish growth rate, final body weight, survival rate, and feed conversion efficiency were inversely related to stocking density. Annual return to risk for a hypothetical cage culture enterprise in a 2 ha watershed pond was higher at 300 fish/m^3 ($41,506) than at 400 fish/m^3 ($35,439) or 600 fish/$m^3$ ($30,745). High growth rates at low density and use of male fingerlings improved feed conversion efficiency (reduced costs) and allowed the production of more large fish of higher value (increased revenue). Breakeven price was most sensitive to changes in manager time allocated to production activities and moderately sensitive to changes in feed cost and hired labor time. Although return to risk was greatest at 300 fish/m^3, good returns were obtained from a cage culture enterprise using a stocking density as high as 600 fish/m^3. Given the relatively minimal labor requirements of this production enterprise, a farmer can significantly increase farm revenues by adding cage culture to the farm business.

INTRODUCTION

Cage culture of fish is generally practiced in bodies of water that cannot be drained or for which the water has competing uses, such as crop irrigation, livestock watering, or recreation. Cages facilitate stocking, feeding, and harvest operations, and provide protection from predators.

A farmer can affect caged fish production by manipulating density. Fish production in cages increases as a function of stocking density to the point of cage carrying capacity. However, fish growth rate, feed conversion efficiency, and survival rate are inversely proportional to stocking density. The optimum cage stocking rate depends on prevailing market weight, length of the production period, and cage volume.

Research was conducted for several years on St. Croix, U.S. Virgin Islands on the production of tilapia in cages in watershed farm ponds (Hargreaves *et al.*, 1988; Hargreaves *et al.*, 1989; Rakocy *et al.*, 1989). One of the objectives of this research was to evaluate the effect of fish stocking density on growth rate, production, survival, and feed conversion efficiency. The use of these data as the basis for analysis of profitability and economic performance has not been undertaken.

As farmers seek to maximize returns from limited land, water, labor, and capital resources, the addition of a cage culture enterprise may enhance the profitability of a farm business, particularly within the context of low-input, part-time, agriculture common in the Virgin Islands. Objective criteria are required by farmers to evaluate the risks in selecting enterprises. Farmers can analyze risks and returns by preparing *pro forma* budgets for the proposed enterprise.

An enterprise budget is an economic tool used in making farm management decisions. The budget is prepared before the start of production to estimate the potential revenues and costs for each technology or method considered. The return to risk is the amount the farmer is rewarded for his management efforts.

A breakeven price can be calculated by dividing total costs by total production to determine the cost of production and the market price required to recover variable and fixed costs. The enterprise may be able to continue production over the short run if variable costs are recovered. In the long run, a price must be obtained that covers both fixed and variable costs. The breakeven price is sensitive to changes in input costs and quantities. The relative importance of each change can be determined by sensitivity analyses.

On the whole, capital costs for cage culture are lower than for other culture methods (Collins and Delmendo, 1976). Costs are affected primarily by the choice of feed quality (protein level), feed delivery method (labor), and fingerling costs. For example, the use of demand feeders for cage culture will reduce labor requirements for feeding by 90% (Hargreaves *et al.*, 1988).

This paper evaluates three stocking rates for tilapia cage culture from an economic perspective, using enterprise budgets prepared for a hypothetical cage culture enterprise in the U.S. Virgin Islands as the basis of analysis. The relative effects of price and quantity changes of several inputs on breakeven price are examined by sensitivity analysis. Based on the results of this study, it is recommended that, to maximize returns to risk, farmers should stock larger, male fingerlings at a relatively low density for maximum growth and high production wherein most fish are of a larger, more valuable size.

MATERIALS AND METHODS

Data from two tilapia cage culture experiments, conducted in a 2 ha farm pond on St. Croix, U.S. Virgin Islands during 1986–88, were used to develop *pro forma* enterprise budgets. In both studies, fish were stocked in 1 m^3 cylindrical cages and obtained a nutritionally-complete diet (36% protein, Purina #5144) of floating pellets *ad libitum* from demand feeders. Fish growth, feed conversion, survival, and production at each density were compared (Table 1).

In the first study, the culture performance of two tilapia species and three varieties of red tilapia was evaluated. Male fingerlings (70 g/fish) were stocked at 300/m^3 and cultured for 20 weeks (December to May). Florida red tilapia was

Table 1. Growth and production data for three stocking densities of caged Florida red tilapia cultured in a 2 ha pond during 1986-1988, St. Croix, U.S. Virgin Islands.

Parameter	Density (#/m³)		
	300[1]	400[2]	600[2]
Culture period (days)	140	140	140
Production cycles per year (#)	2.61	2.61	2.61
Pond carrying capacity per cycle (kg)	6000	6000	6000
Stocking weight (g)	70	50	50
Harvest weight (g)	586	370	335
Feed conversion ratio	1.45	1.69	1.80
Survival (%)	93.3	94.7	90.6
Growth rate (g/day)	3.6	2.2	2.0
Final cage biomass (kg)	164	140	182
Fish required per cycle (#)	10800	16800	19200
Cages required per cycle (#)	36	42	32
Fish required per year (#)	28188	43848	50112
Total annual production (kg)	15409	15347	15201
Production ≥ 454 g/fish (%)	91	51	38
Production < 454 g/fish (%)	9	49	62

[1]Males only
[2]Mixed-sex

the fastest growing red variety.

In the second experiment, the effect of two stocking rates and four levels of diffused aeration on the culture performance of Florida red tilapia was evaluated. Mixed-sex fingerlings (50 g/fish) were stocked at 400/m^3 and 600/m^3 and cultured for 20 weeks (October to March). Aeration did not have a significant effect on culture performance. However, stocking density did affect several production parameters.

Using growth and production data (Table 1) and actual and estimated costs (Table 2), *pro forma* budgets were developed for a hypothetical cage culture production enterprise at each of the three stocking densities (Table 3). A pond carrying capacity of 6000 kg/crop (3000 kg/ha) was assumed. Carrying capacity was divided by final cage biomass to determine the number of cages required for each 140-day crop cycle. Fractional cages were rounded to the next lowest whole number. The number of cages x stocking density yielded the number of fish required per cropping cycle. Total annual production was the product of the number of cycles per year (2.61) x number of cages x cage biomass at harvest.

Revenue for the enterprise was the sum of earnings from fish sales at two retail price levels. Fish ≥ 454 g were sold for \$5.50/kg; fish < 454 g were sold

Table 2. Assumed value of revenue, variable cost, and fixed cost items used in the development of pro forma budgets for a hypothetical Florida red tilapia cage culture enterprise.

- Florida red tilapia ≥ 454 g have a retail value of \$5.50/kg; fish < 454 g have a retail value of \$4.40/kg.
- Male fingerlings cost \$0.50 each; mixed-sex fingerlings cost \$0.25 each
- A 36% protein, extruded, floating catfish feed (Purina #5144) cost \$0.49/kg plus \$0.24/kg shipping.
- Manager (10%) and hired labor (25%) are a proportion of total farm labor allocated to the tilapia production enterprise.
- Cages with demand feeders cost \$125 each and are depreciated over 5 years.
- Other fixed cost items include: pickup truck, paddlewheel aerator,and feed storage facility.
- Paddlewheel aeration is used only in an emergency situation after severe weather lowers the dissolved oxygen to < 2 ppm. Electric use of \$1.00/hr is based on the manufacturer's recommendations. Sixty days of use are budgeted per year.
- Land is leased for \$247/ha/yr.
- Overhead is estimated as 2.8% of total variable costs.

for \$4.40/kg. The proportion of harvested fish in each weight category was multiplied by total annual production to determine the quantity of fish sold at each price.

Variable costs included fingerlings, feed, electricity, and labor (Table 2). Fixed costs included cages with demand feeders and other capital requirements (paddlewheel aerator, pickup truck, feed storage facility) in support of the fish production enterprise. The proportion of each variable and fixed cost item to total costs was calculated for each stocking rate (Table 4) for comparison with other reported fish culture budget analyses.

Breakeven price (BEP) at each density was calculated by dividing total costs by total production. Sensitivity of mean change in BEP to incremental (10%) changes in the price of individual input parameters was calculated (Table 5) using production and economic data of the enterprise and a stocking density of 400/m^3 as a base case. The price or quantity of one input variable was changed by 10%, while holding all other input costs constant, and the new BEP

Table 3. Revenue, variable costs, fixed costs, returns to management and risk, and break-even price ($) and yield (kg) for a hypothetical cage culture enterprise in a 2-ha pond using three stocking densities of caged Florida Red tilapia.

		Density (#/m^3)		
Item	**Price/Unit**	**300**	**400**	**600**
REVENUE				
≥ 454 g/fish	5.50/kg	77,134.31	43,095.74	31,787.84
< 454 g/fish	4.40/kg	6,102.93	33,124.57	41,491.50
TOTAL REVENUE		83,237.25	76,220.31	73,279.34
VARIABLE COSTS				
fingerlings[1]		14,094.00	10,962.00	12,528.00
feed	0.73/kg	14,224.43	16,249.68	16,692.92
electrical	1.00/hr	1,488.00	1,488.00	1,488.00
manager labor	24,000.00/yr	2,400.00	2,400.00	2,400.00
hired labor	15,000.00/yr	3,750.00	3,750.00	3,750.00
TOTAL VARIABLE COSTS		35,956.43	34,849.68	36,858.92
TOTAL FIXED COSTS		4,076.79	4,264.6	3,951.54
OTHER COSTS				
land charge	247.00/ha	691.60	691.60	691.60
general overhead	2.80%	1,006.78	975.79	1,032.05
TOTAL COSTS		41,731.60	40,781.73	42,534.10
RETURNS TO MANAGEMENT AND RISK		41,505.65	35,438.58	30,745.24
Breakeven price - all costs		2.71	2.66	2.80
Breakeven yield - all costs		7,727	8,220	8,828

[1] $0.50 each for 300 fish/m^3
$0.25 each for 400 and 600 fish/m^3

was calculated. The price was changed over a reasonable range and the changes in BEP were averaged.

RESULTS AND DISCUSSION

Highest annual returns to risk ($41,506) for the hypothetical cage culture enterprise were obtained at the low stocking density (300/m^3). Returns declined to $35,439 (400/m^3) and $30,745 (600/m^3) as stocking density increased (Table 5). Highest annual returns to risk per cage were also obtained at a density of 300/m^3 ($1,153). Returns were maximized by reducing the stocking rate and

Table 4. Variable and fixed costs as a proportion (%) of total costs for a hypothetical cage culture enterprise in a 2-ha pond using three stocking densities of caged Florida red tilapia.

	Density (#/m3)		
Cost area	**300**	**400**	**600**
VARIABLE COSTS:			
Feed	34	40	39
Fingerlings	34	27	29
Hired labor	9	9	9
Manager labor	6	6	6
Electrical	4	4	4
Subtotal:	87	86	87
FIXED COSTS:			
Cage and equipment	10	10	9
Land charge	2	2	2
General overhead	2	2	2
Subtotal:	14	14	13

Table 5. Sensitivity analysis of changes in breakeven price (BEP) to 10% changes in input parameters.

Parameter		**Range Tested**	**Change BEP/10% ($)**
Fingerling ($/each)		$0.25-$0.75	0.07
Feed ($/kg)		$0.37-$1.10	0.11
Manager labor	(%/year)	10%-100%	0.16
	($/year)	$24,000-$33,600	0.02
Hired labor	(%/year)	10%-100%	0.10
	($/year)	$15,000-$21,000	0.03
Survival (%)		70%-100%	0.09
Feed Conversion Ratio		1.00-2.32	0.09

stocking large, male fingerlings. Relatively high returns at the low stocking density can be attributed to higher growth rates which resulted in a greater proportion of harvested fish in the large (higher value) weight category. Although production levels were assumed to be approximately equivalent (carrying capacity ≈ 6000 kg/crop), it is evident that the large proportion of fish in the large weight category at the low density increased revenue. Costs were reduced at the low density by using fewer fingerlings and proportionally less feed as fish converted feed more efficiently.

The lowest breakeven price ($2.66) was obtained at the intermediate density (400/m^3). BEP increased to $2.71 at 300 fish/m^3 and $2.80 at 600 fish/m^3. Compared to the intermediate density, BEP was higher at the low density due to higher costs for male fingerlings. Compared to the intermediate density, BEP was higher at the high density as a greater number of fingerlings were required to achieve an equivalent level of production, and growth and survival rates were correspondingly lower. BEP does not take account of the value structure of fish production and therefore has limited utility as an economic index to evaluate an enterprise. However, if access to capital is a constraint, the lowest BEP will indicate the least-cost enterprise.

Feed constituted the greatest proportion of total costs for the enterprise at all densities (34 – 40%). This is somewhat lower than the 57% of total costs reported for intensive catfish cage culture (Collins and Delmendo, 1976). However, this is consistent with the 35 – 40% of total costs derived from budgets prepared to describe the economics of semi-intensive pond catfish culture (Keenum and Waldrop, 1988; Pomeroy *et al.*, 1989).

Shipping accounts for approximately 33% of feed cost and is an area of potential cost reduction if a local source of feed becomes available. A feed formulated for freshwater prawns (30% protein, Molinos de Puerto Rico #785) is manufactured in nearby Puerto Rico and costs $0.55/kg ($0.44/kg base price, $0.11/kg shipping). Although less expensive, the feed sinks and a substantial quantity may be lost through the cage. Assuming an increased feed conversion ratio to 2.3, annual returns to risk would actually decline by 1.2% to $35,015. The reduced cost associated with a lower quality feed would most likely be offset by slower growth, reduced feed conversion efficiency, and potential water quality deterioration, and therefore would offer no advantage to the farmer.

A floating feed formulated specifically for tilapia (32% protein, Purina #5125) would reduce total feed cost by 10%. Assuming equivalent growth rates, feed conversion, and production at 400 fish/m^3, annual returns to risk will increase 5% to $37,269 and the BEP will decline by $0.11.

The cost of fingerlings is the second most important cost item. Male fingerlings are estimated to cost twice as much as mixed-sex fingerlings and increase total costs by 5 – 7%. At the low density, the higher cost for male fingerlings was compensated for by superior growth rate, more efficient feed conversion, and larger size at harvest, a combination that increased returns to risk by 17 to 35%.

Hired (9%) and manager (6%) labor combined are the third most important cost category. Of all input parameters evaluated, BEP is most sensitive to changes in the amount of time allocated to production activities. However, BEP is relatively insensitive to changes in salary or hourly wages. A 10% increase in the time required for production by manager or hired labor will increase BEP by

$0.16 and $0.10, respectively, while a 10% increase in salary or wages will increase BEP by only $0.02 and $0.03, respectively. A relatively small amount of time is budgeted for cage culture production as demand feeders minimize labor requirements. The remaining time can be allocated to other farm enterprises or earning off-farm income.

The annual (amortized) cost of cages and equipment comprise only 9 – 10% of total costs. This relatively low proportion of total costs indicates that cage cost has only a small effect on the selection of a density for cage culture production. The cost for cages and equipment was lowest at the highest density as fewer cages were utilized.

While survival rates at each density are different, the range is narrow (90.7 – 94.7%). The range of survival rates tested for changes in BEP is much greater than that observed. BEP changes $0.03 over the observed range and $0.09 over the tested range. As tilapia are a very hardy fish, it is unlikely that a 10% reduction in survival would occur, barring a catastrophic event. The stress of poor water quality, exacerbated by high stocking density, has a greater impact on feed conversion and growth rate than mortality. Managing water quality (monitoring dissolved oxygen at dawn, exchanging water if possible) to create an environment conducive to rapid growth and high survival is important for a producer.

The budgets for this hypothetical tilapia cage culture production enterprise suggest that good returns to risk can be obtained at any of the densities tested and that the stocking rate for greatest return to risk is 300 fish/m^3. High growth rate at the low density and the use of male fingerlings improved feed conversion efficiency (reduced costs) and allowed the production of more large fish of higher value (increased revenue).

Given the part-time nature of agriculture in the Virgin Islands and the relatively minimal labor requirements of this production enterprise, a farmer can significantly increase farm revenues by adding cage culture to the farm business. Cage culture can expand the capabilities and increase the profitability of a multi-use farm pond resource for a relatively small investment of time and capital resources.

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