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Economic Analysis of Prawn *(Penaeus monodon)* Culture in the Philippines, II: Grow-out Operations

U. HATCH[1], R. AGBAYANI[2] and E. BELLEZA

[1]*Department of Agricultural Economics and Rural Sociology Auburn University, AL 36849-5406, USA*

[2]*Southeast Asian Fisheries Development Center Tigbauan, Iloilo, Philippines*

Abstract

The dramatic fall in prawn prices coupled with environmental concerns has resulted in a relative stagnation of prawn grow-out operations in the Philippines. Leaders of the Philippine aquaculture sector are concerned that their cost of production is higher than that of their close competitors in Indonesia and Thailand. Also, the environmental and production "crash" experienced in Taiwan has led to a general perception that intensive culture cannot be sustained. The sector recently experienced a lack of direction and growth, combined with crowded watersheds, excessive use of water bodies, overuse of groundwater and continued destruction of mangrove.

A field survey of prawn growers was conducted in August-October 1992 using a standardized economic questionnaire that included costs, returns and growers' perceptions of constraints. Economic estimates were developed for representative production systems: intensive, semi-intensive, extensive and prawn-milkfish rotation.

The incentive to expand the prawn pond area is not strong. Existing intensive facilities can be operated efficiently and profitably, but new intensive operations will most likely need to include water treatment capabilities for water entering and exiting grow-out ponds. Canals, reservoirs or ponds used for water quality improvement may be able to concurrently produce a profitable crop, such as milkfish-prawn rotation. Internal rate of return for semi-intensive ponds using earthen ponds was higher than for other culture systems. If, over time, water quality and conservation constraints are sufficiently addressed, stocking densities might be increased. Research and extension programs targeting equity should focus on integrated systems.

Introduction

Production of cultured prawn *(Penaeus monodon)* in the Philippines grew rapidly from an estimated 1,800 tonnes in 1982 to a peak of 47,600 tonnes in 1990, increasing in value from P22 million to over P9 billion (Table 1). This dramatic increase in brackishwater production of prawn was attributed to the adoption of intensive culture technology from Taiwan combined with major breakthroughs by research institutions in the country, e.g., University of the Philippines in the Visayas - Brackishwater Aquaculture Center, and the Southeast Asian Fisheries Development Center). The incentive to engage

Table 1. Total production of tiger prawn in the Philippines, with value for cultured production, 1982-91.

Year (t)	Wild catch %	Percent (t)	Cultured %	Percent (Pmillion)	Value (t)	Total
1982	1,184	40	1,805	60	22	2,989
1983	1,465	14	9,287	86	836	10,752
1984	1,065	4	26,357	96	2,244	27,422
1985	105	4	26,537	96	2,494	27,592
1986	1,367	5	27,980	95	3,777	29,347
1987	2,370	7	32,380	93	4,461	34,750
1988	3,951	9	41,548	91	7,438	45,499
1989	3,537	8	43,539	92	6,966	47,076
1990	1,835	4	47,591	96	9,279	49,426
1991	1,526	3	45,740	97	8,247	47,266

Source: Bureau of Agricultural Statistics, as cited in Philippine Prawn Industry Policy Study 1993. Values are expressed in Philippine pesos P25 = US$1.

in prawn production, even among non-traditional fish farmers, was also spurred by the growing world demand (Keithly et al. 1993) and high export prices in the early 1980s. Following the proliferation of prawn farms in the country, prawn culture became a significant export industry (second to coconut oil among agricultural exports) with sales of about 30,500 tonnes in 1991 valued roughly at US$276 million (ICAAE 1993).

The huge profits enjoyed by prawn producers, however, proved to be short-lived. In 1989, export prices suddenly dropped by more than half, causing the majority of prawn farmers, as well as hatcheries, shrimp processors and feed millers, to reduce production or shutdown operation. Erratic demand, higher feed and energy costs, poor quality fry, limited capital and marketing inefficiences beset the industry. The environmental and production “crash” in Taiwan in 1988 also led to the general perception that intensive culture using high nutrient input cannot be sustained. In addition, external factors beyond the control of prawn farmers, e.g., natural calamities, continued environmental degradation of water bodies, and government policies, have contributed to the lack of direction and growth of the industry in recent years.

Prior to the dramatic drop in prices in 1989, Posadas (1988) analyzed the economic cost and returns from prawn farming and found the industry highly sensitive to changes in prices. Although prices started to increase in 1990, there is still much uncertainty about market prospects and the stability of the industry in view of growing technical constraints related to the use of more intensive culture systems and increasing competition from other Asian producers.

Using data from a field survey of prawn farming conducted in 1992, this paper examines the operation of alternative production systems for prawn farming in various regions of the Philippines. The objective is to develop economic estimates of operating cost and returns which can be used as a benchmark in evaluating the viability and relative profitability of different culture systems. The results of the study are intended to provide policymakers and prawn growers with baseline indicators to determine the appropriate and cost-efficient production system to be adopted given the problems, constraints and opportunities currently facing individual prawn growers, and the industry in general.

This paper presents a brief background of prawn farming in the Philippines, its problems and constraints, and a comparative financial and economic analyses of alternative production systems. Enterprise budgets, cash flows and sensitivity analysis are employed to measure net returns, breakeven prices and quantities, and the degree of risk associated with certain changes in production parameters, e.g., feed cost and prawn prices. The desirability of new investments or improved pond facilities is also evaluated. The paper concludes with a discussion of potential areas for improvement in prawn farming that can lead to more sustainable and environmentally sensitive culture practices.

Industry Background

Prawn farming in the Philippines gained impetus in the early 1980s when wholesale prices in the world market rose above $\$10 \cdot kg^{-1}$ (Office of International Affairs 1992). In the past, the bulk of prawn production came from capture fisheries. Aquacultural production of prawn was traditionally undertaken with milkfish production which comprised roughly 90% of total fishpond production in 1987 (Juliano and Baylon 1990).

When Japan expanded its import demand for prawn in 1984, farmgate prices soared, triggering the unprecedented interest in prawn culture among Filipino entrepreneurs and big corporations (e.g., San Miguel Corporation) who wanted to cash in on the huge profit margin. Net profit was so high that some prawn producers were known to recover their initial capital investment after a year or two. Around the same time, the supply of shrimp from the wild had substantially declined due to pollution and overfishing, further reinforcing the need for more pond-raised prawn to meet the increasing world demand. Large areas of sugarland and rice land were converted to fish farms, and more mangroves reclaimed for prawn cultivation. Milkfish ponds were used instead to monoculture prawn which was more lucrative. Consequently, the share of prawn supplied from the wild decreased from 40% in 1982 to about 4% in 1991. The "prawn production fever" which gripped the country in the mid-1980s resulted in further destruction of coastal mangroves and pollution of surface and groundwater bodies. Excessive pumping of water from wells, and the propagation of a more intensive culture system adversely affected the freshwater supply and the quality of agricultural land.

In 1992, a total of 49,478 ha were devoted to prawn culture: 20,940 (44%) in Luzon, 14,314 (30%) in Visayas, and 12,519 (26%) in Mindanao. The combined hectarage represented 23% of the total brackishwater fishponds in the country. Pond production of prawn consists of growing black tiger prawn (97%), endeavor shrimp (2%) and white shrimp (1%) (ICAAE 1993).

Over 90% of total farmed production of prawn in 1991 was exported, primarily to Japan (71%) and the USA (23%) (Government of the Philippines 1990). Exported prawns were sold either head-on, headless or peeled; frozen, salted or dried. Japan is the largest and the most important market for prawn-producing countries in Asia accounting for 85% of total supply (Liao et al.

1990). The severity of the prawn market crash in 1989 reflects the heavy dependence of Philippine producers on the Japanese market. Domestic consumption of prawn in the Philippines represents only a small percentage (2-3%) of total production because of its relatively higher price compared to fish.

Growers' Perceptions of Problems and Constraints

Leaders of the Philippine aquaculture sector recognized that the ablity of Philippine prawn to compete in the world market hinged, to a large extent, on harvest quality and size, and on the cost-efficiency of the culture system adopted. Among other things, industry leaders were concerned that production cost was higher than that of competitors in Indonesia and Thailand. Philippine cost of production was estimated at US$4.50·kg^{-1} against $3.30·kg^{-1} and $3.60·kg^{-1} for Thailand and Indonesia, respectively (Akiyama 1989). Feed cost is a major constraint in prawn growout because it absorbs more than 50% of total variable costs for semi-intensive and intensive systems. Feed prices paid by Philippine prawn growers were 36% more than Thailand, and 25% more than Indonesia, due primarily to high tariffs levied on imported feed. The high feed prices led growers to believe that feed millers had changed the feed formulation, substituting the more expensive fish meal with less expensive protein from soybeans, thereby affecting feed quality and prawn harvest quality. The increasing competitive pressure on Philippine producers was compounded by the possibility of Vietnam, Bangladesh and Burma becoming important suppliers in the international market, in addition to China and India.

Most growers also felt that fry quality was deteriorating due to the degradation of the environment for wild spawners, and the increasing competition to capture wild spawners (wild fry tend to grow faster and reach larger size). In addition to growth problems, many growers experienced an increased incidence of viral and bacterial diseases, particularly MBV (Monodon baculovirus). There was also a general perception among growers that the current fry criteria were not good indicators of successful growout. Some producers suggested that the criteria were useful only for judging success for the first 30 d in the pond, but not thereafter.

Data and Methods

A nationwide survey of prawn growers was undertaken in August-October 1992 using standardized questionnaires, interviews and field visits of pond areas. Survey questions covered production, costs, income and growers' perceptions of operational constraints.

The Philippine archipelago is composed of three main islands: Luzon, Visayas and Mindanao, each subdivided into 12 regions (Regions 1-12). The major prawn-producing regions are located in Western Visayas (Negros, Iloilo, Capiz, Aklan) accounting for 16,435 tonnes (35%) of farmed production in 1990, Central Luzon (Bulacan, Pampanga, Bataan, Zambales) with 12,857 tonnes (27%), and Southern Tagalog (Cavite, Mindoro, Quezon, Batangas) with 8,431 tonnes (18%) (Bureau of Agricultural Statistics). Altogether, these three regions accounted for approximately 80% of total prawn production in the country.

Thirty-seven surveys were completed covering seven regions (Regions 1, 3, 4, 6, 7, 10 and 11). The sample population was determined based on the most common culture method used in the region, current pond area, production potential, and cooperation of growers. The survey focused on semi-intensive systmems in Negros, Southern Mindanao, Eastern Visayas and Central Luzon where prawn farms are heavily concentrated.

Key production parameters considered in the survey were: pond area, stocking density, culture period, survival rate, average prawn size at harvest, feed conversion, and yield per hectare (Table 2). Problems and opportunities perceived by growers are also addressed, as they bear upon yield and cost efficiency of a particular production system. Survey results were analyzed by comparing operating costs and returns from alternative production systems. However, for the purpose of this paper, and for ease of presentation of results, only the average cost and returns for each culture system will be presented (ICAAE 1993) for the regional breakdown. Costs and returns were analyzed on a hectare and kilogram basis at one harvest, and annual costs and returns were calculated based on 1.5 production cycles. Estimates for existing ponds reflected average operating costs and returns presuming that pond owners had fully paid off their capital investment, especially for those enterprises which started operation during the initial years of high prices. Economic estimates for the representative production systems were computed based on projected costs and returns considering expanded or new capital investment.

Table 2. Production parameters for prawn farming in the Philippines, 1992.

Production parameters	Extensive	Semi-intensive	Intensive
Stocking density (pieces·ha^{-1})	22,400	120,000	233,800
Survival rate (%)	57	68	77
Days of culture	151	138	156
Feed conversion rate	0.70	1.79	2.04
Yield (kg·ha^{-1})	303	2,772	5,325
Average Price (P·kg^{-1})	194.67	150.96	145.33

Values are expressed in Philippine pesos P25 = US$1.

Results

The field survey identified four types of production systems for prawn growout: extensive or traditional, semi-extensive, intensive and rotation. The distinction from one production system to another is based primarily on stocking density, feed intake and water management. Broadly defined, the extensive system is characterized by low stocking density and low nutrient input. It relies heavily on natural food in the pond (e.g., algae) for feeding, and tidal exchange for water management. The intensive system utilizes higher stocking rates, high nutrient inputs (completely formulated feeds) and water pumps/ aerators to improve water quality. The semi-intensive system, with its supplemental feeding and occasional pumping of water supply, is considered a hybrid of extensive and intensive production systems. The rotation system involves the culture of milkfish during the relatively dry season (November-March), and prawn during the rainy season (May-October) in association with the semi-intensive culture environment. Culture of shrimp tends to be more favorable during the rainy season when water salinity is generally known to decrease (Boyd 1989; Boyd and Fast 1992). Milkfish production improves water quality between prawn crops because milkfish feed on organic debris in the pond, and the fish is popular in the market. A choice of earthen, riprap or concrete ponds were utilized for all the production systems.

The pond area, stocking density and yield varied with each culture system and regional location. Survey results showed great variation in average farm size. The smallest pond area in the sample was 0.5 ha, and the largest was over 20 ha, with extensive systems utilizing more land than any other system. Stocking density for extensive systems were 10,000-50,000 postlarvae (PL)$\cdot$ha^{-1}, and yield was less than 500 kg$\cdot$ha^{-1}. Semi-intensive systems had stocking densities of 50,000-120,000 PL$\cdot$ha^{-1}, and yield varied from 500 to 3,000 kg$\cdot$ha^{-1}. Intensive systems could accommodate much higher stocking rates, 200,000-500,000 PL$\cdot$ha^{-1}, with yields of over 5,000 kg$\cdot$ha^{-1}. The average harvest size was relatively larger for extensive systems (25-61 g) than for semi-intensive (20-47 g) or intensive systems (26-40 g). Culture period ranged from one to two crops per year depending on the intensity of the culture system adopted. Extensive systems were usually limited to one crop because of its long growing season (120-220 d) and use of traditional technology. Under normal conditions, it takes 4-5 months to raise prawn to marketable size (30-35 g).

Information about operating expenses (variable cost of production) guides decisions on production prices during the cycle, and, when analyzed in conjunction with gross receipts, provides a useful measure of net operating income. The variable costs of production consist of expenditures on fry, feed, pond preparation, power, fuel/oil/lube, salaries and allowances, repairs and maintenance, interest on operating capital and other inputs (Table 3). Operating cost per hectare for the various prawn production systems varied significantly from one region to another.

The survey results revealed that the fry share of total variable costs was 8-22% and was generally higher for extensive systems (22% for extensive, 13% for semi-intensive, and 8% for intensive). These fry shares correspond to a value of P4,000-85,000$\cdot$ha^{-1}. The cost of fry per hectare was P4,000-7,000 for extensive, P19,000-64,000 for semi-intensive; and P35,000-85,000 for intensive systems. The average cost of fry per hectare for extensive systems was only P6,600 compared to P47,200 for semi-intensive and P51,600 for intensive systems.

Operating expenses for semi-intensive and intensive systems were dominated by feed cost. On a hectare basis, the proportion of feed cost to total operating cost was 25% (P7,400) for extensive systems, 54% (P208,830) for semi-intensive systems, and 63% (P398,090) for intensive systems. For semi-intensive practices, feed cost accounted for 51-76% (P163,000-302,000) of operating costs. Feeds share for intensive systems was 57-73% of total variable costs.

Table 3. Operating cost per hectare by production system for prawn farming in the Philippines, 1992.

Item	Extensive		Semi-intensive		Intensive	
Operating cost (P·ha^{-1})	Amount	%	Amount	%	Amount	%
Fry	P 6,610	22	P 47,600	13	P 51,610	8
Feeds	7,400	25	208,830	54	398,090	63
Pond preparation	980	3	19,650	5	10,890	2
Power	10	0.01	42,310	11	58,400	9
Fuel/oil/lube	27	0.09	3,910	1	7,780	1
Salaries and allowances	3,960	14	30,510	8	39,500	6
Repairs and maintenance	3,630	12	11,370	3	17,850	3
Others	5,200	18	7,040	1	15,830	3
Interest on operating capital	1,400	5	16,790	4	30,870	5
Total variable cost (P·ha^{-1}cycle^{-1})	29,217	100	388,010	100	630,820	100
Interest on variable cost (P·ha^{-1}year^{-1})	1,910		24,230		44,830	
Annual variable cost (P·ha^{-1}year^{-1})	40,200		560,110		916,090	

Values are expressed in Philippine pesos P25 = US$1.

Extensive systems in the Philippines utilized fertilizers to maximize production from natural fertility and often used "wet feed" (mussels or snails) in place of extensive formulated feeds. The use of wet feeds, however, is limited by the large volume that would be needed because it requires one feed animal (wet feed animal) for each animal being grown out, to maintain the desired, relatively uniform size in the grow-out population. Also the build up of sediments in the pond bottom would be substantial with this form of feeding.

Power cost per hectare for extensive systems was negligible (0.01%) in all the surveyed regions. For intensive farming systems, however, power cost accounted for 6-12% (P25,000-101,000) of total operating cost, while for semi-intensive systems, it was 3-15% (P7,000-80,000). Power expenses, on average, were 11% of operating cost (P42,310) for semi-intensive systems, and 9% (P58,400) for intensive operations. The cost of electric power, principally used for aeration, varies greatly among regions of the Philippines and is substantially higher than in many countries around the world. The price per kilowatt hour ranged from P1.50 in the southern part of the country (e.g., General Santos, Mindanao) to P4.10 in the northern part (e.g., Pangasinan, Luzon). In addition to the cost of electric power, growers had to contend with the problem of power outages which have the potential of adding to the cost of operating semi-intensive and extensive systems by increasing the needed power capacity.

The proportion of salaries and allowances relative to operating expenses tended to be higher the less intensive the production system (14% for extensive, 8% for semi-intensive, and 6% for intensive). Repairs and maintenance were also higher for extensive systems (12%) compared to both semi-intensive and intensive systems (3%). Other inputs of production represented 18% of operating costs for extensive, 1% for semi-intensive, and 3% for intensive systems. The higher cost for extensive systems could be attributed to the extra maintenance needed for the dikes, generally in the form of additional labor needed to prepare the pond between crop seasons.

Overall, extensive systems were found to have the lowest total operating cost per hectare (P29,200), followed by semi-intensive systems (P388,000), then intensive systems (P630,800). Annually, this corresponds to approximately P40,200·ha^{-1} for extensive, P560,100·ha^{-1} for semi-intensive and P916,000·ha^{-1} for intensive systems. On a kilogram basis, the estimates showed that extensive systems also incurred the lowest annual variable costs at P88, and semi-intensive the highest at P135. The annual operating cost for intensive systems averaged P115·kg^{-1}.

In general, the economic analysis indicates that extensive systems were the least risky in terms of variability of results. In contrast, semi-intensive and intensive systems were quite risky because they involved greater production costs and higher stocking densities per hectare.

Prawn prices are subject to seasonal fluctuations over time and differ considerably by market location throughout the country. Estimates of gross receipts per hectare in the sample regions were P53,000-66,000 for extensive systems; P704,000-303,000 for semi-intensive operations; and P445,000-956,000 for intensive systems. Average gross receipts for the different culture systems surveyed were P59,000 (extensive), P418,000 (semi-intensive) and P774,000 (intensive). The prices received by prawn growers ranged from P130 to P206 per kilogram depending on the average harvest size (30-35 g). The wide range of prices received for prawns of approximately the same size is determined by the time of the year, location and size of purchase. Prices tend to be higher toward December and relatively lower in the beginning of the year. Location affects transportation cost and the seasonal variation in prices offered to processors in the world market can be substantial.

Representative Production Systems

Based on the estimated costs and returns obtained from the survey, investment requirements, cash flows and breakeven prices and quantities are projected for representative production systems assuming recommended management practices. The estimates for a representative production system can be used as a guide in management decisions to expand or invest in new pond facilities. Sensitivity analyses are also performed to show the degree of stability and relative profitability of alternative production systems given changes in input cost, feed conversion ratios or market prices.

Investment cost per hectare and return on investment for prawn growers in the Philippines can vary significantly by region and production system. Capital investment includes investment on land and its improvements (construction cost), building and equipment (Table 4). Average cost of land may range from P150,000 to P300,000 per hectare. The extensive system may use earthen ponds, semi-intensive has a choice among any of the basic construction methods (earthen, riprap, concrete), and itensive systems may use either riprap or concrete. The estimated total cost for intensive systems using concrete ponds (P1.5 million) is approximately twice that of riprap ponds (P700,000) which are in turn about twice as expensive to construct as earthen ponds (P360,000). Intensive systems need concrete ponds and a special central drainage system. Semi-intensive and extensive systems probably do not require concrete ponds or central drainage.

Table 4. Projected investment cost for various prawn culture systems in the Philippines (P000·unit^{-1}), 1992.

Item	Extensive	Semi-intensive	Intensive	Rotation
Construction cost				
Earthen	P150	P150	P150	P150
Riprap	450	450	450	450
Concrete	700	700	700	700
Equipment				
Paddlewheel aerator	11.5	46	80.5	46
Generator	10	10	10	10
Lab equipment	6	6	6	6
Electric transformer and lines	5	50	50	50
Pump	4	20	20	20
Total equipment	36.5	132	166.5	132
Buildings				
Feed shed	10	10	10	10
Pump house	4	4	4	4
Office	0	10	10	10
Housing (tech)	0	20	20	20
Total buildings	14	44	44	44
Total investment				
Earthen	200.5	326	360.5	326
Riprap	500.5	626	660.5	626
Concrete	750.5	876	910.5	876

Values are expressed in Philippine pesos P25 = US$1.

Return on investment criterion is generally used as an indicator of the incentive for new investment or, in the case of prawn farming, the construction of new pond facilities. Using the average return on the improvement investment and a 24% cost of capital, the only profitable concrete ponds were those of the intensive systems. In contrast, earthen ponds were always profitable. The cost of land is a small percentage of the total investment for semi-intensive and intensive systems, but can be important for extensive systems. These results tend to indicate that semi-intensive systems should probably not use concrete ponds. Owners of existing concrete facilities will have to decide, based on their remaining debt, as to the appropriate stocking density. To assess profitability, growers with existing ponds will have to calculate gross receipts from harvest less operating cost (Table 3), plus their own debt repayment schedule. Many existing growers may have already paid off some or all of the initial construction and start-up costs depending on the year in which operation was initiated and the degree of self-financing. Operators of owner-financed ponds will only look at returns above operating expenses to make current decisions and, possibly, consider the opportunity cost (in terms of foregone investment opportunities) as they contemplate possible expansion. Managers of facilities that have been able to put off their investment will consider only returns over operating expenses for current cycle decisions and will look at the full cost for potential investment in new pond capacity.

Projected cash flow statements indicate that extensive systems have the lowest breakeven price needed to cover variable (P66), followed by the rotation system (P88) (see Table 5). For existing ponds, the breakeven price to cover total cost was lowest for the rotation system (P107) and slightly higher for extensive systems (P115). Given new capital investments, however, the price required to breakeven (cover total costs) tend to be lower for intensive (P134) and semi-intensive systems (P158) compared to extensive systems (P224), for all types of ponds. The lowest breakeven price to cover total cost was reflected in the rotation system using earthen ponds. The higher price for extensive systems may be explained by the fact that extensive systems use more land (fixed cost) while stocking density is low to be able to spread out the fixed cost of production to so many units of output.

Table 5. Estimated breakeven price and quantity under alternative production systems of prawn farming in the Philippines, 1992.

Breakeven price to cover (P·kg^{-1})	Extensive	Semi-intensive	Intensive	Prawn-milkfish rotation
Variable costs	P 66.00	P 114.17	P 114.09	P 83.85
Total cost				
Earthen pond	155.00	143.96	NA	114.99
Riprap pond	NA	158.52	134.37	129.10
Concrete pond	NA	NA	139.59	NA
Existing pond	115.39	136.02	124.77	107.04
Breakeven quantity to cover: (t·ha^{-1})				
Variable costs	0.28	2.40	5.99	1.76
Total cost				
Earthen pond	0.65	3.02	NA	2.41
Riprap pond	NA	3.33	7.05	2.71
Concrete pond	NA	NA	7.33	NA
Existing pond	0.48	2.86	6.55	2.25
Net returns (P·ha^{-1}·year^{-1})				
Earthen	P 3.28	P 53.88	NA	P 12.04
Riprap	NA	4.98	123.09	-35.36
Concrete	NA	NA	81.96	NA
Existing pond	29.98	80.58	198.70	38.74
Internal rate of return (%)				
Earthen	19.73%	51.47%	NA	27.39%
Riprap	NA	20.44%	51.18%	11.60%
Concrete	NA	NA	31.84%	NA

Values are expressed in Philippine pesos P25 = US$1.

The level of production per hectare required to cover variable and total costs increases with the intensity of the culture system adopted: 0.941 tonnes·ha^{-1} for extensive; 3.31 tonnes·ha^{-1} for semi-intensive; and 7.04 tonnes·ha^{-1} for intensive. The rotation system needed 2.69 tonnes·ha^{-1} of prawn production to breakeven. Intensive and semi-intensive production systems usually yield smaller sizes of prawn relative to extensive systems due to higher stocking densities.

Intensive systems using riprap and concrete provide the greatest annual net returns (P123,000·ha^{-1} and P82,000·ha^{-1}, respectively). Semi-intensive systems using earthen ponds have the next highest returns (P53,900·ha^{-1}), while extensive systems using earthen ponds have the lowest annual returns

(P3,028·ha^{-1}). Annual returns for the milkfish-prawn rotation system are slightly higher than for extensive systems. The internal rate of return (IRR), however, of semi-intensive systems using earthen ponds are higher than for any other system.

Sensitivity analysis is a valuable tool for determining the margin of operating safety associated with each system of production given changes in key production variables affecting profitability. Economic indicators such as breakeven prices and quantities, net returns and IRR are important in assessing the economic viability and overall profitability of investments. In particular, IRR takes into account the time value of money and the opportunity cost of capital in terms of alternative investments.

In this study, a sensitivity analysis is performed particularly for increases (decreases) in prawn prices and feed costs. Demand for prawn is known to be price elastic and is susceptible to wide fluctuations in the world market because of tight competition among suppliers. Moreover, Philippine producers have relied heavily on a limited number of foreign markets to sustain its increasing level of production, making the industry highly vulnerable to changes in the economy of these foreign markets, i.e., Japan and the USA. Feed cost is a critical variable in prawn farming because it comprised the largest percentage of operating costs (50-70%) for semi-intensive and extensive systems.

The results of the sensitivity analysis are presented in Appendix 1 and 2. Market prices and feed cost both increased (decreased) by 20-25%. The results suggest that the grow-out operation is sensitive to fluctuations ni market prices. The different production systems, with the exception of intensive systems, cannot absorb more than a 10% decrease in prices, assuming the baseline price of $160·kg^{-1}, *ceteris paribus*. Further decreases in prices would generally result in negative returns. Intensive systems using riprap and concrete ponds appeared to be more flexible and can sustain a much lower market price of P140·kg^{-1}. Annual net returns for extensive systems in earthen ponds are P3,300·ha^{-1} compared to P53,900·ha^{-1} for semi-intensive systems using earthen ponds and P160,000·ha^{-1} for intensive systems using concrete ponds. At a price of P160-200·kg^{-1}, semi-intensive systems and intensive systems registered higher IRR: 55-201% (semi-intensive, earthen); 79-316% (intensive-riprap) and 47-143% (intensive-concrete). Extensive systems exhibit the lowest IRR (20-45%) given a 25% increase in prawn prices.

For feed cost changes, earthen ponds are shown to be a stable system for both semi-intensive and rotation systems, and can absorb as much as 10% increase in feed prices over P31,000·tonnes^{-1}. Intensive systems using riprap ponds tend to manifest a greater margin of operating safety compared to intensive systems using concrete. By lowering feed prices from P33,000·tonnes^{-1} to P27,000·tonnes^{-1}, IRR for semi-intensive systems using earthen ponds varies from 39% to 79%; intensive systems using riprap from 39% to 80%, and concrete from 24% to 49%. Although intensive production systems using riprap appeared to be more profitable than semi-intensive systems, intensive culture entails greater risks because of higher production cost and higher stocking density. Management practices of intensive systems are also less sensitive to the environment.

Appendix 1. Sensitivity analysis for feed cost changes in various prawn farming systems in the Philippines, 1992. (US$1 = P25).

Indicators	Extensive systems			Prawn-milkfish rotation		
Feed price ($P \cdot t^{-1}$)	27	31	33	27	31	33
Breakeven price						
Earthen pond	150.00	155.00	160.00	107.86	114.99	118.55
Existing pond	111.83	115.39	117.16	133.88	107.04	144.57
Breakeven quantity ($t \cdot ha^{-1}$)						
Earthen pond	0.64	0.65	0.66	2.27	2.41	2.49
Existing pond	0.47	0.48	0.49	2.10	2.25	2.32
Net returns ($P \cdot ha^{-1}$)						
Earthen pond	5.67	3.28	2.09	35.98	12.04	0.07
Existing pond	32.37	29.98	28.79	62.69	38.74	26.77
Internal rate of return (%)						
Earthen pond	21.77	19.73	18.71	45.93	27.39	19.20
	Semi-intensive systems			Intensive systems		
Feed price ($P \cdot t^{-1}$)	27	31	33	27	31	33
Breakeven price ($P \cdot kg^{-1}$)						
Earthen pond	133.27	143.96	149.31	NA	NA	NA
Riprap pond	147.83	158.52	163.86	123.68	134.37	139.71
Concrete pond	NA	NA	NA	128.90	139.59	144.94
Existing pond	125.33	136.02	141.36	114.08	124.77	130.11
Breakeven quantity ($t \cdot ha^{-1}$)						
Earthen pond	2.80	3.02	3.14	NA	NA	NA
Riprap pond	3.10	3.33	3.44	6.49	7.05	7.33
Concrete pond	NA	NA	NA	6.77	7.33	7.61
Existing pond	2.63	2.86	2.97	5.99	6.55	6.83
Net returns ($P \cdot ha^{-1}$)						
Earthen pond	89.80	53.88	35.92	NA	NA	NA
Riprap pond	40.89	4.98	-12.98	207.27	123.09	81.00
Concrete pond	NA	NA	NA	166.14	81.96	39.87
Existing pond	116.50	80.58	62.62	282.88	198.70	156.61
Internal rate of return (%)						
Earthen pond	79.39	51.47	39.23	NA	NA	NA
Riprap pond	29.63	20.44	16.09	80.45	51.18	38.84
Concrete pond	NA	NA	NA	48.59	31.84	24.29

The impact of changes in survival rate and feed conversion ratio were also analysed. Results of the sensitivity analysis indicate that the minimum survival necessary to cover total cost varies from 50% for extensive systems to 55-60% for semi-intensive and intensive systems. Further analysis suggests that the feed conversion ratio for semi-intensive and intensive systems are quite sensitive, as changes from the baseline of 2.1 to 2.4-2.5 would result in losses. Extensive systems have little risk in relation to feed conversion due to the consumption of natural food by the prawn.

Discussion

The crucial issues confronting Philippine prawn producers are related to higher cost of production, limited export markets, the continued degradation of the environment, and uncertainties associated with government policies. There is a pressing need to address these issues if the industry is to remain

Appendix 2. Sensitivity analysis for changes in prawn price in various prawn farming systems in the Philippines, 1992. (US$1 = P25).

Indicators	Extensive systems			Prawn-milkfish rotation		
Prawn price ($P \cdot kg^{-1}$)	140	160	200	140	160	200
Breakeven quantity ($t \cdot ha^{-1}$)						
Earthen pond	0.74	0.65	0.52	2.76	2.41	1.93
Existing pond	0.55	0.48	0.39	2.57	2.25	1.80
Net returns ($P \cdot ha^{-1}$)						
Earthen pond	-10.16	3.28	30.16	-32.76	12.04	101.64
Existing pond	16.54	29.98	56.86	-6.06	38.74	128.34
Internal rate of return (%)						
Earthen pond	8.82	19.73	45.14	0	27.39	123.86
	Semi-intensive system			Intensive systems		
Prawn price ($P \cdot kg^{-1}$)	140	160	200	140	160	200
Breakeven quantity ($t \cdot ha^{-1}$)						
Earthen pond	3.46	3.02	2.42	NA	NA	NA
Riprap pond	3.80	3.33	2.66	7.56	6.61	2.29
Concrete pond	NA	NA	NA	7.85	6.87	5.50
Existing pond	3.26	2.86	2.29	7.02	6.14	4.91
Net returns ($P \cdot ha^{-1}$)						
Earthen pond	-13.32	53.88	188.28	NA	NA	NA
Riprap pond	-62.22	4.98	139.38	44.34	201.84	516.84
Concrete pond	NA	NA	NA	3.21	160.71	465.71
Existing pond	13.38	80.58	214.98	119.95	277.45	592.45
Internal rate of return (%)						
Earthen pond	9.50	51.47	200.65	NA	NA	NA
Riprap pond	4.82	20.44	59.31	29.05	78.34	316.15
Concrete pond	NA	NA	NA	18.08	47.44	142.82

competitive in the global market and continue to be economically viable in the long run. The importance of the prawn industry to the Philippine economy, as a foreign exchange earner and as a source of additional employment and income particularly in rural areas, cannot be overemphasized at this point. Results of the survey and economic analysis indicate that the following areas offer the greatest potential for sustainable growth of the industry, given existing resources and constraints.

The incentive for expanding prawn pond areas is not strong. While existing intensive facilities can be operated efficiently and profitably, new intensive operations will most likely need water treatment capabilities for water entering and exiting grow-out ponds. Canals, reservoirs or ponds used for water quality improvement may be able to concurrently produce a profitable crop, such as a milkfish-prawn rotation.

The greatest regional comparative advantage in prawn production is observed in Southern Mindanao where costs for energy and land are lower. New pond construction should focus on earthen ponds. Current aeration practices may be excessive and bio-economic research is needed to determine the appropriate level of aeration under various stocking densities and biomass levels. The majority of ponds should be in semi-intensive systems because the IRR for semi-intensive ponds using earthen ponds tends to be higher than for other culture systems. Semi-intensive systems using earthen ponds are also found to be more stable given increases in feed cost or decreases in prawn prices. If, over time, water quality and conservation constraints are sufficiently addressed, stocking densities might be increased. Moreover, semi-intensive culture systems have less adverse effects on the environment compared to intensive systems.

Reduction of tariffs on feed ingredients by 10% would significantly reduce feed cost. Results of the sensitivity analysis clearly demonstrate the enormous impact small changes in feed cost can have on semi-intensive and intensive operations. The high level of feeding might be a potential topic for study as a cost-saving measure, especially when prawn prices are low and feed prices are high. There is also a need to look closely at the potential of substitute feed ingredients such as rice bran, and to encourage government policies that would reduce the price of imported fish meals.

Prawn growers will most likely benefit from export promotion. Improved coordination between marketing and production will result in higher profits, and more value-added from processed prawn products. Better coordination will get growers away from a raw commodity orientation, and will improve their knowledge of consumer needs in export markets. At present, approximately 80% of Philippine prawns are sold in 5-lb. frozen packs. More value added to the final product will result in greater profit and additional employment in the local processing sector, which often result in the processors' increased ability to offer growers a better price for high quality prawns. Industry sales may be increased not only by increasing production volume, but also by increasing the average price per unit of the product.

The Comprehensive Agrarian Reform Program (CARP) in the Philippines adds considerable uncertainty to investment decisions for prawn growers. Prawn growers feel that their ponds should be exempt from land reform due to the specialized nature of the facilities and the high investment per hectare, in contrast to regular agricultural land. Due to the possibility of losing the ponds to land reform, banks do not allow growers to use the ponds as collateral for loans. A firm government policy regarding which lands will be subject to redistribution under the land reform program will allow better investment planning and greater access to financing.

Research and extension programs targeting equity should focus on integrated systems. The crucial issue is economies of size and appropriate production systems for small farmers. Tilapia, milkfish, mussels and snails are aquatic species with proven integrative capabilities for low-resource farming systems worldwide. Government policy and research efforts should therefore be geared toward developing an integrated farming system that will increase production and resource-base utilization while protecting the environment.

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