A Breakeven Price Analysis of Four Hypothetical Freshwater Prawn, *Macrobrachium rosenbergii*, Farms Using Data from Kentucky

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ABSTRACT. Freshwater prawn, *Macrobrachium rosenbergii*, are a relatively recent aquaculture crop in Kentucky and neighboring states. Kentucky State University's Aquaculture Research Center (ARC) has been involved in prawn production research in ponds since 1991. Technologies prior to 1996 involved stocking juveniles at relatively low densities (20,000-40,000/ha) and feeding a 32% protein diet, resulting in an average yield of approximately 1,000 kg/ha. From 1996 onwards, artificial substrate has been installed in ponds, which offer greater habitable area, and have increased average yields to more than 1,500 kg/ha (in 1998). Although stocking and feeding rates increased with substrate use, the average feed conversion ratio decreased, indicating more efficient feed usage. From 1998 onwards, a phase feeding practice, with higher feeding rates, was introduced. This involved feeding prawn distiller's grains, 32% protein feed, and 40% protein feed at different stages of the growout period. These feeding practices, in conjunction with a higher stocking density, substrate use, etc., have produced average yields in excess of 2,500 kg/ha (in 1999 and 2000).

While the technological evolution has steadily increased average yields, production costs have also increased. However, breakeven price of production (in year 2000 dollars/kg) decreased from $18.37/kg (1991) to $9.93/kg (2000). Breakeven price analyses, taking output, input quantity, and price risk into consideration, indicate that the technology devel-

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oped in 2000, using intensive stocking, phase feeding and artificial substrate, is the most competitive.

KEYWORDS. Prawn, economics, breakeven price, risk

INTRODUCTION

Production of freshwater prawn, *Macrobrachium rosenbergii,* in Kentucky and surrounding regions is becoming an increasingly popular aquaculture enterprise. Kentucky's prawn production volume has increased from 454 kg (liveweight) in 1994 to 6,350 kg (liveweight) in 1999 (KDA 2000). Factors such as large size of prawn (> 30 g), short production cycle (approximately 100-120 days), and single-batch production system with relatively low management requirements have contributed to the popularity of this industry. Interviews with Kentucky producers have indicated that prawns are highly regarded by local consumers, and typically, most of a harvest is sold at the pond bank at retail prices varying from $11 to $22 per kilogram (liveweight). Some producers have also succeeded in direct marketing as a seasonal specialty to local restaurants.

Similar to other small-scale agricultural industries, as aggregate production increases, market competition could lower sales prices and profit margins. As Kentucky's prawn industry grows, economic analyses of prawn farming are necessary to understand the dependence of profit and costs on technology and market factors, which will ultimately determine the fate of the industry.

The Aquaculture Research Center (ARC) at Kentucky State University has been involved in prawn research for more than 10 years. The evolution of prawn production methods include increasing stocking densities (e.g., 20,000/ha in 1991; 40,000/ha in 1992-94; 60,000/ha in 2000); use of artificial substrate in ponds; increased feed allocations; and shifting from a uniform feed type to feeding distiller's grains, 32% protein feed, and 40% protein feed at different growth stages of prawn. A preliminary survey of Kentucky producers indicated that while most farms have adopted earlier ARC-developed technologies, the more recent management practices have not been widely implemented. Since current technology information is available through Kentucky State University's aquaculture extension program, a plausible explanation for not using recent technology is the lack of information about expected cost/returns and risk issues associated with the different production practices.

Investigating the profitability of ARC-developed technologies from 1991 to 2000 is the aim of this study. Different ARC technologies are compared by investigating investment requirements and evaluating the expected value and variability of breakeven prices under uncertain technology and price parameters. The aquaculture economics literature has seen several recent examples of this type of analysis. Valderrama and Engle (2001) conducted an enterprise budget/risk analysis study of marine shrimp production in Honduras. Engle and Valderrama (2001) provided another instance of this study's simulation methodology in projecting the variable costs and returns in catfish fingerling production.

In the following section an exposition of data and methods of analysis is provided. Results pertaining to breakeven price analysis and risk analysis for three prawn production technologies are then presented. A discussion of the results and their implications on the incipient prawn industry in Kentucky concludes the study.

MATERIALS AND METHODS

Data for this paper were obtained from a variety of sources. Information on input and output quantities was available in the ARC prawn research reports. Table 1 summarizes key production parameters (stocking and feeding rates, yield, etc.) for relevant ARC technologies. For example, research in 1991 led to a low-density protocol, i.e., stocking 20,000/ha (Tidwell et al. 1993). Management practices developed between 1992 and 1994 were almost identical: stocking 40,000/ha and feeding 3,380 kg/ha of a 32% protein diet; this protocol is termed "semi-intensive" (Tidwell et al. 1994, 1995, and 1997). During 1996, stocking density was increased to 60,000/ha, and artificial substrate was introduced into ponds to increase habitable area by 20% (Tidwell et al. 1998). The 1997 management practices involved stocking either 60,000/ha or 120,000/ha with sufficient substrate to increase the pond's habitable area by 80% (Tidwell et al. 1999). The stocking rate was kept fixed at 75,000/ha in 1998, but substrate quantity was kept at either 40% or 80% of a pond's surface area (Tidwell et al. 2000).

The 1999 prawn research used a 65,000/ha stocking density, phase feeding and artificial substrate to increase a pond's habitable area by ei-

TABLE 1. Summary information on different ARC-developed freshwater prawn production technologies since 1991. Substrate use indicates the percentage of a pond's surface area that is additionally available for habitation due to use of artificial substrate, i.e., 0% substrate use implies no substrate has been installed in the pond. Vertical orientation of artificial substrate was introduced only during (and after) 1999.

Name	Stocking density (Juveniles/ha)	Feed type and feeding rate (kg/ha/year)	Average yield (± yield std. dev.) (kg/ha/year)	FCR[a]	Substrate use (%)
1991 technology[b]	20,000	2,569[e]	834 (± 38)	3.13	0
1992 technology[c]	40,000	3,380[e]	1,268	2.90	0
1993 technology[c]	40,000	3,380[e]	990	3.90	0
1994 technology[c]	40,000	3,380[e]	1,261 (±119)	2.31	0
1996 technology	60,000	2,580[e]	1,268 (±81)	2.33	20-Horizontal
1997 technology 1	60,000	2,958[e]	1,195 (±75)	2.51	80-Horizontal
1997 technology 2	120,000	4,383[e]	1,744 (±218)	2.54	80-Horizontal
1998 technology 1	75,000	4,193[e]	1,659 (±32)	2.6	40-Horizontal
1998 technology 2	75,000	4,315[e]	1,816 (±75)	2.4	80-Horizontal

1999 technology 1	65,000	DDGS[f]: 341 32% protein feed: 2,447 40% protein feed: 1,842	2,453 (±116)	2.7	50-Horizontal
1999 technology 2	65,000	Phase feeding (as above)	2,453 (±61)	2.6	50-Vertical
1999 technology 3	65,000	Phase feeding (as above)	2,653 (±214)	2.50	100-Vertical
2000 technology 1[d]	60,000 Ungraded[g]	DDGS[f]: 1,276 32% protein feed: 1,377 40% protein feed: 3,258	2,549 (±100)	2.26	50-Vertical
2000 technology 2	60,000 Small, Graded[g]	DDGS[f]: 1,276 32% protein feed: 2,081 40% protein feed: 3,258	2,945 (±127)	2.20	50-Vertical

[a] FCR stands for Food Conversion Ratio.
[b] Identifying name for this technology: Low density.
[c] Identifying name for this technology: Semi-intensive density.
[d] Identifying name for this technology: Intensive stocking with phase feeding.
[e] Feed type: 32% crude protein, sinking pellets.
[f] DDGS stands for distiller's grains with solubles.
[g] 'Ungraded' means stocking juveniles of varied sizes; graded juveniles have a relatively uniform size.

ther 50% or 100% (Tidwell et al., In Press). Phase feeding involved increasing feed allocation by approximately 20% above the D'Abramo et al. (1995) recommendations and feeding unpelleted distiller's grains with solubles (DDGS) for the first four weeks, followed by a 32% protein sinking pelleted feed (weeks 5-12) and a 40% protein shrimp diet (week 12 to harvest). Size-graded juveniles were introduced in 2000 (unpublished data). Stocking rate was kept at 60,000/ha; phase feeding was used; and substrate quantity was kept at 50% of a pond's surface area. The 2000 management protocol using ungraded juveniles is called "intensive stocking with phase feeding."

Land was assumed to be valued at $2,500/ha, and pond construction cost was assumed to be $3,500/0.4-ha pond in western Kentucky and $5,000/0.4-ha pond in central Kentucky. The lower pond construction cost in western Kentucky is partially accounted for by more flat land and less rocky soil than the land in central Kentucky. Since most Kentucky prawn ponds are filled by runoff from a watershed, well construction costs and pumping costs to fill a pond were omitted.

A survey of Kentucky's prawn producers (sample size = 16, population size = 80) indicated juvenile (age: 60 days) prices varied from between $0.08 and $0.12, for each 0.3 g to 0.5 g animal, although $0.10/head was the most typical price (unpublished data). A price range for DDGS feed was also evaluated from the producer survey: from $158/metric ton to $354/metric ton (average price = $254/metric ton). Average price of 32% protein feed (sinking channel catfish feed pellets) at, $240/metric ton, was obtained from ARKAT Feed Mill (Dumas, Arkansas[1]) and average price of 40% protein shrimp feed, at $729/metric ton, was obtained from Rangen Inc. (Buhl, Idaho). These prices include shipping charges to Frankfort, Kentucky.

Electricity prices were obtained from United States Department of Energy (USDOE) reports and were $0.067/KWH. Pond aeration is the main source of electricity use, and a single 1-hp paddlewheel aerator per 0.4 ha pond was assumed. Such an aerator is rated at 1,760 watts, which translates to 42.24 KWH/24 hours (Aquatic Eco-Systems Inc., Apopka, Florida).

Labor data were derived from both field trials of ARC technologies and producer estimates. Labor requirements for a single, 0.4 ha pond was two hr for stocking, 24 man-hours for substrate installation (six individuals working for four hr), 1 hr/day for feeding and water quality tests, 0.5 hr/day for making management decisions, and 20 man-hours

1. Use of trade or manufacturer's name does not imply endorsement.

for harvesting (five individuals working for four hr). Labor for mowing, weed removal, etc. was assumed to be two hr/week/0.4-ha pond. The opportunity cost for labor used in stocking, feeding, mowing and harvesting was assumed to be $5.25/hr, and management was available at $8.00/hr.

Harvesting typically involves draining a pond to concentrate prawn in a catch basin, from which they are collected by seines and transferred to holding tanks, in preparation for sale. Kentucky prawn farmers have access to harvest trailers rented from the Kentucky Aquaculture Association (rate: $50/3 days), which come equipped with pumps, nets, holding tanks and aeration equipment. Apart from trailer rental and labor, other harvest inputs include fuel and oxygen. While a harvest trailer has a few holding tanks, if a farm has multiple ponds, additional holding tanks are necessary at harvest. Harvesting every additional 0.4-ha pond was assumed to require four 800-gallon (polyethylene) holding tanks at $400/tank (Aquatic Eco-Systems Inc., Apopka, Florida).

Many Kentucky prawn farmers incur marketing expenses for pondbank sales, such as Ziplock bags, newspaper advertisements, etc. Marketing costs were broken into packaging and advertisement costs. Producer interviews suggested that pond side sales, on average, required $50 of packaging materials per 0.4-ha pond. Advertisements also accounted for a $50 investment. Ice (priced at $0.31/kg) is essential for post-harvest storage; the quantity of ice purchased should equal the volume of output (Madrid and Phillips 2000). Other variable costs include chemicals ($61/0.4-ha pond), accounting and legal fees ($100/farm), telephone ($80/farm), fuel (pumping, truck, and mower), and annual maintenance expenses (charged at 2% of the value of depreciable assets).

A small-scale prawn farm requires a 1-hp electric aerator per 0.4-ha pond ($750), one dissolved oxygen (DO) meter ($715), one 5-hp water pump ($542), and one water-quality test kit ($179) per two ponds per year (Aquatic Eco Systems Inc., Apopka, Florida). Other equipment includes a pickup truck ($20,000), mower ($1,000), weed eater ($150), storage shed (charged at $108/m^2), weighing scale ($194), and miscellaneous items ($50). Most producers use the truck, mower, and weed eater in prawn farming in conjunction with other agricultural enterprises. Hence, we charged only a percentage of the use of a truck (3%), mower (4%), and weed eater (4%) to the prawn farming enterprise.

The ARC experiments found that 120 cm-wide panels of polyethylene "construction/safety fence" with a mesh opening (length $\times$ width) of 7.0 cm $\times$ 3.5 cm are an optimal choice for substrate (Tidwell et al. in press). Polyethylene fence is available to Kentucky prawn producers in

37.17 m^2 rolls, at \$22/roll (United Rentals, Lexington, Kentucky). An identical roll of fence is available nationwide at \$50/roll (Aquatic Eco Systems Inc., Apopka, Florida). If the area of a 0.4 ha pond is to be increased by 50%, 2,024.16 m^2 of solid area must be added in substrate. Since only 60% of the substrate area is solid material, 3,373.60 m^2 or 91 rolls must be installed in the pond at a cost of \$2,002 (in Kentucky) or \$4,550 (nationwide).

Kentucky's climate allows a single annual growing season for prawn, typically from the beginning of June to mid-September (107 days, approximately). Breakeven prices for four hypothetical prawn farms in Kentucky containing one, two, three and four ponds (each 0.4 ha), respectively, are analyzed in this study. For sake of brevity, three management protocols that represent technologies that have been commercially adopted were focused on: (1) low density, (2) semi-intensive, and (3) intensive stocking with phase feeding. The analytical procedure can be divided into two sections: breakeven price analysis and risk analysis.

The breakeven price analysis was based on small-scale Kentucky prawn farms consisting of one, two, three, or four 0.4-ha watershed ponds. Since most prawn culture in Kentucky is limited to farms with a few (less than four) 0.2-ha and 0.4-ha ponds, our model's framework is relatively representative of reality. Breakeven prices were derived from enterprise budgets developed for different ARC management protocols. These budgets contain both experimental and farm data. Experimental data were available for stocking density, feed type, feed rates, and yield (Table 1). A farm survey provided data on items such as cost of aeration, labor, chemicals, harvesting, telephone, accounting/legal fees, etc. These costs were assigned to the four hypothetical farm sizes (0.5 ha to 2 ha) to explore economies of size in prawn farming.

Fixed costs were broken into annual depreciation and interest expenses. Depreciation was computed on a straight-line schedule (Kay and Edwards 1999). The service lives of depreciable items were as follows: pond-10 years, substrate-5 years, aerator-3 years, DO meter-5 years, pump-10 years, truck-10 years, mower-10 years, weed-eater-5 years, weighing scale and miscellaneous items-10 years. Interest on capital assets was computed at a 10% per-annum rate on land and pond construction costs; however, interest on all other depreciable items was computed on an average investment basis (one-half of initial investment). Dividing total costs with total output provided a breakeven price of prawn (\$/kg), under each ARC experimental protocol. All prices and costs were reported in U.S. dollars for the year 2000.

Kentucky producers have the option of purchasing juveniles directly from independent hatcheries or contracting with regional prawn marketing firms, from which a farmer purchases seed and feed at a contracted price and sells harvested prawn to the marketing firm at a pre-determined price. Recent trends have shown that while juvenile prices from independent hatcheries/nurseries have remained fairly stable ($0.10/head), prawn-marketing firms have been increasing juvenile prices to $0.12/head. Accordingly, the paper included sensitivity analysis on breakeven prices for three juvenile prices: $0.08/head, $0.10/head, and $0.12/head.

While total production volume was derived from the ARC-average yields, it is unlikely that producers would receive 100% of the experimental yields. Typically, experimental stations, such as the ARC, are staffed with a skilled and vigilant workforce. Most small-scale prawn farmers are concurrently involved in other farming activities, and many have a maximum of two individuals to manage the ponds. Hence, the type of care and level of scientific expertise available in experiment stations are often unavailable in real-world prawn farms. This is typically exhibited in the form of commercial farms having lower-than-experimental yields. In a recent producer survey of Kentucky's prawn farms it was found that producers using semi-intensive management (stocking 40,000/ha) were receiving yields that were 92% of experimental yields (unpublished data, Kentucky State University). This 92% figure was used to calculate yields; i.e., it was assumed that real-world farm yields were 92% of experimental yields, on average, for all management protocols.

Risk analysis illustrates how the average production cost varies when yields, input levels, and prices are unpredictable. Uncertain output was captured through the yield standard deviation, which is part of ARC technology reports. A management-risk factor was also included in determining risky yield, as a multiplicative random variable. Management risk incorporates the likelihood of a total loss due to pond management errors, sudden temperature drops (prawn die if water temperature falls below 15.56°C), etc. It also models yield reduction due to bird and animal predation. The management risk random variable was assumed to have a triangular distribution with minimum value = 0 (total loss), maximum value = 1, and likeliest value = 0.92. Electric power necessary to operate aerators was also a variable quantity: power needs for 1-hp paddlewheel aerators vary between 6.8 to 8 watts (Aquatic Eco-systems, personal communication). Input price variability was another source of risk. In this study, prices of juveniles, electricity, and DDGS feed, sinking catfish feed, and shrimp feed were considered uncertain.

Table 2 summarizes the choice of distribution of each uncertain parameter used in evaluating the breakeven price. Triangular distribution was assumed for these items, which is considered to be a good representation of empirical distributions when only a few data points of random variable values are available (Valderrama and Engle 2001).

Variation of catfish and shrimp feed prices were derived from Hanson and Hopper (2000), who provided deflated prices of catfish feed from 1986 to 1999. Using the deflated prices, time-series analyses were conducted to identify trend, seasonal, and other systematic components in historic catfish feed prices. Catfish feed prices were found to have the following structure: $\text{FeedPrice}_t = \text{Exp}[-2.27^* - 0.002^* \times t - 0.000007 \times t^2] + r2_t$ (coefficient estimates with an asterisk are significantly different from zero, adjusted $R^2 = 63\%$), where $r2_t = 0.959^* \times r2_{t-1} - 0.152 \times r2_{t-12} - 0.195^* \times r2_{t-24} + e_t$ (e_t is a stationary time series, t: time).

TABLE 2. Assumed probability distribution of random variables used in the risk analysis of prawn farming in Kentucky. All prices are in year 2000 $.

Variable	Unit	Distribution	Parameter	Parameter value
Yield	Kg/ha	Normal	Mean (Std. Deviation)	Reported in Table 1
Management risk	-	Triangular	Minimum	0
			Maximum	1
			Likeliest	0.92
Juvenile price	$/head	Triangular	Minimum	0.08
			Maximum	0.12
			Likeliest	0.10
DDGS[a] price	$/metric ton	Triangular	Minimum	158
			Maximum	354
			Likeliest	254
Sinking catfish feed price	$/metric ton	Normal	Mean (Std. Deviation)	240 (107)
Shrimp feed price	$/metric ton	Normal	Mean (Std. Deviation)	729 (107)
Electricity price	$/kilowatt hour	Extreme value distribution	Mode	0.04
			Scale	0.07
Aerator wattage	Watts	Uniform	Minimum	6.8
			Maximum	8.0

[a] DDGS stands for distiller's grains with solubles.

Several probability distributions were fitted to the de-trended residuals (e_t): a normal distribution with zero mean and standard deviation = \$0.07/kg was chosen (chi-square test statistic value for goodness-of-fit was 41.82, p-value = 0). Hence, the randomness of catfish feed price was characterized by normal distributions with standard deviation of \$0.07/kg. Dasgupta and Engle (2000) illustrated that shrimp and catfish feed prices exhibit similar fluctuations over time. Lim (1998) and Robinson (1998) show that catfish and shrimp diets have many common ingredients. Hence, catfish and shrimp feed prices are dependent on the prices of their common components, which led to this study's assumption that deflated shrimp feed price is also normally distributed with a standard deviation of \$0.07/kg.

Electricity prices have also varied over the last few years. A time series analysis was conducted on deflated annual electricity retail prices, based on USDOE data since 1985. Results show that electricity prices (E_t) have a linear trend component, with AR(1) error terms: $E_t = 9.773^* - 0.184^* \times t + 0.649^* \times E_{t-1} + u_t$ (coefficient estimates with an asterisk are significantly different from zero, adjusted $R^2 = 96\%$), where u_t represents a white-noise series. In fitting a probability distribution on u_t, an extreme value distribution was chosen (mode = 0.04, scale = 0.07, Anderson-Darling test-statistic value = 0.2532; i.e., accept null hypothesis that the test distribution is not significantly different from an extreme value distribution).

The risk analyses were conducted as a stochastic simulation using Crystal Ball, a spreadsheet add-in program (Zucker and Anderson 1999, Valderrama and Engle 2001). Monte Carlo simulations (5,000 simulations) were used to generate probability distributions of breakeven price based on probability distribution of prawn yield, input quantities, and input prices.

RESULTS

Breakeven Price Analysis

Table 3 outlines variable and fixed costs for three technologies: low-density, semi-intensive, and intensive stocking with phase feeding. Apart from different stocking densities, the technologies differed primarily in the type and quantity of feed. Stocking costs were substantially higher than feeding costs: Table 3 shows that the cost of stocking was 1.7 times (under intensive stocking with phase feeding) to 4 times

TABLE 3. Annual costs and breakeven price for prawn farming in a 0.4 hectare watershed pond using three example ARC-developed technologies. All price/costs are reported in U. S. dollars for the year 2000. Assume a 107-day growing season (i.e., from June 1st to September 15th).

			Low-density technology		Semi-intensive technology		Intensive stocking with phase feeding	
Item	Unit	Cost/Unit ($)	Quantity/pond	Value $/pond	Quantity/pond	Value $/pond	Quantity/pond	Value $/pond
Yield	Kg		306		373		934	
Variable Costs								
Juveniles	each	0.10	8,000	800.00	16,000	1,600.00	24,000	2,400.00
Feed: DDGS[a]	Kg	0.29	0	0.00	0	0.00	511	148.19
Feed: 32%[b]	Kg	0.28	1,027	287.56	1,352	378.56	551	154.28
Feed: 40%[c]	Kg	0.82	0	0.00	0	0.00	1,303	1,068.46
Chemicals	Appl.	61.00	1	61.00	1	61.00	1	61.00
Electricity	KWH	0.07	4,520	316.40	4,520	316.40	4,520	316.40
Pumping cost	# of times	20.00	1	20.00	1	20.00	1	20.00
Labor	Hours	5.25	159	834.75	159	834.75	159	834.75
Management	Hours	8.00	54	432.00	54	432.00	54	432.00
Fuel	Gallon	1.50	50	75.00	50	75.00	50	75.00
Accounting/legal fees	$	100.00	1	100.00	1	100.00	1	100.00

Maintenance	$			169.00		169.00		169.00
Harvest trailer	Day	50.00	1	50.00	1	50.00	1	50.00
Ice	Kg	0.31	334	103.54	408	126.48	1,020	316.20
Oxygen	Tank	17.00	1	17.00	1	17.00	1	17.00
Telephone	$			80.00		80.00		80.00
Packaging and advertisements	$			100.00		100.00		100.00
Interest on var. cost	$	10%		114.88		145.34		211.41
Total variable cost				3,446.25		4,360.19		6,342.28
Fixed Costs								
Total depreciation				1,254.70		1,254.70		1,779.81
Interest on fixed cost	$	10%		797.00		797.00		928.26
Tax				8.50		8.50		8.50
Total fixed cost				2,060.20		2,060.20		2,716.57
Total cost				5,621.33		6,565.73		9,270.26
Breakeven price	$/Kg			18.37		17.60		9.93

[a] DDGS stands for distillers grain with solubles.
[b] Sinking feed containing 32% crude protein (Tidwell et al., in press).
[c] Sinking shrimp feed pellets containing 40% crude protein (Tidwell et al., in press).

(under semi-intensive management) the cost of feeding. While semi-intensive and intensive stocking with phase feeding technologies were more costly to implement, they produced proportionately higher yields. Hence, breakeven prices fell from $18.37/kg (low-density) to $17.60/kg (semi-intensive) to $9.93/kg (intensive). If artificial substrate was purchased at $50/roll, the breakeven price for the intensive stocking with phase feeding technology would increase to $10.60/kg.

Table 4 consists of a breakdown of fixed costs for a hypothetical farm with a single 0.4-ha pond. While total fixed costs were relatively low for all technologies, the substrate-free low-density and semi-intensive technologies required less capital investment. This cost difference has often been cited as a factor for some farmers to avoid using substrate in prawn ponds.

Table 5 indicates variable cost items (juveniles, feed, labor, and energy) as a percentage of total costs for each technology. In channel catfish, *Ictalurus punctatus*, aquaculture, feed, fingerlings, and labor are

TABLE 4. Resources and equipment[a] necessary for a hypothetical freshwater prawn farm in Kentucky with a single 0.4-ha pond. Prices and costs are in 2000 U.S. dollars.

Resource/Equipment	Cost ($)	Lifespan	Depreciation ($/year)	Annual Interest ($/year)
Land (0.5 ha)	1,250	-	-	125.00
Pond (0.4 ha)	5,000	10 yrs	500.00	500.00
Aerator (1 hp)	750	3 yrs	250.00	37.50
Water pump (5 hp)	540	10 yrs	54.00	27.00
DO meter	715	5 yrs	143.00	35.75
Water quality kit	179	1 yr	179.00	8.95
Weighing scale	194	10 yrs	19.40	9.70
Substrate[b]	2,626	10 yrs	262.60	131.30
Pickup truck[c]	20,000	10 yrs	2,000.00	1,000.00
Lawn mower[c]	1,000	10 yrs	100.00	50.00
Storage building[c]	1,000	10 yrs	100.00	50.00

[a] Harvesting was excluded, based on the assumption that the equipment is rented from Kentucky Aquaculture Association. Depreciation was computed based on a straight-line method with zero salvage value. Interest was computed based on a 10 % annual rate.
[b] "Substrate costs" represent the volume of polyethylene construction fence material, stakes, and other supplies necessary to increase the surface area of a 0.4-ha pond by 50%.
[c] It is assumed that the pickup truck, lawn mower/weed-eater and storage shed are used for prawn farming for 3%, 4%, and 33% of the time during a year, respectively.

TABLE 5. Major variable cost items for a hypothetical prawn farm with a single 0.4-ha watershed pond, expressed as a percentage of total cost for each technology.

	Technology		
	Low-density	Semi-intensive	Intensive stocking with phase feeding
Juveniles	14.34%	24.55%	26.05%
Feed	4.95%	5.58%	14.78%
Labor and management	22.63%	9.37%	13.71%
Fuel (electricity, gasoline, and diesel)	7.07%	6.05%	4.28%

45%, 8%, and 9% of total costs, respectively (Engle and Kouka 1996). In prawn farming, juveniles are often the proportionately highest cost variable input. Feed costs are a relatively small proportion of total costs; however, the introduction of phase feeding with expensive shrimp diet (> $700/metric ton) increased the cost share of feed from 5% to 15% (approximately).

Table 6 reports the breakeven price ($/kg) for the three technologies by altering the juvenile price from $0.08/head to $0.12/head. The breakeven prices are also tabulated by changing the pond construction cost from $3,500/0.4-ha pond to $5,000/0.4-ha pond. This reflects the differences in building ponds in western Kentucky versus central Kentucky, respectively. The change in pond construction cost reduced the breakeven price by (approximately) 5% for low-density and semi-intensive technologies, and 3% for the intensive stocking with phase feeding technology. Finally, Table 6 shows the change in breakeven price resulting from having progressively bigger farms (i.e., for farms with one to four 0.4-ha ponds). The breakeven price falls by 16%, 14%, and 10% for low-density, semi-intensive, and intensive stocking with phase feeding technology, respectively, if farm size increases from having one 0.4 ha of water to four 0.4 ha ponds.

Prawn marketing firms in Kentucky advertised wholesale prices for live prawn from $9.57/kg to $12.10/kg in 2000-2001. Table 6 shows that only intensive stocking with phase feeding was able to generate a sufficiently low breakeven price that would make wholesale marketing of prawn profitable. Table 6 also indicates that prawn producers would find it difficult to compete in the wholesale market for jumbo marine shrimp: average ex-vessel price for gulf shrimp (31-35 count) was

TABLE 6. Breakeven price of producing prawns (in 2000 $/kg) in four hypothetical farms containing one, two, three, and four 0.4-ha watershed ponds.

	Juvenile price = $0.08/head				Juvenile price = $0.10/head				Juvenile price = $0.12/head			
	1 pond	2 ponds	3 ponds	4 ponds	1 pond	2 ponds	3 ponds	4 ponds	1 pond	2 ponds	3 ponds	4 ponds
Pond construction cost = $3,500/0.4-ha pond												
Low-density	16.74	15.69	14.40	13.87	17.28	16.23	14.94	14.41	17.82	16.77	15.48	14.95
Semi-intsv[a]	15.75	14.89	13.84	13.41	16.64	15.78	14.73	14.30	17.52	16.66	15.61	15.18
Phase feed[b]	9.01	8.67	8.25	8.07	9.54	9.20	8.78	8.60	10.07	9.73	9.31	9.14
Pond construction cost = $5,000/0.4-ha pond												
Low-density	17.72	16.67	15.38	14.85	18.26	17.12	15.92	15.39	18.80	17.75	16.46	15.93
Semi-intsv[a]	16.56	15.70	14.65	14.21	17.44	16.58	15.53	15.10	18.33	17.47	16.41	15.98
Phase feed[b]	9.33	8.99	8.57	8.40	9.86	9.52	9.10	8.93	10.39	10.05	9.63	9.46

[a] "Semi-intsv" stands for the semi intensive technology.
[b] "Phase feed" stands for the intensive stocking with phase feeding technology.

$10.35/kg (tails) or $4.93/kg (prawn liveweight, assuming a 47.6% dressout yield).

Risk Analysis

Table 7 reports the likelihood of breakeven price falling below $11/kg, $13.20/kg, $15.40/kg, $17.60/kg, $19.80/kg, and $22/kg, for each of the three prawn technologies. These probabilities can be perceived as the odds of making a positive profit if prawn were sold at the above prices. Clearly, low-density and semi-intensive technologies have a low profit potential if the selling price of prawn is less than $15.40/kg. This should be of interest to producers who use the semi-intensive technology and attempt to sell their crop at wholesale prices, which are usually less than $15.40/kg.

The minimum breakeven price for each technology indicates the best production/price scenario specific to that technology. Producers are assured of a loss if they sell prawn at less than the minimum breakeven price. Due to economies of size, the minimum breakeven price is lower for larger farms. For example, the minimum breakeven price for a 2-ha farm (with four 0.4-ha ponds) is $14.11 (low-density technology), $10.06/kg (semi-intensive technology), and $7.47/kg (intensive stocking with phase feeding technology). Since average wholesale marine shrimp prices (for jumbo shrimp comparable to the prawn) in year 2000 were $4.93/kg (based on prawn liveweight), none of the three prawn technologies are competitive in the marine shrimp market.

Figure 1 illustrates the cumulative distribution functions (CDF) of breakeven price for the selected technologies. The breakeven price CDFs submit an efficiency grading of the different prawn technologies. If one CDF is to the left of another CDF, the former technology is more likely to achieve a profit than the latter technology. Clearly, the intensive stocking with phase feeding technology is dominant over the two other technologies, which is followed by the semi-intensive technology.

DISCUSSION

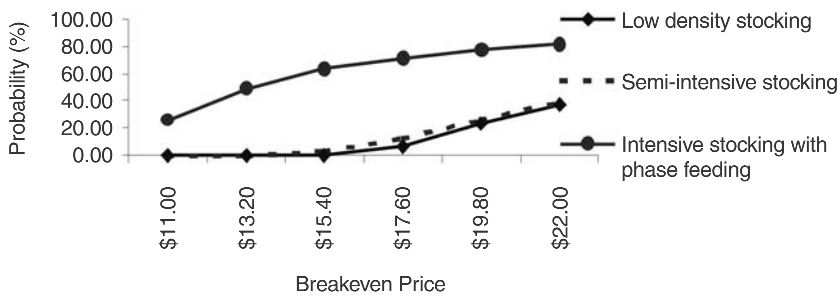
Freshwater prawn culture is attractive to Kentucky farmers with limited aquaculture experience, because of its relatively low management requirements and good consumer acceptance. Of the different pond management methods developed by the ARC, three technologies have seen commercial adoption: low-density stocking, semi-intensive stock-

TABLE 7. Risk analyses results: probability (%) of breakeven price being less than $11/kg, $13.20/kg, $15.40/kg, $17.60/kg, $19/80/kg and $22/kg, for each ARC-developed freshwater prawn technology, for four hypothetical farm sizes (size 1: one 0.4-ha pond, size 2: two 0.4-ha ponds, size 3: three 0.4-ha ponds and size 4: four 0.4-ha ponds). All prices are reported in U. S. year 2000 $. Assume pond construction cost is $5,000/0.4-ha pond.

Tech	P(BP[a] < $11)				P(BP[a] < $13.20)				P(BP[a] < $15.40)				P(BP[a] < $17.60)				P(BP[a] < $19.80)				P(BP[a] < $22)			
	Farm Sizes				Farm Sizes				Farm Sizes				Farm Sizes				Farm Sizes				Farm Sizes			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Low-density	0	0	0	0	0	0	0	0	.1	.9	5.9	12	6.6	13	26	31	24	32	41	46	38	44	53	56
Semi-intensive	0	0	.2	.2	.3	1.2	2.6	3.6	3.7	6.5	13	15	13	19	27	32	27	35	42	44	40	46	53	54
Phase feeding[b]	26	31	38	41	49	53	58	58	64	66	69	70	71	73	76	77	78	79	81	82	82	83	84	85

[a] "BP" stands for breakeven price.
[b] "Phase feeding" stands for the intensive stocking with phase feeding technology.

FIGURE 1. Cumulative probability distributions of breakeven price for selected ARC prawn technologies.



ing, and intensive stocking with phase feeding. This study outlines the costs of implementing the three technologies; it also indicates the range of breakeven prices under output quantity, price, and management factor uncertainty.

The low-density technology is associated with the highest breakeven price. While this might indicate a low profit potential, ARC research has shown that the harvested prawn from low-density stocking are relatively large (average size > 50 g) (Tidwell et al. 1993). Capitalizing on the large prawn size in specialty niche markets could be the key to making this technology profitable.

Interviews with farmers have shown that many are using the semi-intensive technology. The popularity of this technology can be traced to the following reasons: (1) relatively low stocking and feeding costs, (2) no substrate investment required, (3) relatively large harvest size of prawn (average size > 30 g), and (4) this technology required of producers who contract-grow prawn with prawn-marketing firms. Results of this study show that producers have a less than 5% probability of making a profit at prices less than $13.20/kg; this price is slightly more than the contracted prices currently offered by prawn marketing firms.

This paper indicates that stocking juveniles at 60,000/ha with phase feeding in ponds with artificial substrate produced the lowest breakeven prices. The breakeven prices for this technology were also sufficiently low to allow profitable marketing at current wholesale prices of prawn ($9.57/kg to $12.10/kg in 2000-2001). However, despite its potential, producers have not widely adopted this technology. Some farmers are opposed to installing artificial substrate because of the additional investment and labor. Even if these issues are surmounted, using a high yield producing technology presents marketing challenges of its own. Currently, producers using the lower-yield, semi-intensive technology have reported insufficient demand for pond bank sales, their main outlet for prawn, and have not been able to sell their entire crop. Hence, prior to adopting the intensive stocking with phase feeding technology that produces more than twice the yield of the semi-intensive technology, producers should explore new markets.

Results of this paper suggest, as corroborated by producer interviews, that marketing prawn raised in small-scale farms can be a challenge. This is partly due to the relatively high breakeven prices in comparison with prices of imported prawn and marine shrimp. As this paper indicates, wholesale markets are still unprofitable for many producers. Additional research is necessary to open new niche markets that can profitably support this industry.

Infrastructure development should be another arena of progress for the long-term success of prawn farming. For example, stocking costs are proportionately one of the highest input cost items (Table 5). Efficient hatcheries and nurseries might make juveniles available at lower prices, which would decrease breakeven prices and make marketing prawn more competitive. Infrastructure development should also include issues such as scheduling harvests with market demand and improvement of storage and transportation techniques. These issues would help determine the future of the prawn industry and are food for future studies.

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