

Economics of Penaeid Culture in the Americas

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Abstract Shrimp culture in the Americas began in the early 1970's and has experienced rapid growth in some Latin American countries. Currently, Latin America produces one-third of all cultured shrimp with Ecuador as the leading country in the world. Availability of postlarvae and a favorable year-round climate have been the most important factors causing a "Gold Rush" expansion in Ecuador. The long-term potential for shrimp mariculture in Latin America is promising. Projections for 1990 production of cultured shrimp by Latin American countries are between 60,000-70,000 metric tons (mt). Shrimp culture in the United States has begun with the entry of a few small firms.

In this paper, investment and production costs are examined for a semi-intensive farm that purchases postlarvae and operates in the southern United States. Total investment decreases as pond size increases for a given size facility. Investment per kilogram of annual average production ranges from just under US \$20.00 for a 20-surface ha farm using 2-ha ponds to \$80.00 for a 400-ha system using 20-ha ponds. Operation costs per kilogram decline as the size of the system and the size of the ponds increase. It costs \$10.10 to produce one kilogram of shrimp on a 20-surface ha farm using 2-ha ponds compared to \$5.50 on a 400-surface ha farm using 20-ha ponds.

In comparing the operation of a semi-intensive 200-ha farm in Ecuador with a similar farm in the United States, costs of production were \$3.12 and \$5.83 per kilogram, respectively. The after-tax internal rate of return (IRR) was 59% in Ecuador and 21% in the United States. These IRR's were calculated under the assumption that production, costs and prices received are constant over the investment period (10 years) considered. When risk and timing of investment are considered, these IRR's are reduced.

Introduction

Shrimp mariculture is becoming a reality in many countries on the American continent. Some countries which had only a small amount of cultured shrimp are now beginning to report growth of their industry. Other countries that have not been significantly involved are taking steps to encourage shrimp culture. The Branch of the Foreign Fisheries Analysis of the United States reports that of the 16 countries in the world producing cultured shrimp, half are located in Latin America and half are in Asia (Table 1). Latin America produced over one-third of the cultured shrimp in the world in 1982 and Ecuador is the largest producer of cultured shrimp (D.M. Weidner, pers. comm., 1984).

The long-term potential for shrimp culture is promising. Factors affecting the advancement of shrimp culture in the Americas, as well as the world, are economic, technology, environment and politics (D.M. Weidner, pers. comm., 1984). In terms of economics, international demand and supply determine world shrimp prices. Cultured shrimp are only a minor part of total supply which is determined mostly by the harvest of wild stocks. Harvest of wild stocks is at or near maximum sustainable yield (National Oceanic and Atmospheric Administration, 1980; Robinson, 1982) and any

significant increase in world supply will come from cultured shrimp. The expansion of cultured shrimp will depend on its cost of production relative to world shrimp prices.

The major objective of this paper is to examine the cost of producing shrimp in the Americas. A review of shrimp culture in the Americas will first be given. Second, costs of producing shrimp relative to size of pond and total size of facility will be examined. The cost of producing postlarvae will also be briefly examined. Third, cost and returns comparisons will be made between the United States and Ecuador for constructing and operating a 200-ha shrimp farm. Finally, some indication of risk will be discussed.

Review of the Americas

It is reported that shrimp farming in Ecuador began by accident in 1962 (Hirono, 1983). A perimeter berm around a farmer's plantation, where he had planted coconut palm trees, was damaged by unexpected high tides. When the farmer returned some months later, he noticed birds dining on large shrimp in a pool of water. This gave rise to the idea of shrimp farming in Ecuador. The first shrimp farm was constructed in 1969 (Shrimp Notes, Inc., 1983).

The most important factor leading to the development of shrimp farming in Ecuador was the availability of postlarvae caught from the wild. These postlarvae, predominantly *Penaeus vannamei*, are caught by artisanal fishermen in estuaries and sold to shrimp farmers for stocking in ponds or nurseries. The major limitation to the development of commercial shrimp farming in Ecuador and the Western Hemisphere is maturation/reproduction in captivity with the production of viable larval nauplii (Lawrence et al., 1984). The natural abundant source of postlarvae along with cheap labor and absence of legal restrictions allowed rapid growth of shrimp culture in Ecuador. Other important factors influencing the development of shrimp culture were favorable climate, inexpensive coastal land, fuel, and wage rates (D.M. Weidner, pers. comm., 1984). These conditions plus high prices for shrimp led to a "Gold Rush" fever in Ecuador (Hirono, 1983). In 1982, there were 112 farms in Ecuador ranging from less than 50 ha to more than 200 ha (Table 2). The area in production increased over 13 times and production increased over 18 times from 1977 to 1982 (Table 3).

Other Latin American countries on the Pacific possess favorable conditions similar to Ecuador and culture methods developed in Ecuador and Panama are now spreading to other countries. *P. vannamei*, the dominant species used in these countries is not available on the Atlantic coast and is, at certain times of the year and for some geographical locations, in short supply on the Pacific coast. As a result, companies are building hatcheries to produce postlarvae but they have had problems. Agromarina, S.A., a division of Ralston-Purina, has had the largest hatchery success and supplies approximately 80% of the postlarval requirement

Table 1. Cultured shrimp production in the world in 1982, by country (D.M. Weidner, pers. comm., 1984).

Continent/country	Production (mt)
Asia	
India	15,000 ^a
Indonesia	11,313
Taiwan	9,575
Thailand	10,091
Philippines	3,900 ^b
China	1,400 ^a
Malaysia	157
Korea (ROK)	109
Total	51,545
Latin America	
Ecuador	21,500
Brazil	200 ^a
Peru	600 ^a
Panama	1,500
Honduras	250 ^a
Guatemala	100 ^a
Martinique	150 ^a
Jamaica	25
Total	24,325

^aEstimated

^bProduction in 1981

Table 2. Total numbers of Ecuadorian marine shrimp farms by size in 1982 (Shrimp Notes, Inc., 1983).

Farm size (ha)	No. of farms
<50	52
51-100	25
101-150	14
151-200	7
>200	14
Total	112

for their more than 600 ha of grow-out ponds (D.M. Weidner, pers. comm., 1984).

Brazil, which has the most extensive coastal area for shrimp culture, has been discouraged with native species. The import of exotic species, however, has been encouraging. *P. japonicus* has been cultured in their tropical climate and Brazilian farmers report that this species has reproduced in ponds. Therefore, they can produce their own postlarvae without the necessity of maturation/reproduction in captivity. Other Caribbean countries are now beginning to copy this method of shrimp mariculture (D.M. Weidner, pers. comm., 1984).

Although the long-term potential for the Americas is encouraging, it is not without problems. Shortages of postlarvae slow the growth rate at which the industry can expand. Advances in the technology of larval (nauplii) production with construction of hatcheries will allow significant increases in production.

Some governments promote shrimp culture, but on the whole government policies tend to slow expansion of the industry. Some countries prevent or discourage private domestic or foreign investment. Mexico, which has one of the greatest potentials, has restricted shrimp culture to the fishermen's cooperatives. Ecuador, as well as other countries, controls the exchange rate which discourages investment. Some countries have complicated shrimp hatchery and farm operations by restricting the import and export of *Artemia*, shrimp nauplii, postlarvae, broodstock and some equipment. Those countries which do not have a culturable native species will not be able to develop a shrimp farming industry until a reliable source of postlarvae can be imported (D.M. Weidner, pers. comm., 1984).

Despite these difficulties, shrimp culture in the Latin American countries will continue to grow. When maturation/reproduction and hatchery technology that can produce healthy postlarvae becomes available, shrimp culture will most likely increase at a rapid rate. This unknown of postlarvae availability, plus the other problems mentioned above, make projecting production difficult. However, projections are that Latin America will produce between 60,000-70,000 mt by 1990 (Table 4). If technical problems are overcome early, then production could exceed this estimate (D.M. Weidner, pers. comm., 1984).

Unlike the Latin American countries, the United States has a limited growing season for culturing shrimp. Shrimp culture has been researched for 15 years in the United States and growing shrimp has been attempted since the early

1970's with limited technical and no economic success. Currently, there are 16 farms in the continental United States or Hawaii that are either in the planning or pilot stage of production. At least six of these have or plan to have hatcheries for postlarvae production. These farms range from a large 60-ha pond extensive system to very small 0.2-ha intensive ponds.

Investment and operation costs

This section deals with investment and operating costs for semi-intensive shrimp farms using *P. vannamei* as the cultured species. Farms in this analysis range in size from 20 to 400 ha and use ponds ranging in size from 2 to 20 ha. The major objective of this section is to determine the economies of size associated with total size of the farm and size of the pond. Investment and operating cost are developed in this analysis using the Generalized Budget Simulation Model (Griffin et al., 1983) and research data. Although the generated investment and operating costs are for a farm located in the southern United States, the relative investment operating cost relationship between size of farms will be the same regardless of where a farm is located.

Investment costs

Table 5 shows the total investment of major items for a semi-intensive 200-surface ha shrimp farm using 20-ha ponds. This is similar to a typical large farm being constructed in Ecuador today. Notice that land and construction cost are by far the major investment items. Land prices ranged from \$1,500 to \$8,000/ha. A price of \$3,750/ha was used in this analysis. Land is 43% of total investment cost. Pond construction includes earth moving, pipes, gate valves, engineering fees, etc., and is 40% of total investment which for this 200-ha facility is slightly under \$2 million.

Figure 1 shows total investment by all size farms considered in this analysis. For the 200-ha system just discussed, the total investment would increase from \$1.9 million to \$2.2, \$2.7 and \$3.4 million as the size of the grow-out pond is decreased from 20 to 10, 4 and 2 ha, respectively. Investment cost increases because it requires more land, earth mov-

Table 3. Total marine shrimp farm harvest (heads-off) for Ecuador, 1977 to 1982 (preliminary) with projection from 1983 to 1986 (Shrimp Notes, Inc., 1983).

Year	Area (ha)	Production (mt)	($\times 10^6$ lb)	Productivity (kg/ha/yr)	(lb/acre/yr)
1977	3,000	818	1.8	273	243
1978	5,500	1,682	3.7	306	273
1979	8,200	2,545	5.6	310	277
1980	18,570	5,909	13.0	318	284
1981	27,000	9,091	20.0	337	301
1982*	40,000	15,040	33.1	376	335
1983	45,000	17,818	39.3	396	353
1984	55,000	24,955	55.0	454	405
1985	62,000	34,955	77.1	564	503
1986	65,000	48,909	107.8	752	671

*Preliminary data based on 80% aquaculture production.

Table 4. Cultured shrimp production in 1982 and projected production in 1990 for Latin America (D.M. Weidner, pers. comm., 1984).

Country	Production (mt)	
	1982	1990
Ecuador	21,500	40,000
Brazil	200*	4,000
Peru	600*	3,500
Panama	1,500	3,000
Honduras	250*	2,500
Colombia	—	2,000
Mexico	—	2,000
Venezuela	—	1,500
Belize	—	1,500
Bahamas	—	1,300
Guatemala	100*	1,000
Martinique	150*	750
French Guiana	—	750
Dominican Republic	—	500
Puerto Rico	—	500
Costa Rica	—	500
Haiti	—	400
Guadeloupe	—	250
El Salvador	—	200
Nicaragua	—	200
Dominica	—	200
Suriname	—	100
Jamaica	25	100
Cuba	—	50
Guyana	—	50
Uruguay	—	—
Argentina	—	—
Chile	—	—
Others	—	250
Total	24,325	67,110

*Estimate

ing and inflow and outflow equipment to maintain 200-surface ha of production as the size of ponds decreases. Clearly, as the grow-out pond increases in size, investment cost per surface hectare will decrease for any given size farm.

Figure 2 shows the same investment cost as Fig. 1, but on a per kilogram of shrimp basis. Production per hectare is assumed to be held constant at 1,159 kg/ha across all size facilities and is based on research data from the Research Facility at Corpus Christi, Texas, U.S.A. Investment cost per kilogram of annual production, assuming a single crop per year in the United States, would be \$8.30 for a 200-ha farm using 20-ha ponds. For the same size farm, the investment cost would be \$6.00 higher (\$14.60) if 2-ha ponds were used. Fig. 2 illustrates that there are significant economies of size to be captured relative to investment cost both by increasing the size of farm and ponds. This analysis is consistent with other aquaculture systems studied (Giachelli et al., 1982).

Operating costs

Costs considered in this analysis do not include income tax. The only operating cost (fixed and variable) not included is interest since it is assumed that private investors will provide all capital needed to build the facility (opportunity cost

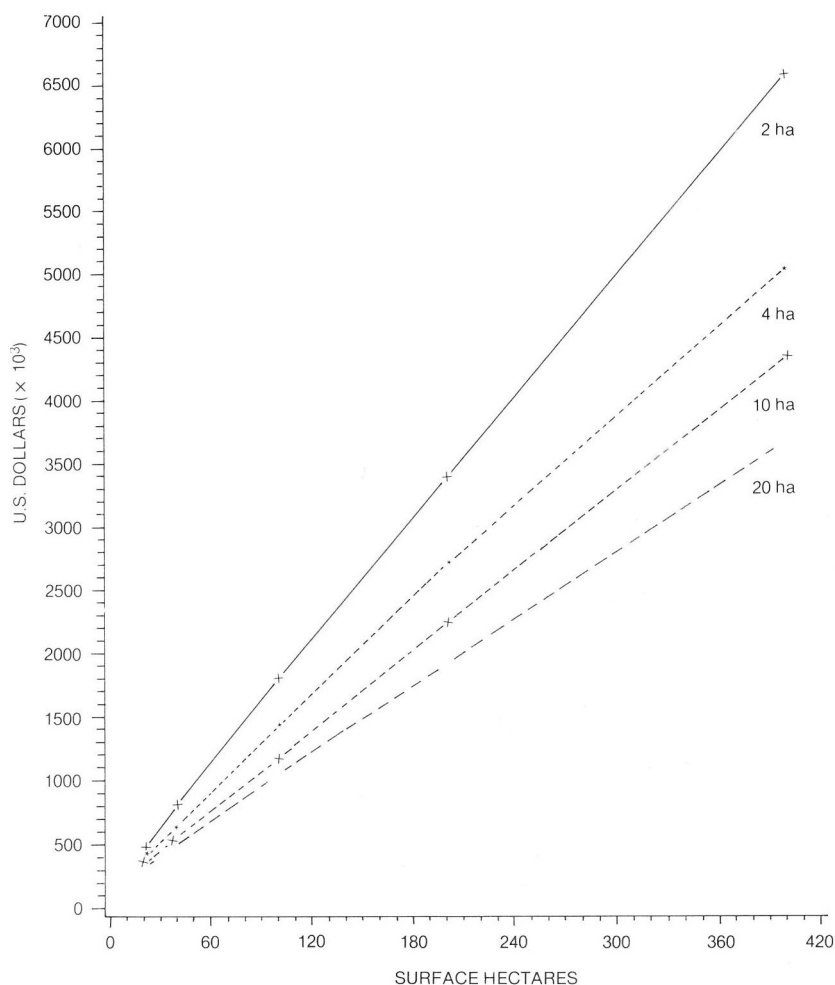


Fig. 1. Total investment costs for semi-intensive shrimp farms ranging from 20 to 400 total surface ha using 2- to 20-ha ponds producing *Penaeus vannamei* located in the southern United States, 1984.

of capital not included in cost figures). This cost represents the total annual cost of producing shrimp in ponds when under conditions of certainty (no risk).

Table 6 presents the annual variable and fixed costs of operating a 200-ha shrimp farm using 20-ha grow-out ponds. Farms in this analysis are assumed to stock 150,000 postlarvae/ha at a cost of \$12/thousand. Only one crop is produced during the growing season of 185 days. After stocking, water is exchanged in the pond from 3 to 5% daily until

Table 5. Investment cost in a semi-intensive 200-surface ha shrimp farm using 20-ha ponds producing *Penaeus vannamei* located in the Southern United States, 1984.

Item	Cost (US \$)
Land	828,000
Pond construction	764,232
Building construction	64,155
Equipment	183,529
Machinery	74,724
Total	1,914,640

harvest. Shrimp are fed 3 to 18% of their body weight depending on the average size of animals in the pond. The average food conversion ratio is 2.5:1.

Feed, which costs \$440/mt in the United States, is the most expensive item listed in Table 6 and represents 36% of variable cost. Postlarvae is second to feed at 32% of variable cost. Labor is the next highest (12%) followed by harvest cost (10%). Total variable cost is in excess of \$1 million and is 83% of total cost.

Depreciation is more than half of total fixed cost (53%) and overhead, which includes a manager and an assistant manager's salary, is 36% of total fixed cost. Total annual cost for producing one crop of shrimp per year is \$1.3 million. Cash operating expenses are \$1.2 million per year.

Figure 3 shows the variable, fixed and total cost per year for various size systems using four different size ponds. Notice that as size of the system becomes larger, costs (variable, fixed and total) increase. The difference in total cost for using different size grow-out ponds is almost the exclusive result of fixed cost. Thus, once a system is built, it takes basically the same amount of variable cost to operate

the system, regardless of size of grow-out pond used. This is because postlarvae, fuel, fertilizer and harvest cost per hectare are constant across all size facilities. Some small economies of size are available for repairs, labor, utilities and payroll taxes.

Figure 4 illustrates the cost per kilogram (heads-off) to produce shrimp for the various size systems. A 400-ha system using 20-ha ponds can produce shrimp for \$5.50/kg (heads-off) where a 20-ha system using 2-ha ponds cost almost twice as much. Increasing the pond size from 2 to 20 ha for a given size system reduces the cost of production by almost \$0.70/kg.

Hatchery costs

In the above analysis it was assumed that a farmer would purchase his postlarvae from an outside source which is the basic practice in Ecuador. However, in the United States, only two companies have begun to sell postlarvae in limited amounts. Therefore, supply and demand are erratic and uneven. If a farm does not have its own supply of postlarvae, it may not be able to stock its ponds at the beginning of the season. By the time postlarvae are acquired, a significant portion of the limited growing season may be lost.

Table 6. Annual cost for operating a semi-intensive 200-surface ha shrimp farm using 20-ha ponds producing *Penaeus vannamei* located in the Southern United States, 1984.

Item	Cost (US \$)
Variable cost	
Postlarvae	360,000
Repairs	27,729
Fuel	45,093
Feed	408,000
Fertilizer	10,845
Labor	132,640
Utilities	3,912
Harvest	109,545
Payroll taxes	20,185
Total	1,117,949
Fixed cost	
Overhead	80,795
Depreciation	118,944
Insurance and taxes	11,023
Taxes	14,131
Total	224,893
Total cost	1,342,842

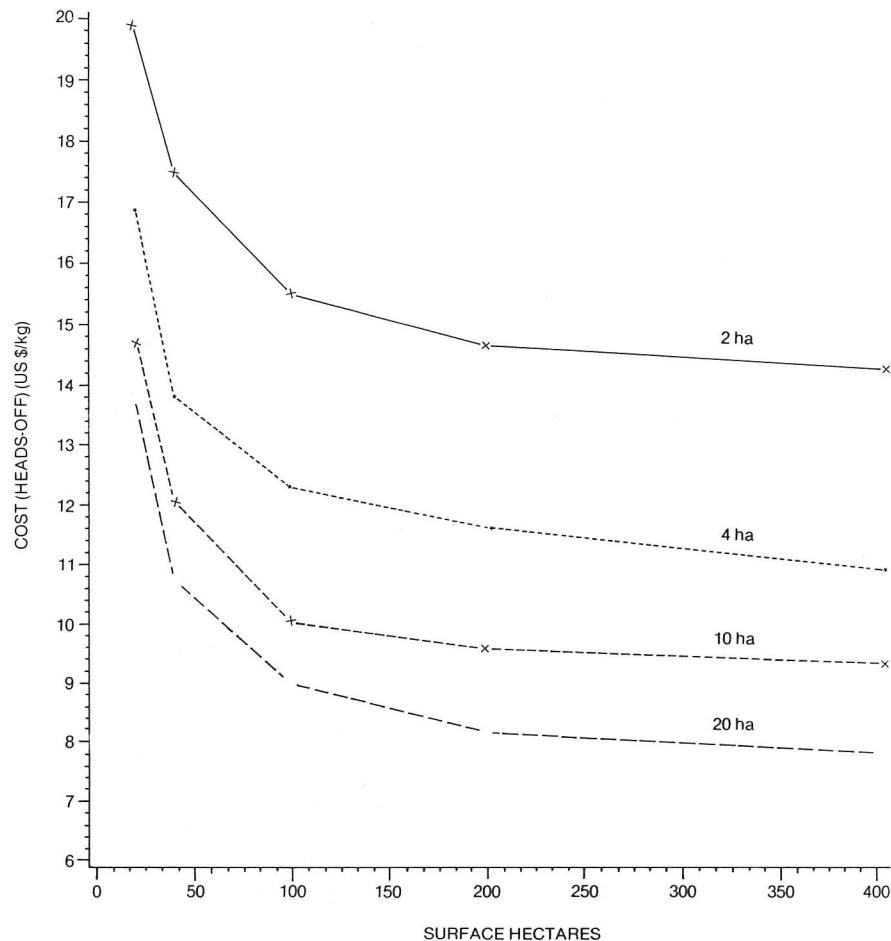


Fig. 2. Investment cost per kilogram for semi-intensive shrimp farms ranging from 20 to 400 total surface ha using 2- to 20-ha ponds producing *Penaeus vannamei* in the southern United States, 1984.

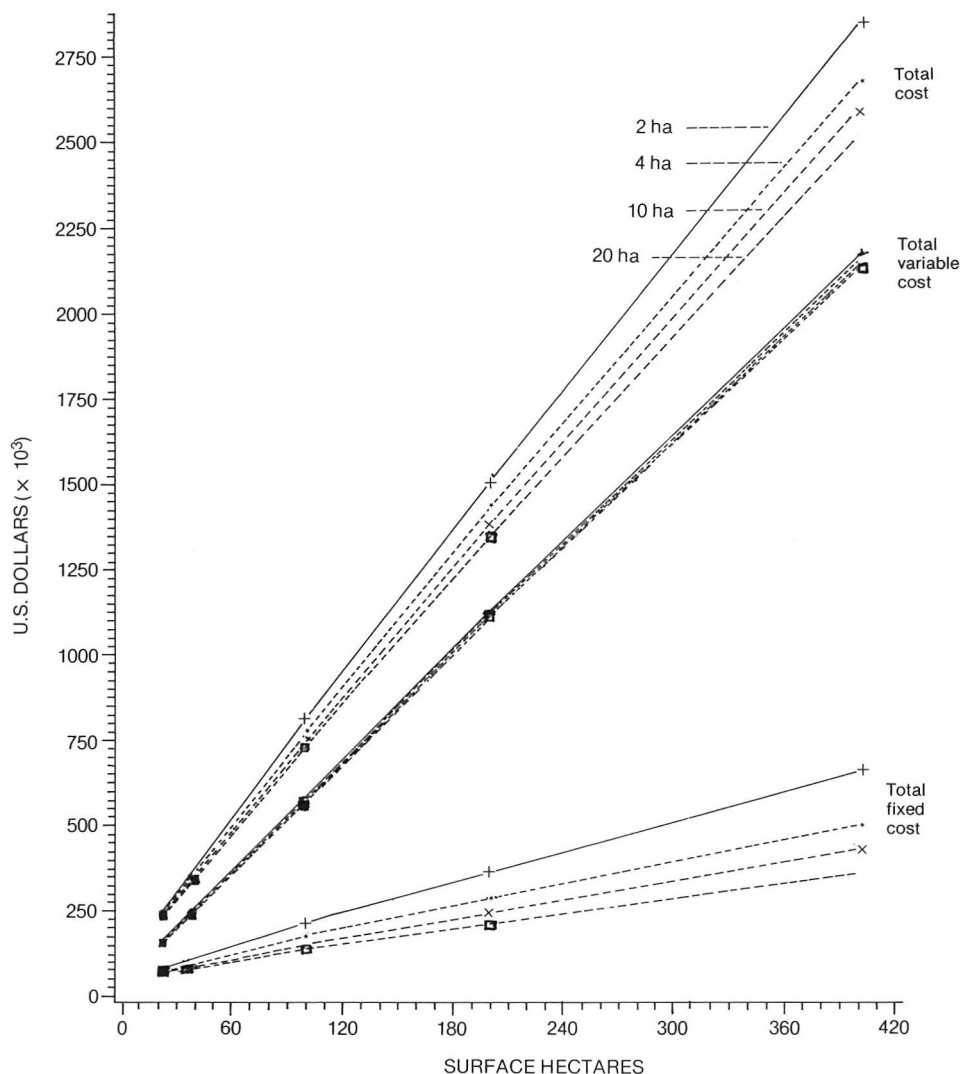


Fig. 3. Total fixed cost, total variable cost and total cost for semi-intensive shrimp farms ranging from 20 to 400 total surface ha using 2- to 20-ha ponds producing *Penaeus vannamei* located in the southern United States, 1984.

Table 7. Break-even price (US \$) for production of *Penaeus vannamei* postlarvae utilizing an onsite reproduction unit to stock the entire farm in two reproduction unit runs for a farm located in the Southern United States that produces one crop per year, 1984.

Pond size	Total surface hectares				
	20	40	100	200	400
2	15.00	13.83	11.13	11.97	11.38
4	17.00	13.83	11.47	11.97	11.38
10	19.67	13.83	11.13	12.00	11.38
20	22.00	13.83	11.67	12.00	11.40

Table 7 shows the break-even price per thousand for producing *P. vannamei* in an onsite farm reproduction unit. It assumes that the farm produces a single crop per year and two 20-day hatchery cycles are required to stock all the grow-out ponds. Shrimp are assumed to spawn at 5% per night with eggs having a 50% hatch rate. Survival in the hatchery is assumed to be 40%.

Postlarvae cost for a pond production system of 100 ha or greater is estimated to be \$11.00 to \$12.00/thousand. It was assumed in the above cost analysis that farmers could buy postlarvae for \$12.00/thousand. If the market price for *P. vannamei* is \$12.00/thousand, then farmers would be indifferent between buying or producing their own postlarvae. If the market price exceeds \$12.00/thousand, it would be better for farmers to produce their own postlarvae. If the market price is less than \$12.00/thousand, farmers would not buy from an assured source of supply.

For farms less than 100 ha in size, the farmer would benefit by purchasing postlarvae if the market price was \$12.00/thousand. The price per thousand for producing postlarvae for these smaller farms increases as pond size increases due to restrictions on how fast a pond or hatchery tank must be stocked. A 20-ha farm using a 20-ha pond requires the pond to be filled in one hatchery run causing it to have the highest unit cost for postlarvae production. In countries with year-round growing season, the size of the re-

production unit can be reduced substantially since it could be operated year-round to stock ponds, thus reducing fixed cost. The cost of postlarvae in Ecuador is approximately \$4.00/thousand, however, the need for reproduction units in Latin American countries is based more on shortage of postlarvae rather than a high market price.

Comparison of Ecuador and the United States

This section will compare the economics of operating a shrimp farm in Ecuador and the United States. For this comparison, a 200-surface ha farm using 20-ha ponds will be used. A semi-intensive farm in the United States (SI-US) will be compared to a semi-intensive (SI-E), semi-extensive (SE-E) and an extensive (E-E) operation currently used in Ecuador.

Although there are several differences between Ecuador and the United States in their ability to produce shrimp in ponds, the two most important differences are availability of postlarvae and length of growing season. Ecuador has wild postlarvae available through fishermen and a year-round

growing season. The United States, on the other hand, does not have a ready source of postlarvae and the growing season is limited to 180 to 240 days/year.

Table 8 shows the production specifications for comparing the farms. The United States farm is based on data from research ponds at Corpus Christi, Texas. Ecuadorian farms are based on actual farms as described by Hirono (1983).

Stocking density of the SI-US farm is triple that of the SI-E farm. Stocking density decreases as the intensity of production decreases for the Ecuadorian farms. Percent survival generally increases as the stocking density decreases. A 19 g animal is produced in approximately 190 days on the SI-US farm, whereas a 21 count animal is produced in approximately 175 days (45 days in nursery and 130 days in grow-out ponds) on the SI-E farm. Only one crop is produced per year on the SI-US farm. As the farms in Ecuador become more intense in their operation, the number of crops produced per year increases.

The total number of kilograms produced with one crop on the SI-US farm is only a little less than the SI-E farm that produces 2.4 crops/year. The annual production decreases

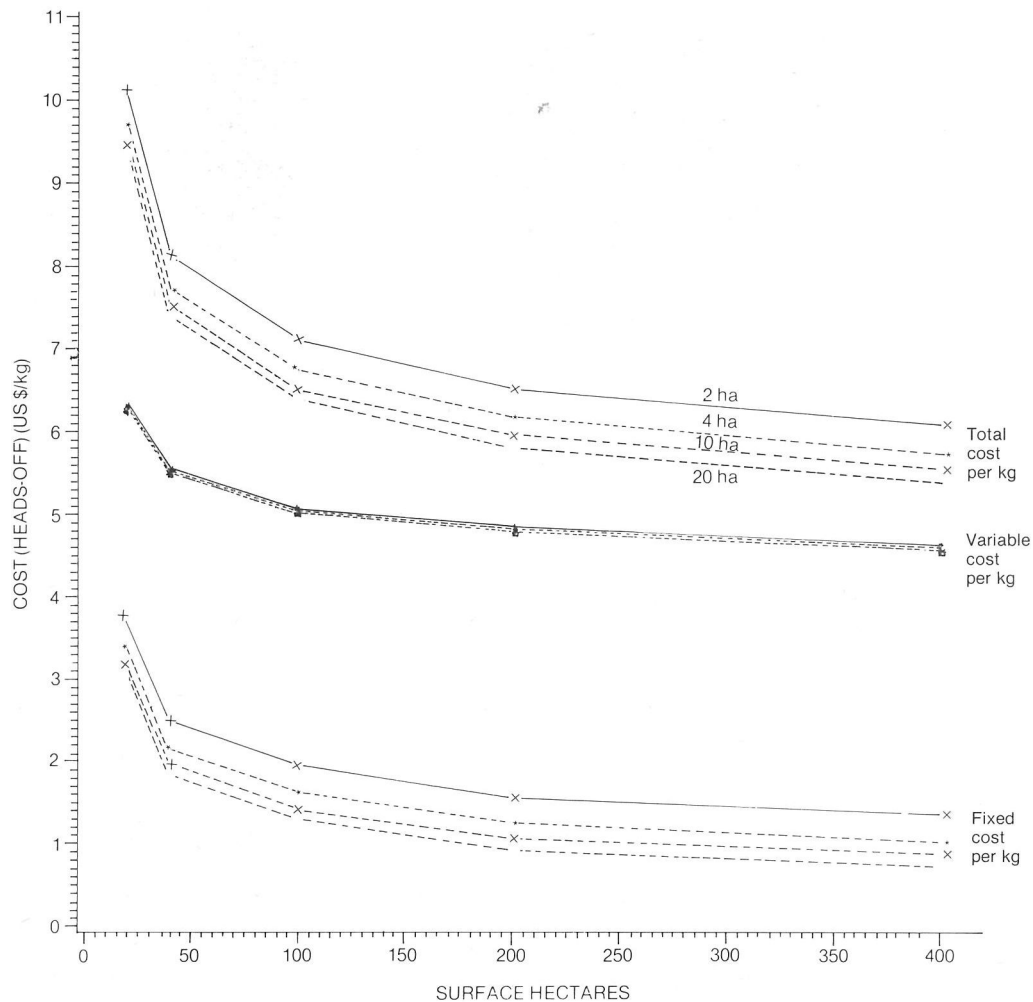


Fig. 4. Fixed cost, variable cost, and total cost per kilogram for semi-intensive shrimp farms ranging from 20 to 400 total surface ha using 2- to 20-ha ponds producing *Penaeus vannamei* located in the southern United States, 1984.

Table 8. Production specifications for a semi-intensive farm located in the United States and a semi-intensive, semi-extensive and extensive farm located in Ecuador (Hirono, 1983).

Item	United States	Ecuador		
	Semi-intensive	Semi-intensive	Semi-extensive	Extensive
Stocking density/ha	150,000	50,000	25,000	12,000
Survival (%)	65	75	80	85
Harvest size (g)	19	21	22	25
Number of crops	1	2.4	1.8	1.3
Total production (heads-off) (kg/ha/yr)	1,159	1,323.1	554.4	232.1
Food conversion ratio	2.5:1	2.5:1	1:1	—
Fertilizer	Yes	Yes	Yes	No
Water exchange	Continuous	Continuous	Continuous	Minimal
Nursery ponds	No	Yes	Yes	No

substantially as farms become less intensive in their operation.

Only the E-E farm does not use fertilizer and only uses minimal water exchange. The SI-US farm and the E-E farm do not use nursery ponds. A 5 day-old postlarva is stocked in the SI-US and a 10 to 40 mm shrimp is stocked in the E-E farm. Since nursery ponds are used with the SI-E and SE-E farms, a 1 to 3 g shrimp is usually stocked in the grow-out ponds.

Results of the economic analyses are presented in Table 9. Economic data for a SI-E farm were obtained through personal communication (S. Horton, 1983; C.R. Mock, 1984; B. Price, 1984) and through Shrimp Notes, Inc. (1983). The SE-E and E-E farm cost information was developed by modifying the data for the SI-E farm based on descriptions by Hirono (1983) of each type of farm. All analyses are in United States dollars at the official exchange rate of 54 sucres: US\$1. Prices received and unit cost for this analysis are based on beginning 1984 dollars.

Production per hectare is greatest for the two semi-intensive systems (Table 9). The SI-E farm produces 14% more kilograms shrimp per hectare per year than the SI-US farm. The reason is the SI-E farm produces 2.4 crops through a full year of production using a nursery pond system whereas the SI-US farm produces only one crop per year without a nursery pond in a 185-day growing season. Production per crop is much greater in the SI-US since stocking density is three times larger and the crop is growing in the pond almost 50% longer. Production on the SE-E and E-E farms are only 42% and 18%, respectively, of production on the SI-E farm.

The difference in prices received by each type of farm is a result of the different sizes of shrimp produced. As the size of shrimp increases, the price increases. Prices received by Ecuadorian farmers for a given size shrimp are only slightly lower than those received in the United States (Shrimp Notes, Inc., 1983).

The value of the annual production of the SI-E farm is 22% greater than that of the SI-US farm. The production value of the SE-E and E-E farms are only 47% and 21%, respectively, of the SI-E farm.

The most significant variable cost item for the two semi-intensive systems is feed. It is 37% of variable cost on the SI-US farm and 43% of variable cost on the SI-E farm. The unit

cost of feed was estimated to be 18% higher in the United States than in Ecuador. Postlarvae cost is the second most significant variable cost in the SI-US farm and ranked third for the SI-E farm. Postlarvae cost per thousand used in this analysis was three times greater (\$12.00 vs. \$4.00) in the United States than Ecuador and the total shrimp stocked in one year is 25% greater for the SI-US farm than the SI-E farm.

The second most important cost for the SI-E farm is miscellaneous which is composed of miscellaneous, payroll tax (40% of wages) and meals. Wages are the third most important item for the SI-US farm, but rank fifth for the SI-E farm. Even though wages are much higher for the SI-US farm, it has only 11 employees compared to 30 for the SI-E farm.

Table 10 shows the percent value of the crop produced for variable cost, fixed cost and total cost for each type of farm. Cost per value of crop produced is approximately 50% higher for the SI-US farm compared to the Ecuadorian farms.

Income tax is assumed to be 50% for all type farms. The authors are not familiar with the tax rate in Ecuador, however, Ecuadorian farmers have to exchange 70% of their dollars to sucres at the official exchange rate (54 to 1) and 30% can be exchanged at the market rate (approximately 100 to 1) causing a significant tax on all shrimp exported to the United States (Shrimp Notes, Inc., 1983). However, it must be remembered that all costs in this analysis were converted at the official rate making returns above cost a conservative estimate.

The cost to produce one kilogram of shrimp (heads-off) is greatest for the SI-US farm and least for the SI-E farm (Table 9). For Ecuador, the less intensive the farm operation, the higher the cost per kilogram to produce the product. It should be noted that two of the major cost items for the SE-E and E-E farms are repairs and miscellaneous. These values are rather arbitrarily estimated and, therefore, could be significantly over-estimated. However, the cost for maintenance in Ecuador would be greater than the United States because of low availability of replacement parts and skilled labor. If these costs were reduced by half, then the cost to produce shrimp for the SE-E and E-E farms would be approximately the same as the SI-E farm.

The after-tax internal rate of return (IRR) based on a

Table 9. Economic comparison (per hectare) of a 200-surface ha shrimp farm using 20-ha ponds by intensity of system for the United States and Ecuador, 1984.

Item	United States	Ecuador		
	Semi-intensive	Semi-intensive	Semi-extensive	Extensive
Kg/ha/yr (heads-off)	1,159	1,323	554	232
\$/kg	8.47	9.00	10.00	11.00
Value/ha (\$)	9,798	11,908	5,544	2,553
Total variable cost (\$)				
Postlarvae	1,800	480	180	62
Wages	663	317	190	78
Fuel	225	106	75	40
Feed	2,040	1,995	334	0
Fertilizer	54	269	269	0
Repairs	138	311	234	179
Packing	548	448	188	79
Miscellaneous	120	687	339	129
Total	5,588	4,613	1,809	567
Total fixed cost (\$)				
Overhead	404	230	130	100
Depreciation	595	396	268	192
Miscellaneous	175	91	57	50
Total	1,174	717	455	342
Total cost (\$)	6,762	5,330	2,264	909
Revenue before taxes (\$)	3,036	6,578	3,280	1,644
Taxes (\$)	1,518	3,289	1,640	822
Revenue after taxes (\$)	1,518	3,289	1,640	822
B-E price/kg (heads-off) (\$)	5.83	4.03	4.09	3.91
IRR (%)	21	59	39	25
Total investment (× \$1,000)	1,915	1,243	937	715

10-year planning horizon is attractive for all farms considered. It should be noticed that the IRR is much greater for most of the Ecuadorian farms which explains the rapid rise of shrimp culture in Ecuador. Also, the significant increase in the IRR as the intensity of the farm increases explains why investors are putting in more semi-intensive systems.

Risk and time considerations

In the two previous sections, no consideration was given for risk and time consideration. It was assumed that production, prices and unit cost were known with certainty and they did not vary from year to year. In addition, it was assumed that in the year the initial investment was made, the farm would be in full production. When these assumptions are made, the results can lead to over-confidence in the economic feasibility of the investment.

Large shrimp farms are usually built in stages. The first year will, more than likely, not have production. The second year will partially produce while in the third year full production could be realized.

There are many factors that investors will not know with certainty and that will vary over time. Price received, inflation and interest rates will vary and can be rather volatile at times. Production can vary from pond to pond through

Table 10. Total variable cost, total fixed cost, and total cost as a percent of the value of the crop produced per year.

Cost	United States	Ecuador		
	Semi-intensive	Semi-intensive	Semi-extensive	Extensive
Total variable	57	39	33	23
Total fixed	12	6	8	13
Total	69	45	41	36

growth rates and mortality. Temperature variation in the United States can affect the growth of shrimp. Environmental conditions, such as hurricanes in the United States and heavy rainfall in Ecuador, can cause damage and loss of production.

A firm level simulation model (MARSIM) was developed to simulate the annual activities of a shrimp farm taking into account timing and risk. A firm is replicated 50 times over a 10-year planning horizon. Random values for pond growth, pond survival, temperature, hurricanes and prices received in each of 10 years are generated from empirical probability density function for these variables.

When all timing and risk are incorporated into the analysis, it can have a substantial impact on the IRR. Table 11 shows that when producing *P. stylirostris* on a

Table 11. Comparison of after-tax internal rate of return for producing *Penaeus stylirostris* in semi-intensive ponds and operating a postlarvae reproduction unit in the Southern United States, 1984 (Hanson et al., 1984).

Total surface ha	Surface ha per pond	IRR: No risk and full production since Year 1 (%)	IRR: Risk and production developed over 2-3 years + (%)
40 ^a	4	7.3	1.56
	10	9.1	2.19
	20	10.2	3.44
100 ^a	4	15.9	9.69
	10	19.3	11.41
	20	20.8	15.31
200 ^b	4	20.1	9.65
	10	23.8	10.68
	20	26.8	11.80
400 ^b	4	24.7	13.20
	10	28.0	13.98
	20	31.6	14.06

^aDeveloped in two years

^bDeveloped in three years

200-surface ha farm using 20-ha ponds, the IRR is less than half when risk and timing of production are considered. The high IRR in Ecuador allows for a larger margin of error when an investor is performing a feasibility analysis. The United States does not have the luxury of error through overly high returns.

Conclusions

Shrimp culture in the Americas is in the infant stages in all countries, except Ecuador and Panama. How fast cultured shrimp production will expand will depend on technology to produce larvae (nauplii). Those countries having a year-round growing season have a much lower cost of production than countries like the United States with a limited growing season. Expansion then will be very dependent on the price received for shrimp. If production is significantly increased by cultured shrimp so as to cause the real price of shrimp to decrease over the next 10 years, development of shrimp culture in the United States will most likely be curtailed. However, prices can fall considerably for countries like Ecuador and investors can still receive a fair rate of return on their investment.

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