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RISK ANALYSIS OF SHRIMP FARMING IN HONDURAS

Eighth Work Plan, Marketing and Economic Analysis Research 2 (8MEAR2)
Final Report

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ABSTRACT

Honduras has established itself as the leading producer of pond-raised shrimp in Central America. Although this activity already represents the third staple of the national economy, relatively few economic analyses have been conducted to date. For this study, data on production of farm-raised shrimp were collected from 21 farms. Data are from the year 1997. Information was collected on technical aspects of shrimp culture (stocking densities, feeding rates, FCRs) as well as on financial performance of the farms (production costs, farm revenue) during the considered period. A risk analysis was carried out from the resulting data. Three scenarios were defined according to farm size and a fourth was created to aggregate farms with uncommonly high yields. Scenarios were defined in order to identify possible differences in management strategies. Simulations for this study were run with commercially available risk analysis software. Results indicated that farms of the last scenario have developed a major potential for profit, far greater than that of those farms adopting more conservative approaches. Risk is more associated with low yields than with high production costs. Regardless of size, farms should target a minimum acceptable yield. Annual production of less than 450 kg ha^{-1} is connected with a large potential for loss.

INTRODUCTION

Honduras is the major producer of farm-raised shrimp in the Central American region with 12,000 metric tons (live weight) produced on 14,000 ha of shrimp farms during 1998 (Rosenberry, 1998). The first commercial shrimp operations in Honduras began in 1980 (Weidner, 1991), and the industry entered into a period of rapid growth in 1987 when new farms were opened and existing operations were expanded. Annual shrimp exports increased steadily for several years, but production declined in 1994 when the first incidences of Taura Syndrome Virus (TSV) were reported in Honduras. Some analysts (ANDAH, 1997) point out that the industry may have already entered a stage of maturity and that profitability of operations in the future will depend largely on the efficient use of available resources.

Shrimp farming has grown at an accelerated pace worldwide. The rapid growth of the industry has been accompanied by fluctuating prices and quantities supplied that have contributed to an unstable market. The collapse of the shrimp farming industries in China, the Philippines, and Taiwan due to diseases caused by overstocking and the lack of rotation of ponds further contributed to the instability in the shrimp market.

Continued problems with disease and environmental concerns have encouraged shrimp farmers to evaluate traditional management practices and to seek to reduce dependence on external resources such as abundant supplies of wild seed and clean estuarine waters. There is a recognized need for tools that quantify the uncertainties and risks associated with shrimp production.

Optimization models have been developed for shrimp farming in Panama (Pérez, 1986), Ecuador (Dunning, 1989), and Honduras (Stanley, 1993). Using linear programming, these models have been used to determine profit-maximizing stocking densities and production scheduling for representative farms. Hatch et al. (1987) evaluated shrimp production in Panama with a MOTAD (Minimization of Total Absolute Deviations) risk model that considered the worst possible outcomes (e.g., shrimp are hit by a disease and the final survival rate is 0%).

The primary objective of this study was to analyze the profitability of shrimp farming in Honduras under conditions of risk and uncertainty. Specifically, enterprise budgets were developed for typical farm situations and management options without accounting for risk. Finally, the effect of risk on profitability was evaluated through Monte Carlo simulation.

Results of the risk analysis are intended to provide the farm manager–decision maker with a compendium of possible outcomes that could be obtained under different scenarios, which are modeled according to the characteristics of the Honduran shrimp industry. This information can be used to redirect current practices to either minimize the impact of operation failures or improve the chances of an increased profit.

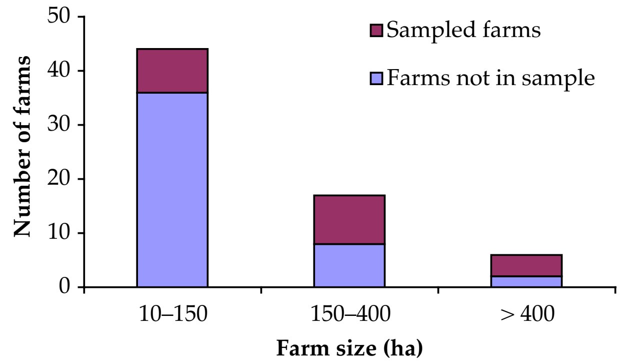
MATERIALS AND METHODS

A direct, personal survey of shrimp farms was conducted in Honduras to obtain information on production costs and technical aspects of shrimp culture such as stocking densities, feeding rates, and FCRs. A stratified random sample of 21 farms was drawn from the sampling universe of 67 commercial shrimp growers identified by the National Aquaculture Association of Honduras (ANDAH). Farms were stratified by size based on previous studies (Aguirre and Torres, 1991) and

Table 1. Size distribution of shrimp farms in Honduras.

Farm Size	Farms		Area	
	Number	*%*	*ha*	*%*
10 to 150 ha	44	66	2,710.13	22
150 to 400 ha	17	25	4,605.75	37
> 400 ha	6	9	5,089.28	41
Total	67		12,405.16	

Source: ANDAH (1997).



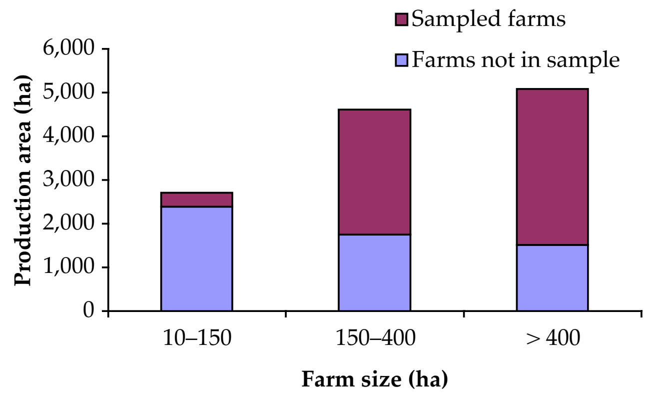


Figure 1. Distribution of shrimp farms in Honduras by size range: small (10 to 150 ha), medium (150 to 400 ha), and large farms (more than 400 ha). Bar height indicates number of farms and total production area for each size group. Upper portion of the bars represents number and production area of the farms included in the survey.

by the current size distribution of shrimp farms in Honduras (Table 1). Farms of similar size were substituted for those selected in the original sample that refused to participate. Survey data were entered into spreadsheets, summarized, and cross-tabulated. Figure 1 displays the proportion of shrimp farms in the sample in terms of the number of farms and the production area.

Representative enterprise budgets were developed for each farm size group based on the survey data using standard budgeting techniques (Kay and Edwards, 1994). Values used in the enterprise budgets were means for a given parameter for each respective farm size. A fourth enterprise budget was developed for some large- and medium-sized farms having yields greater than 1,250 kg ha^{-1} yr^{-1}. Stocking and feeding rates and production costs are also higher for this group of farms. These differences in production, management, and cost characteristics made it necessary to develop a separate enterprise budget. To facilitate denomination of scenarios for the risk analysis, the last group of farms are called "intensive," even though in shrimp aquaculture this term is applied worldwide to units producing more than 4,500 kg ha^{-1} yr^{-1} (Fast, 1992). Operations of this type are rare in Latin America since a high capital input is needed in response to constraints in availability of land, water, and cheap labor. Although by definition the term "intensive" is not used correctly in this study, it serves to illustrate differences among scenarios.

The risk analysis was conducted as a stochastic simulation using Crystal Ball™ software. This is a spreadsheet add-in program that allows the incorporation of uncertainty in risk analysis models. Previous applications of this program to aquaculture situations include the stochastic model of a summer flounder firm developed by Zucker and Anderson (1999). In the simulations, ranges of values that individual variables or parameters may take are defined by probability distributions instead of the single mean values used in standard enterprise budgets. Monte Carlo simulation techniques (using 500 iterations) are used to generate values for individual cost and quantity parameters based on the probability distributions. Results present the entire range of possible outcomes and the likelihood of achieving them.

Different distribution forms were selected for different parameters based on availability of data and with input from professionals with long-term experience with the shrimp industry in Honduras. Table 2 summarizes the choice of distributions for each item in the enterprise budgets and the correspondent values selected as distribution parameters.

Production area (ha) within each farm size category was defined with a uniform distribution: all values between the minimum and maximum occur with equal likelihood, and minimum and maximum values correspond to the limits for each size range. Normal distributions were used to define shrimp yields and prices. These parameters are highly variable and influenced by many factors. Yield is determined by stocking densities, feeding rates, cycle length, and overall survival, but is also influenced by weather patterns that fluctuate randomly. Farm prices depend on average shrimp size, marketing strategies, and supply-demand interactions in the international market at the moment of harvest. These uncertain variables can be described by a normal distribution. Within each farm size category, the mean and standard deviation values for yields and shrimp prices were used to define the probability distributions.

Costs were described by triangular distributions based on the most likely value (which was used in the enterprise budget) and minimum and maximum values determined from the original data for each scenario. In general, minimum values were calculated by assuming that the smallest farm of each size group has the lowest usage rate of a given resource and pays the lowest possible price for it. Likewise, maximum values are obtained under the assumption that the largest farm of each size group will have the highest rate of input usage and will acquire resources at the highest price. Occasionally, minimum values were zero (e.g., fertilizer and electricity costs) since at least one of the farms within each scenario did not report the usage of the respective input. Blank spaces in Tables 3 through 6 indicate that no corresponding information was obtained from any of the farms within the respective farm group. An additional cost variable ("others") was included to account for costs such as security expenses, insurance payments, and estimates of losses by bird depredation and poaching. Most farm managers expressed that expenses of this type can be considerable. The variable ("feed costs") was divided into two categories (feed quantity and feed price) since a negative correlation was found between farm size and price paid per feed unit. Correlations between variables need to be defined before running the simulations for the risk analysis. Crystal Ball™ normally calculates values independently of other values. Therefore, results could be biased if existing dependencies between variables are not accounted for. In addition to feed price (r = -0.65), production area was found to be correlated with six other variables: seed costs (r = 0.94), feed quantity (r = 0.98), full-time labor (r = 0.71), diesel costs (r = 0.98), debt payment (r = 0.65), and infrastructure depreciation (r = 0.75). These costs increased as a function of farm size. Correlation coefficients were calculated from data of the 19 semi-intensive farms and included in the model for each scenario. Other costs such as fertilizer, part-time labor, and electricity were not related to farm size, but varied according to factors such as management strategies, natural fertility of pond water, and electricity availability. Correlation coefficients could not be calculated for the intensive farm scenario due to the low number of observations. Crystal Ball™ generated random numbers for each cell independently of the values used for others.

The likelihood of achieving profit (positive net returns) and the distribution of outcomes for total revenue, total costs, break-even yield, and breakeven price were calculated for each farm scenario. Overlay and trend charts were developed to compare the distribution of outcomes among farm scenarios and to draw overall conclusions from the risk analysis.

RESULTS AND DISCUSSION

Enterprise Budgets

Tables 3 through 6 present the enterprise budgets developed for each farm scenario: small, medium, large, and intensive farms. Across the four scenarios, yields from the surveyed farms ranged from 250 to 1550 kg ha^{-1} yr^{-1}. These production levels are characteristic of semi-intensive systems in shrimp aquaculture (Fast, 1992).

It is observed from Table 5 that large farms (more than 400 ha) typically produce less than 450 kg ha^{-1} yr^{-1} and have the lowest cost per hectare and break-even yield (Lps. 34,248 ha^{-1} and

Table 2. Assumptions used for the risk analysis of shrimp farming in Honduras. Parameter distributions are given for each variable and scenario. Estimates are based on production data of 21 farms for the year 1997.

Variable	Unit	Distribution	Parameter	Farm-Size Scenario			Intensive Farms
				10–150 ha	*150–400 ha*	*> 400 ha*	
Production Area	ha	Uniform	Minimum	20	150	400	150
			Maximum	150	400	2000	800
Yield	kg head-off shrimp ha^{-1} yr^{-1}	Normal	Minimum	0	0	0	0
			Maximum	1,510	1,202	680	1,860
			Mean	675	724	410	1,426
			Standard Deviation	279	152	159	142
Shrimp Price	Lps kg^{-1}	Normal	Minimum	57	66	66	84
			Maximum	154	139	121	157
			Mean	106	103	92	120
			Standard Deviation	15	11	7	11
Seed Costs	Lps kg^{-1}	Triangular	Minimum	20,000	150,000	320,000	1,575,000
			Maximum	6,000,000	19,200,000	48,000,000	25,600,000
			Likeliest	1,241,791	5,697,705	10,592,895	11,679,531
Feed Quantity	MT	Triangular	Minimum	21	170	635	680
			Maximum	354	816	4,536	5,806
			Likeliest	119	453	1,651	3,003
Feed Price	Lps MT^{-1}	Triangular	Minimum	6,614	4,409	3,748	5,666
			Maximum	8,818	7,937	4,850	6,922
			Likeliest	7,684	6,083	4,365	6,283
Fertilizer Costs	Lps	Triangular	Minimum	0	0	0	-
			Maximum	165,000	420,000	1,300,000	-
			Likeliest	46,400	192,324	141,522	-
Chemical Costs	Lps	Triangular	Minimum	0	0	0	-
			Maximum	79,500	88,000	260,000	-
			Likeliest	11,520	40,524	26,568	-
Labor, Part-time	Lps	Triangular	Minimum	0	0	0	-
			Maximum	495,000	1,104,000	9,000,000	-
			Likeliest	54,202	141,136	2,077,097	-

Table 3. Annual enterprise budget of a 73-ha shrimp farm (representative of the smallest size category, 10 to 150 ha) in Honduras. Estimates are based on production data of eight farms during 1997. US$1 = 13 Lps.

Item	Unit	Quantity	Price	Total
YIELD	kg head-off shrimp ha^{-1} yr^{-1}	675		
SHRIMP PRICE	Lps kg^{-1}		106.00	
GROSS RECEIPTS	Lps			5,223,150
VARIABLE COSTS (VC)				
Seed				
Lab PL	1,000	9,432	65.00	613,057
Wild PL	1,000	15,718	40.00	628,734
Total		25,150		1,241,791
Feed	MT	119	7,684.00	935,816
Fertilizer	kg	14,018	3.31	46,400
Chemicals	kg	320	36.00	11,520
Labor, Part-time	h	8,672	6.25	54,202
Labor, Full-time	annual salary	23	21,797.22	501,336
Diesel	l	31,583	4.23	133,596
Gas	l	1,572	6.08	9,558
Electricity	kWh			-
Equipment Repairs	Lps yr^{-1}			93,714
Levee Repairs	Lps yr^{-1}			289,293
Total VC				3,317,226
FIXED COSTS (FC)				
Interest on Operating Capital	Lps yr^{-1}			908,403
Depreciation	Lps yr^{-1}			564,319
Concession	Lps ha^{-1}	88	17.45	1,529
Others	Lps yr^{-1}			86,748
Total FC				1,560,999
TOTAL COSTS (TC)				4,878,225
COST PER HECTARE	Lps ha^{-1}			66,825
NET RETURNS (NR)	Lps			344,925
NET RETURNS PER HECTARE	Lps ha^{-1}			4,725
RATIO NR/TC (%)				7
BREAK-EVEN PRICE	Lps kg^{-1}			99
BREAK-EVEN YIELD	kg ha^{-1} yr^{-1}			630

372 kg ha^{-1} yr^{-1}, respectively). Given the large number of production units (ponds), profitability of these operations is mainly dictated by keeping costs low. This indicates that managers of these farms have a marked preference for conservative strategies that minimize the potential for losses. If presented alternative production strategies, these managers are expected to assume risk-averse attitudes.

Yields are higher for medium farms (150 to 400 ha) than for large farms (Table 4). On average, these farms produce over 700 kg ha^{-1} yr^{-1}. Costs per hectare increase (Lps. 57,796 ha^{-1}), but so do net returns (from Lps. 3,472 ha^{-1} for large farms to Lps. 16,776 ha^{-1} for medium farms). On average, yields for small farms (less than 150 ha) are about the same (675 kg ha^{-1} yr^{-1}) as those for medium farms, but greater variability was found in the survey data. Some of these operations are owned by small, independent producers. These farmers are not financially secure and are very cautious when presented alternative, riskier strategies. They do not benefit, as larger farms do, from the effects of the economies of scale and vertical integration. In general, large farms rely on their own processing plants, hatcheries, and broker services overseas. Undoubtedly, this represents a competitive advantage over small, family-owned operations.

Total costs of intensive farms in Honduras are higher by 40% than those of the largest farms, even though the former are about half the size of the latter (Tables 5 and 6). Differences are even larger in terms of revenue. Gross receipts of intensive farms (Lps. 79,741,920) are more than double those of the largest farms (Lps. 36,437,520). Obviously, costs per unit area and break-even yields are higher for the intensive farms, but net returns, both total (Lps. 33,937,849 ha^{-1}) and per unit area (Lps. 72,828 ha^{-1}), also increase in an appreciable way, as a function of the high production input.

Data from the enterprise budgets suggests that farmers should intensify activities within the reach of their capabilities. Medium and intensive farms invest more per unit area than larger farms do, so they obtain higher returns per hectare, and

Table 4. Annual enterprise budget of a 293-ha shrimp farm (representative of the medium farm-size category, 150 to 400 ha) in Honduras. Estimates are based on production data of eight farms during 1997. US$1 = 13 Lps.

Item	Unit	Quantity	Price	Total
YIELD	kg head-off shrimp ha^{-1} yr^{-1}	724		
SHRIMP PRICE	Lps kg^{-1}		103.00	
GROSS RECEIPTS	Lps			21,849,596
VARIABLE COSTS (VC)				
Seed				
Lab PL	1,000	72,625	65.00	4,720,625
Wild PL	1,000	24,427	40.00	977,080
Total		97,052		5,697,705
Feed	MT	453	6,083.00	2,755,599
Fertilizer	kg	58,104	3.31	192,324
Chemicals	kg	1,228	33.00	40,524
Labor, Part-time	h	17,642	8.00	141,136
Labor, Full-time	annual salary	50	42,857.00	2,142,850
Diesel	l	191,872	4.04	775,163
Gas	l	8,332	6.07	50,575
Electricity	kWh	77,381	1.40	108,333
Equipment Repairs	Lps yr^{-1}			448,952
Levee Repairs	Lps yr^{-1}			548,538
Total VC				12,901,699
FIXED COSTS (FC)				
Interest on Operating Capital	Lps yr^{-1}			1,958,296
Depreciation	Lps yr^{-1}			1,385,979
Concession	Lps ha^{-1}	352	14.63	5,150
Others	Lps yr^{-1}			683,153
Total FC				4,032,578
TOTAL COSTS (TC)				16,934,277
COST PER HECTARE	Lps ha^{-1}			57,796
NET RETURNS (NR)	Lps			4,915,319
NET RETURNS PER HECTARE	Lps ha^{-1}			16,776
RATIO NR/TC (%)				29
BREAK-EVEN PRICE	Lps kg^{-1}			80
BREAK-EVEN YIELD	kg ha^{-1} yr^{-1}			561

the ratio between net returns and total costs is more favorable (10, 29, and 74% for large, medium, and intensive farms, respectively; Tables 4, 5, and 6). However, costs per unit area are high for small farms but the ratio of net returns to total costs is low (7%; Table 3). Several factors account for this: some of the small farms reported losses in the survey, mostly because of low survival related to disease outbreaks. In addition, these farms pay a higher price per unit of feed. Feed is usually the most expensive component of the cost structure of shrimp farming (Shang, 1992). From the survey data, it is evident that feed mills offer discounts in feed price that vary with the amount of feed ordered. This is an arrangement that represents a considerable reduction of costs for large farms, but from which small farms do not derive any benefit whatsoever. The correlation between farm size and feed price was included when defining the variables for the risk analysis.

High yields of intensive farms appear to be connected with moderate to high stocking densities along with strong reliance on supplemental feed (Table 6). Most of the stocked post larvae (PL) came from hatcheries, which is more expensive than wild PL. There is a considerable degree of risk associated with these practices, as diseases and other mortality factors can decimate shrimp stocks at any time. It is possible that the financial performance of these farms could be reflecting a case of isolated success.

Risk Analysis

Table 6 summarizes the results of the simulations. The entire range of possible outcomes is given for each scenario (Range minimum – Range maximum). Certainty levels indicate the likelihood of achieving values within a specific range. In the case of net returns and net returns ha^{-1}, certainty levels indicate the probability a farm has of achieving profit (positive net returns) given the scenario conditions. Certainties for total costs, break-even price, and break-even yield refer to these values' likelihood of being lower than the mean values of the enterprise budgets. As to gross receipts, the certainty level expresses this value's probability of being higher than the

Table 5. Annual enterprise budget of a 966-ha shrimp farm (representative of the largest size of shrimp farms, more than 400 ha) in Honduras. Estimates are based on production data of three farms during 1997. US$1 = 13 Lps.

Item	Unit	Quantity	Price	Total
YIELD	kg head-off shrimp ha^{-1} yr^{-1}	410		
SHRIMP PRICE	Lps kg^{-1}		92.00	
GROSS RECEIPTS	Lps			36,437,520
VARIABLE COSTS (VC)				
Seed				
Lab PL	1,000	78,927	65.00	5,130,255
Wild PL	1,000	136,566	40.00	5,462,640
Total		215,493		10,592,895
Feed	MT	1,651	4,365.00	7,206,615
Fertilizer	kg	42,756	3.31	141,522
Chemicals	kg	738	36.00	26,568
Labor, Part-time	h	259,637	8.00	2,077,096
Labor, Full-time	annual salary	82	47,685.00	3,910,170
Diesel	l	856,894	3.78	3,239,059
Gas	l	16,302	6.08	99,116
Electricity	kWh	197,087	1.40	275,921
Equipment Repairs	Lps yr^{-1}			144,675
Levee Repairs	Lps yr^{-1}			213,928
Total VC				27,927,565
FIXED COSTS (FC)				
Interest on Operating Capital	Lps yr^{-1}			2,443,736
Depreciation	Lps yr^{-1}			2,166,578
Concession	Lps ha^{-1}	1,160	3.54	4,109
Others	Lps yr^{-1}			541,667
Total FC				5,156,090
TOTAL COSTS (TC)				33,083,655
COST PER HECTARE	Lps ha^{-1}			34,248
NET RETURNS (NR)	Lps			3,353,865
NET RETURNS PER HECTARE	Lps ha^{-1}			3,472
RATIO NR/TC (%)				10
BREAK-EVEN PRICE	Lps kg^{-1}			84
BREAK-EVEN YIELD	kg ha^{-1} yr^{-1}			372

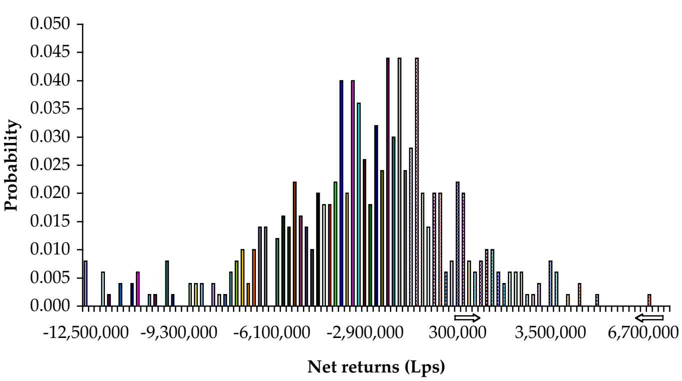


Figure 2. Probability distribution of net returns for a small (10 to 150 ha) shrimp farm in Honduras. Likelihood of achieving profit = 13%. Values between arrows are positive (> 0) and indicate certainty of achieving profit.

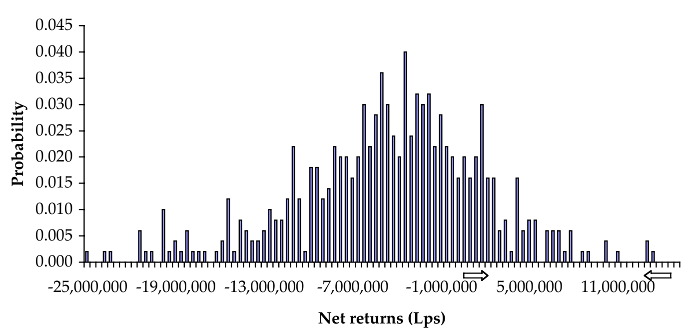


Figure 3. Probability distribution of net returns for a medium (150 to 400 ha) shrimp farm in Honduras. Likelihood of achieving profit = 24%. Values between arrows are positive (> 0) and indicate certainty of achieving profit.

Table 6. Annual enterprise budget of a 466-ha intensive shrimp farm in Honduras (production level of more than 1,250 kg ha^{-1} yr^{-1}). Estimates are based on production data of two farms during 1997. US$1 = 13 Lps.

Item	Unit	Quantity	Price	Total
YIELD	kg head-off shrimp ha^{-1} yr^{-1}	1,426		
SHRIMP PRICE	Lps kg^{-1}		120.00	
GROSS RECEIPTS	Lps			79,741,920
VARIABLE COSTS (VC)				
Seed				
Lab PL	1,000	146,091	78.00	11,395,038
Wild PL	1,000	7,689	37.00	284,493
Total		153,780		11,679,531
Feed	MT	3,003	6,283.00	18,867,849
Fertilizer	kg			-
Chemicals	kg			-
Labor, Part-time	h			-
Labor, Full-time	annual salary	80	43,609.00	3,488,720
Diesel	l	638,106	5.02	3,203,292
Gas	l	43,830	5.81	254,652
Electricity	kWh			-
Equipment Repairs	Lps yr^{-1}			2,260,624
Levee Repairs	Lps yr^{-1}			1,242,599
Total VC				40,997,267
FIXED COSTS (FC)				2,508,306
Interest on Operating Capital	Lps yr^{-1}			1,074,331
Depreciation	Lps yr^{-1}			26,250
Concession	Lps ha^{-1}	1,050	25.00	1,197,917
Others	Lps yr^{-1}			4,806,804
Total FC				
TOTAL COSTS (TC)				45,804,071
COST PER HECTARE	Lps ha^{-1}			98,292
NET RETURNS (NR)	Lps			33,937,849
NET RETURNS PER HECTARE	Lps ha^{-1}			72,828
RATIO NR/TC (%)				74
BREAK-EVEN PRICE	Lps kg^{-1}			69
BREAK-EVEN YIELD	kg ha^{-1} yr^{-1}			819

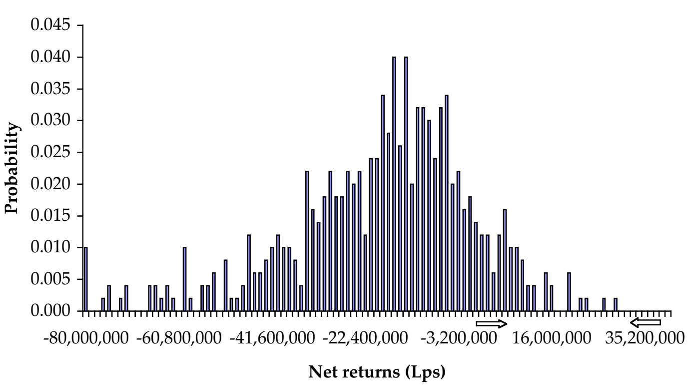


Figure 4. Probability distribution of net returns for a large (> 400 ha) shrimp farm in Honduras. Likelihood of achieving profit = 11%.

mean value of the budgets. In summary, Table 6 indicates the likelihood a farm has of presenting an adequate financial performance (positive net returns, high receipts, and low costs).

The objective of the simulations is to quantify the potential for profit given the characteristics of every farm scenario. Extreme values were generated for every variable with the goal of incorporating the worst and the most optimistic conditions under which a farm would operate, according to information from the survey. Results strongly favor the intensive farm scenario. The certainty for achieving profit is 74%, well above certainties for medium (24%), small (13%), and large farms (11%; Figures 2 through 4). Additionally, the intensive scenario is the only one where mean net returns (overall and per hectare) are positive (Figure 5). Potential for loss is clearly greater for the other three farm scenarios, as indicated by the negative mean net returns and the higher absolute value of range minima over range maxima. Certainty levels for attaining break-even prices and yields less than or equal to the actual value from the enterprise budgets are also greater for the intensive farms (in the case of break-even yields, 37%, compared to 1% for the other three scenarios).

Figures 2 through 5 display probability distributions for net returns under different scenarios. All values within 2.6 standard deviations are included, which represents approximately 99% of the forecast values. Certainty levels are also indicated in the charts. A series of overlay charts is displayed in Figure 6. These charts superimpose frequency data from each forecast under the different farm-size scenarios. Data are grouped in reverse cumulative distributions. These charts show how distributions among farm scenarios are related to each other. Distribution shape for intensive farms is clearly dominant (located farther to the right) for the gross receipts (Figure 6a) and net returns (Figure 6c) forecasts. This suggests that managers can expect to generate more revenue and increased net returns by adopting the strategies chosen by intensive farms. Likewise, it would be reasonable to assume that the range of total costs will be wider than for other scenarios. However, it is observed in Figure 6b that costs are likely to be higher for the large-farm scenario. This explains in part why the likelihood of profit is so low for large farms: under current conditions, operational costs could escalate at a faster pace than gross receipts, since there is a reduced potential for increasing yields.

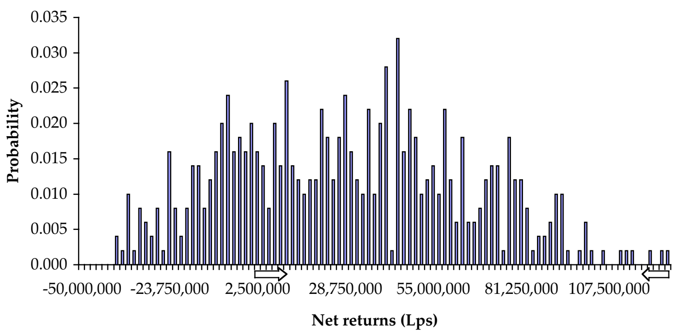


Figure 5. Probability distribution of net returns for an intensive (> 1,250 kg ha^{-1} yr^{-1} yield) shrimp farm in Honduras. Likelihood of achieving profit = 74%. Values between arrows are positive (> 0) and indicate certainty of achieving profit.

Although cost distribution for intensive farms is greater than that for small and medium farms at any point, break-even prices are lower for the former (Figure 6e). This is due to the elevated yields of intensive farms. Break-even price is a function of total costs, yield, and area. Assuming that total costs will increase with increases in farm area, yielding more per unit area (the case of intensive farms) will determine a lower break-even price. Break-even yields are, however, high both for small and intensive farms (Figure 6f). Break-even yield is a function of total costs, price, and area. The distributions for small and intensive farms are similar since the difference in shrimp prices between these scenarios is reduced more than the difference in farm yields (Tables 3 and 6).

The net returns chart (Figure 6c) shows the small-farm curve

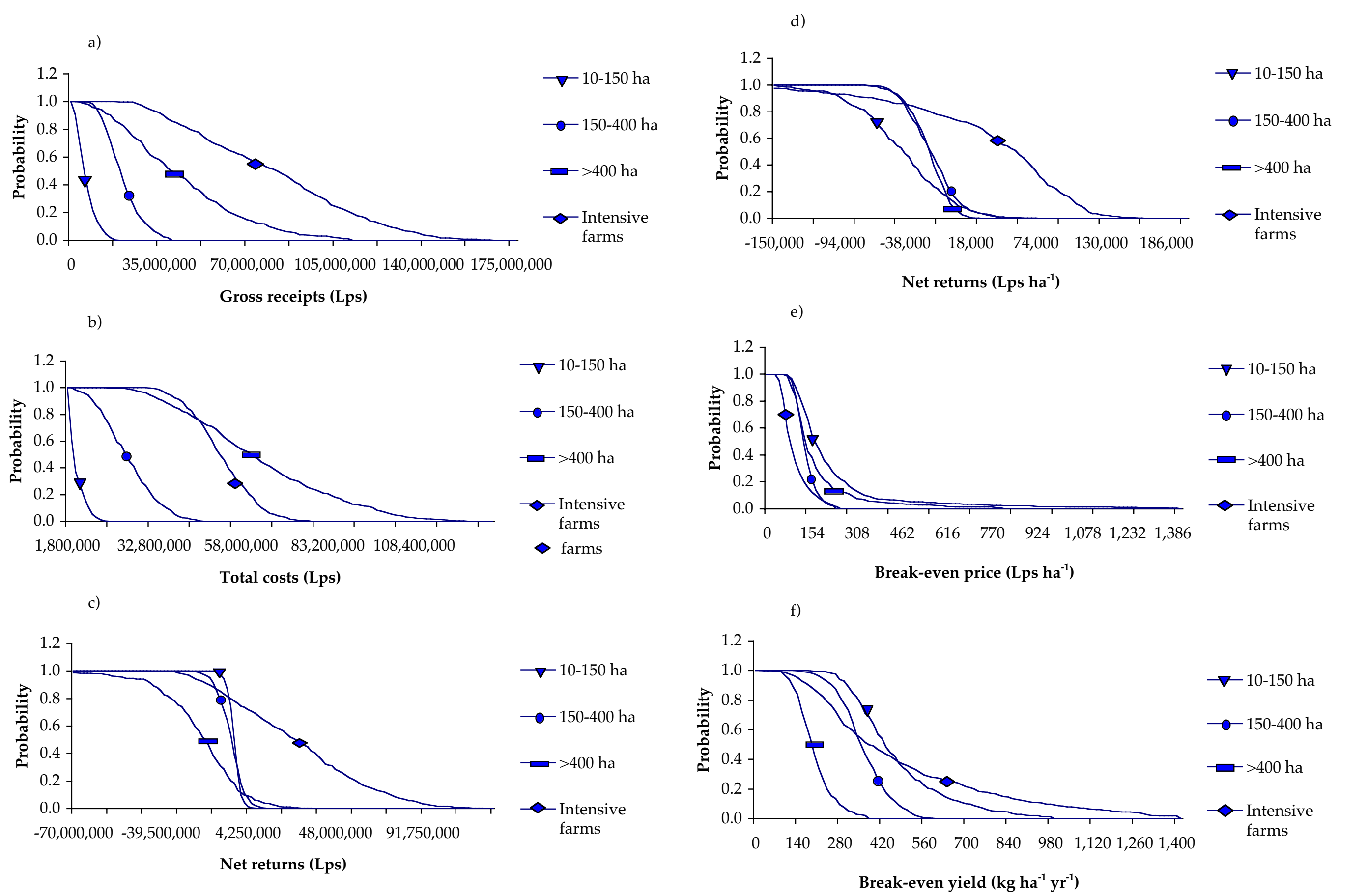


Figure 6. Reverse cumulative distributions for a) gross receipts, b) total costs, c) net returns, d) net returns ha^{-1}, e) break-even price, and f) break-even yield. Distributions from all four farm-size scenarios are shown in each chart.

located to the right of the curve for large farms. The relative position of these distributions changes in Figure 6d (net returns ha^{-1}). This is due to the large potential for loss implicit in both scenarios. Dominance of the net return distribution for small farms in the first chart does not precisely imply that overall returns can be higher, but that losses can be smaller. However, on an areal basis (Figure 6d), it is clearly observed that small farms cope with larger losses.

Figure 7 provides another view of the forecasts. Certainty ranges are displayed in a series of patterned bands. These charts illustrate how the range of possible outcomes and their associated probabilities vary from scenario to scenario. The potential for profit of the intensive farms is related to their capacity to generate higher revenues at the same time that costs are restricted in range (Figures 7a and b). Large farms have in turn a wider distribution of costs (Figure 7b) even though the total cost value is lower for large farms in the enterprise budgets (Tables 5 and 6). Since intensive farms are in actuality producing shrimp at high costs, the model determines that there is not much room for additional expenses, which results in a narrower distribution of costs. Total costs for large farms can amount to more than 120 million Lps., while gross receipts do not surpass this number (Figures 7a and b). This situation occurs in part because of the potential for elevated costs as farm size increases and also reflects the nature of the data as one of the large farms reported losses in the survey.

The net returns chart in Figure 6c illustrates that returns are in general higher for small and medium farms than for large farms. However, the trend chart for net returns in Figure 7c shows the range of positive net returns for large farms is greater than for small and medium farms. This suggests that large farms have a latent potential for obtaining a notable increase of profits by moderately intensifying production.

Potential for loss is magnified for the small- over the medium- and large-farm scenarios when the distribution of net returns is considered on an areal basis (Figure 7d). As mentioned before with Figure 6d, this is because there is a major likelihood that the distribution of overall net returns across the three scenarios will take on negative values.

Mathematical characteristics of the model determine the occurrence of extraordinarily high values for break-even prices in the small-farm scenario, over 10,500 Lps. kg^{-1} (Figure 6e; Table 7). This is the case when a very small farm (e.g., 20 ha) has high production costs but the final yield is close to zero. Results of this type are generated in response to the procedure used to define the variables of the model. In consequence, the use of trend charts is impractical for making comparisons among scenarios for the break-even price parameter.

Net returns is the most common criterion under which management decisions are evaluated in business enterprises, shrimp aquaculture included. Nevertheless, net returns are rarely known with certainty, but are often associated with a distribution of possible outcomes that may include the potential for loss (Hatch et al., 1987). Commonly, strategies targeted to achieve a large profit also contemplate loss possibilities and may look less attractive than conservative choices associated with a narrower distribution of returns and a reduced potential for loss. Decisions depend ultimately on

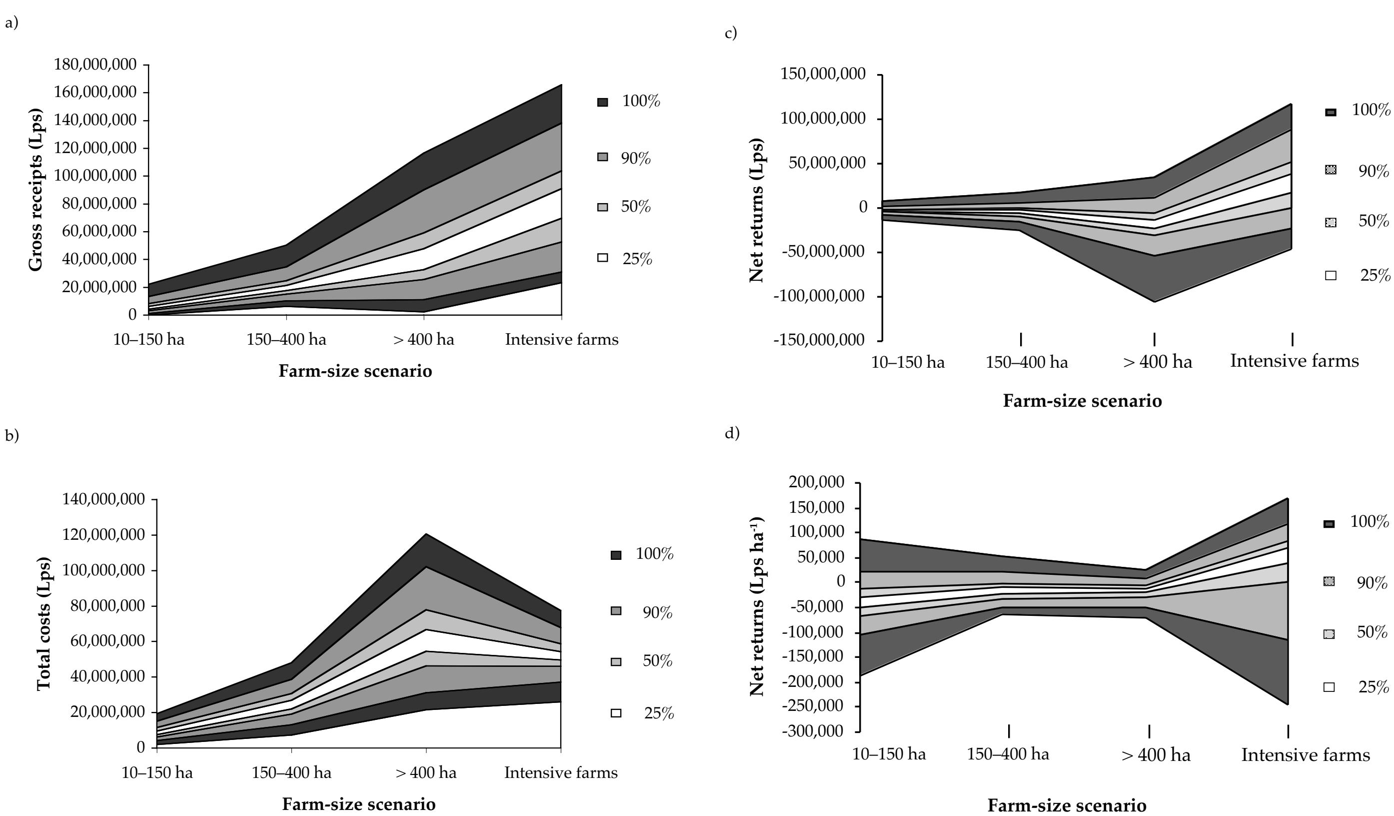


Figure 7. Certainty ranges displayed in series of bands for a) gross receipts, b) total costs, c) net returns, and d) net returns ha^{-1} across all four farm-size scenarios.

the manager's attitudes toward risk. However, results of the analysis indicate that under current strategies followed by farm managers in Honduras, there is more risk associated with adopting conservative practices and a low-cost-per-hectare approach than intensifying shrimp culture by increasing stocking densities and feeding rates. All farms, regardless of size, should target a minimum yield of 450 kg ha^{-1} yr^{-1}. As some of the costs are fixed, farmers could reduce the potential for loss by opting for more intensive strategies. This applies especially to the large farms characterized by low yields. Small farms are more affected by cost factors, such as the higher price of feed. Strategies for these farms should include alternatives that decrease the cost of production per unit area. Cooperatives or other types of agreements between small producers could be implemented to acquire feed at bulk price. Benefits of discounts would then cover a wider range of farms.

Some annotations should be made before stating final conclusions. Enterprise budgets were developed to describe the functioning of "typical" farms during 1997. There are two main production cycles every year in Honduras. These cycles are related to the alternation of dry and wet seasons. There are marked differences of productivity between cycles (Teichert-Coddington et al., 1994). The wet season is recognized as a more desirable period for shrimp grow-out. These differences were not accounted for in this study since the risk analysis is intended to examine the financial performance of the farms for an entire year.

Results of the model should not be considered as definitive. Low return levels for the first three scenarios do not necessarily imply that a new shrimp enterprise adopting similar strategies is doomed before initializing operations. The

Table 7. Forecast parameters and statistics generated from Monte Carlo simulations (500 iterations) of shrimp farming in Honduras. US$1 = 13 Lps.

Forecast	Unit	Parameter	Farm-Size Scenario			Intensive Farms
			10–150 ha	*150–400 ha*	*> 400 ha*	
Gross Receipts	Lps	Mean	6,022,939	20,715,118	43,193,907	79,680,829
		Range minimum	27,234	6,250,731	2,351,653	23,305,090
		Range maximum	22,189,054	50,222,637	116,653,535	165,801,837
		Certainty level	52%	41%	57%	46%
		Certainty range	5,223,150 to ∞	21,849,596 to ∞	36,437,520 to ∞	79,741,920 to ∞
Total Costs	Lps	Mean	8,918,464	24,911,289	63,838,732	52,267,982
		Range minimum	1,894,472	7,343,892	21,650,616	25,9*86,764
		Range maximum	19,348,762	47,993,751	120,653,610	77,376,799
		Certainty level	11%	18%	7%	23%
		Certainty range	-∞ to 4,878,225	-∞ to 16,934,277	-∞ to 33,083,655	-∞ to 45,804,072
Net Returns	Lps	Mean	(2,895,525)	(4,196,171)	(20,644,825)	27,412,846
		Range minimum	(12,500,000)	(24,610,039)	(105,833,371)	(45,680,242)
		Range maximum	7,500,000	16,611,078	34,586,701	118,248,910
		Certainty level	13%	24%	11%	74%
		Certainty range	0 to ∞	0 to ∞	0 to ∞	0 to ∞
Net Returns	Lps ha^{-1}	Mean	(42,064)	(14,751)	(18,985)	34,847
		Range minimum	(188,323)	(62,700)	(71,238)	(245,553)
		Range maximum	87,471	51,794	25,911	168,189
		Certainty level	13%	24%	11%	74%
		Certainty range	0 to ∞	0 to ∞	0 to ∞	0 to ∞
Break-Even Price	Lps kg^{-1}	Mean	251	130	173	96
		Range minimum	64	44	55	25
		Range maximum	10,651	220	1,734	307
		Certainty level	12%	2%	5%	41%
		Certainty range	-∞ to 99	-∞ to 80	-∞ to 84	-∞ to 69
Break-Even Yield	kg ha^{-1} yr^{-1}	Mean	1,094	878	603	1,137
		Range minimum	528	468	319	263
		Range maximum	2,182	1,310	1,037	3,890
		Certainty level	1%	1%	1%	37%
		Certainty range	-∞ to 630	-∞ to 561	-∞ to 372	-∞ to 819

assumptions included very pessimistic estimates (extreme high costs, poor yields) that strongly influenced the results of the simulations. This is especially true of large and small farms. For both scenarios, Crystal Ball™ recalculated the spreadsheet incorporating a certain likelihood of zero yields. Even though it was also considered, the probability of achieving a zero yield is negligible for the medium and intensive scenarios. This is due to the shape of the normal distributions, defined from the survey data.

In any case, the model is categorical as to establishing the wisdom of intensifying shrimp culture. Differences among scenarios are clearly identified and quantified by the analysis, and is here where the usefulness of the model should be found.

ANTICIPATED BENEFITS

This study shows the importance of including risk in economic analyses. Without accounting for risk, management strategies recommended might not be the most appropriate.

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