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Economics of Freshwater Prawn Farming in the United States

Siddhartha Dasgupta[1]

Freshwater prawn (*Macrobrachium rosenbergii*) farming in the United States has been predominantly a small-scale aquaculture industry. The U.S. industry started in Hawaii in the 1960s, followed by South Carolina in the 1970s and Mississippi in the 1980s. Early attempts at prawn culture were hampered by lack of seed stock and problems in marketing the end product. During the 1980s and 1990s, researchers developed several elements important for the industry's growth, such as improved hatchery and nursery technology, pond culture methods, and post-harvest handling protocols for quality control and product preservation. As a result of these and other efforts, several successful prawn hatcheries and nurseries have been established in the U.S. and more domestically produced prawns are being marketed than ever before.

Prawn production in the U.S.

In 1998, the states of Hawaii, South Carolina, Kentucky and Florida had the most surface acres devoted to prawn production. In 2003, Mississippi had the most water acres in prawns (600 acres), followed by Tennessee and Kentucky with 200 acres each and Alabama with 60 acres. There are also a few prawn farms in Arkansas, Georgia, Illinois, Indiana, Louisiana and Ohio.

During the 1980s and 1990s, 0.2 to 0.4 million pounds of prawns per year were produced in the U.S. The crop had an annual wholesale value of $0.89 million to $2.54 million and the prices for whole prawns paid by processors and other wholesale buyers ranged from $4 to $7 per pound. The price of Gulf of Mexico marine shrimp (tails only) declined from $7.00 per pound to $4.50 per pound from 1995 to 2002, which corresponded to an approximate price range of $2.25 to $3.50 per pound for whole prawns. Similarly, the price of imported marine shrimp tails (comparable in size to freshwater prawns) declined from $7.00 per pound to $4.00 per pound (i.e., $2.00 to $3.50 per pound for whole shrimp). At these prices, U.S. prawn producers could not compete in wholesale markets and retail and direct sales were their only marketing options. The freshness of the domestic product was their main marketing asset.

Prawn production methods

Freshwater prawn production occurs in three stages—hatchery, nursery and grow-out. In the hatchery stage, fertilized adult female prawns produce 10,000 to 20,000 eggs, which hatch into prawn larvae in 3 weeks. Newly hatched larvae are kept in brackish water where they need protein-rich feed such as zooplankton. After 22 to 30 days, post-larvae can be stocked in freshwater. The post-larvae are usually nursed for at least 30 more days. Then the juveniles are ready to be stocked into ponds for grow-out to adult prawns.

The parameters of prawn production are

- stocking density (number of juveniles stocked per acre of water),
- age of seed at stocking,
- feeding or fertilization rate (pounds per acre per year applied to a prawn pond),
- feed types, and
- presence of artificial substrates.

Prawns are tropical animals and require water warmer than 65 °F to grow. The growth period from juvenile to a market-size adult is 4 months (June to September) in temperate regions of the U.S. Pond culture of prawns is done in single annual batches during the summer and early fall.

Proper pond management is a vital element of production success. Juvenile prawns are usually stocked in late May or early June and fed a 32% crude protein sinking feed. Feeding rates depend on

[1] Kentucky State University, Aquaculture Research Center, Frankfort, KY.

prawn age and are available from feeding tables such as the one in D'Abramo et al. (2003). Ponds are usually aerated nightly or 24 hours a day. Adult prawns are harvested by late September.

Stocking densities in commercial ponds have mostly ranged from 8,000 to 30,000 per acre. Some farmers stock at low densities (8,000 to 10,000 per acre), which is commonly called extensive or low-input culture. At low densities, prawns are fed at a rate of 1,000 to 1,500 pounds per acre per year. Supplemental aeration may or may not be used. Data from Kentucky showed that when ponds were not aerated yields were 230 to 400 pounds per acre. Average yields in aerated ponds ranged from 300 to 600 pounds per acre.

Many producers use a semi-intensive stocking density (15,000 to 18,000 per acre) and constant pond aeration. At this density the feeding rate is 2,500 to 3,000 pounds per acre and commercial yields typically range from 400 to 800 pounds per acre per year.

Some producers practice intensive stocking of more than 18,000 per acre. Feeding rates for intensive stocking are 5,000 to 6,000 pounds per acre per year. Intensive production is usually done in ponds with artificial substrate formed of plastic mesh (the same as a barrier fence) to create more living area. Prawns are territorial and cannibalistic, so installing substrates decreases mortality by allowing the animals to distribute themselves more widely in the pond. Having more space also allows prawns to grow larger. Experimental yields from intensively stocked ponds with substrates have been 2,000 to 3,000 pounds per acre; however, commercial yields have varied from 1,200 to 2,000 pounds per acre.

Experimental vs. commercial production results

Although commercial producers have tried to follow prawn management methods developed at aquaculture experiment stations in the U.S., small-scale commercial ponds are usually no match for well-supplied and well-managed experimental ponds. Therefore, farm-level production is usually inferior to production at experiment stations.

Tables 1 and 2 summarize production data from commercial and experimental sources, respectively, for several states. In both tables, production has been segregated by stocking density. From Table 1, low stocking densities (8,000 to 10,000 per acre) typically produce 200 to 700 pounds per acre, while experimental results for low stocking densities have produced about 800 pounds per acre (Table 2). Low stocking densities in experimental ponds also resulted in large adult prawns—eight animals per pound or 8-count whole prawn—while commercial harvest weights were approximately 12 per pound or 12-count.

There were similar results for semi-intensive stocking densities. Commercial yields (500 to 800 pounds per acre) trailed behind experimental yields (900 to 1,000 pounds per acre). Posadas (2004) highlighted cases in which commercial yields under semi-intensive and extensive production were similar, despite the almost two-fold stocking difference. The reason was that semi-intensive stocking densities produced smaller prawns (14-count average size) than extensive production (8-count average size). Yield equals the number harvested per acre multiplied by the average size.

Intensive stocking in experimental ponds has often produced yields of more than 2,000 pounds per acre when artificial substrates were used (Table 2). These yields offset the high production costs and result in low break-even prices. Intensive stocking is less common in commercial ponds, although yields have exceeded 1,000 pounds per

Table 1. Prawn production data from commercial farms in the United States. FCR stands for feed conversion ratio.

State	Stocking density (number/acre)	FCR	Average yield (lb/acre)	Survival range (average % survival)	Average size (number /lb)
KY	8,000–10,000	Not available	225–700 (210)	25–32 (28)	12
KY	12,000–17,000	Not available	0-860 (580)	0–100 (56)	14
KY	19,000–22,000	Not available	330–1,292 (964)	23–66 (47)	10
IL	6,000–10,000	1.23:1	533–900 (638)	Not available	Not available
IL	14,000–16,000	5.45:1[a]	120–800 (592)	Not available	Not available
IL	20,000	2.55:1	300[a]	Not available	Not available
OH	15,789–16,204	17:1	139–546	15–46 (32)	13–20
OH	19,427	18:1[a]	229[a]	41[a]	29[a]
MS	10,000–18,000	Not available	750–1,100 (775)	(66)	10–12

[a] Only one data point.

Table 2. Prawn production data from experimental ponds in the United States.

State	Stocking density (number/acre)	FCR	Average yield (lb/acre)	Average % survival	Average size (number /lb)
KY	8,000	3.12:1	734	74	7
KY	16,000	2.85:1	913	79	14
KY [a]	22,000–25,000	2.53:1	2,274	88	11
MS	8,500	3.5:1	897	86	8
MS	15,800	2.5:1	986	82	14
TN [b]	16,000	Not available	910–1,057	80–85	13–14
TN	20,000–24,000	Not available	1,137–1,586	80–85	13–14

[a] These experiments used artificial substrates with a surface area equivalent to 50 percent of the pond bottom area.
[b] Information obtained from the University of Tennessee (Hill et al., 2003).

acre in some cases and been comparable to extensive and semi-intensive yields in other cases. While the potential returns are high, the operating cost is also high, making intensive stocking less attractive to some small-scale producers.

Farm level economics

Site selection, pond construction and water supply

Land costs vary widely, as do pond construction costs, which can be as high as $5,000 per water acre. In traditional aquaculture regions of the U.S., however, pond construction cost is $1,200 to $3,000 per water acre. Ponds used for prawn farming are usually small, less than 2 acres. Feed can be distributed more uniformly in a small pond than in a large one, which is important because prawns, unlike catfish, do not congregate at feeding sites. Some producers culture prawns for supplemental income by adapting existing farm ponds to aquaculture. However, experience has shown that ponds built for prawn production (with catch basins) are easier to manage and harvest and yield more prawns than typical farm ponds (Tidwell et al., 2002).

Well water is best for aquaculture. If small ponds must be filled from streams and creeks, the water should be screened to keep out predatory fish and treated to remove pollutants before prawns are stocked.

Equipment

Equipment needed for prawn farming includes electric aerators, a 5-hp water pump, a feed storage area, a water quality kit, a dissolved oxygen meter, harvesting equipment, a pickup truck, a mower, and artificial substrates (Table 3). Harvesting and holding equipment includes seines, baskets, tanks and oxygen cylinders. Growers who use large ponds also might need feed broadcasting equipment and several vehicles.

The cost of artificial substrate is a major expense in prawn farming. Orange construction fence, a standard substrate material, costs $22 per roll in Kentucky and one roll makes 400 square feet of fence. Ninety-one rolls of this fence are required to provide 0.5 acre of additional surface area in a 1-acre pond. Table 3 outlines the cost of purchasing and installing enough artificial substrate to increase a pond's surface area by 50 percent.

Electric in-pond aerators are usually adequate for supplemental aeration, but a PTO-powered aerator might be handy to have for emergencies. Research shows that sufficient aeration is achieved at the rate of 1 hp per water acre. Many producers use 1-hp paddlewheel aerators that typically cost $500 to $700 and have a 3- to 5-year lifespan. Catfish-type paddlewheel aerators (5- to 10-hp) are more expensive ($3,000 to $6,000) and are usually not used.

Fixed costs

Fixed investments in aquaculture farms (land, ponds/tanks, and equipment) are listed in Table 3. A small-scale prawn farm with a single 1-acre pond is estimated to need approximately $10,500 for these costs (excluding substrates). Sharing resources among several ponds reduces the per-acre fixed cost (e.g., $8,500 for a farm with two 1-acre ponds, $7,891 for a farm with three 1-acre ponds, etc.). Posadas (2004) estimated that the fixed cost of operating 25 2-acre ponds would be about $5,000 per acre (using Mississippi data).

Fixed costs occur during start-up and during pond and equipment renovation or replacement. However, they can be evaluated on an annual basis by depreciating equipment and calculating the interest associated with the fixed investment. To calculate depreciation one must know the initial value, salvage value, and lifespan of each depreciable asset. We assumed that land was valued at $1,000 per acre and did not depreciate, and that the salvage values for a 1-acre pond and equipment were $3,000 and $0, respectively. Hence, the fixed investment values in Table 3 result in a total annual fixed cost, for a small-scale

Table 3. Pond, equipment, and other fixed costs in a small-scale prawn farm.

Item	Life span (years)	Cost	Annual ownership cost
Pond size			
0.25 acre	10	$1,630	$205.48
0.50 acre	10	$2,630	$331.52
0.75 acre	10	$4,130	$520.61
1.00 acre	10	$5,130	$646.65
1-hp paddlewheel aerator	3	$500	$201.06
5-hp water pump	5	$540	$142.45
Holding tanks [a]	10	$800	$260.20
Seine	5	$450	$118.71
Water quality kit	5	$179	$47.22
Dissolved oxygen meter	10	$715	$116.36
Property tax		$8.50	
Use of truck, mower & storage shed	10	$970	$157.86
Artificial substrates [b] for a			
0.25-acre pond	5	$726	$191.52
0.50-acre pond	5	$1,325	$349.53
0.75-acre pond	5	$1,925	$507.81
1.00-acre pond	5	$2,505	$660.81

[a]A small prawn farm requires at least two 400-gallon polyethylene tanks.

[b]The cost of artificial substrates includes installation.

Kentucky prawn farm, of $1,699 without substrate and $2,360 with substrate.

Variable costs

Variable costs include the cost of seed, feed or fertilizer, energy (electricity, gasoline or diesel), chemicals, labor and management, telephone, advertising, legal permits, maintenance, etc. Table 4 lists approximate variable costs, based on current data from Kentucky and Mississippi, for three different production systems. Seed and feed costs increase as the intensity of production increases, while other costs remain fairly stable.

The stocking cost depends on both the seed price and the stocking density. Producers generally stock 30- to 60-day-old nursed, juvenile prawn; a few stock post-larvae at higher densities, after accounting for a 30 to 50 percent post-stocking mortality. Recently the price of juveniles has ranged from $0.07 to $0.12 per head in Kentucky. This price is dependent on juvenile age, whether or not the juveniles were size graded (research has shown that at higher densities, stocking juveniles of uniform size results in more uniformly sized adult prawn), and the hauling distance between the nursery and the farm. Research also has shown that older juveniles (e.g., 60-day-old animals) have a higher survival rate than younger juveniles (e.g., 30-day-old animals). In 2004, juvenile prices in Mississippi were approximately $0.045 per head (Posadas, 2004). Table 4 shows that the stocking cost is 20 to 40 percent of variable cost, so the price of juveniles will have a significant effect on total cost.

Feeding cost is proportionately less than stocking cost. Feeding rates for extensive and semi-intensive operations usually follow the feed tables recommended by D'Abramo and Brunson (1996) (see SRAC publication # 484 for additional details). The feeding rates for intensively stocked ponds, found in Tidwell et al. (2002), are higher than those in D'Abramo and Brunson (1996), not exceeding 60 to 75 pounds per acre per day.

The labor and management cost was $6.00 per hour for a 1-acre pond in Kentucky. Labor cost in Mississippi was substantially lower because there were 50 acres in production, resulting in economies of scale. In most small-scale farming, labor and management are provided by the farm family and are not cash costs. However, labor and management are opportunity costs and should not be ignored in computing total cost.

The chemicals needed for prawn farming typically include agricultural lime, pond fertilizers and rotenone. Legal fees typically involve purchasing an annual propagation permit from a state government agency for fish and wildlife. Marketing costs, which include advertising the harvest date and farm location in the local media, apply primarily to producers who sell prawns directly to consumers. Advertising costs for wholesale sales would be minimal.

Break-even prices

Break-even prices were developed based upon 1) a small prawn farm with a single 1-acre pond in Kentucky, and 2) a medium-size to large prawn farm with 25 2-acre ponds in Mississippi (Posadas, 2004). Commercial data indicate that the size of prawn farms varies widely. The average farm size in Kentucky is 0.86 water acres, with a range of 0.05 to 5 water acres. The break-even price is the total cost (the sum of

Table 4. Operating costs of a single 1-acre pond under three stocking densities in Kentucky and Mississippi. Costs are based on 2003 prices. Some Kentucky costs are derived from Dasgupta and Tidwell (2003); Mississippi costs came from Posadas (2004).

Item	Extensive [a]		Semi-intensive [a]		Intensive [a,b]
	Kentucky	Mississippi	Kentucky	Mississippi	Kentucky
Juveniles [c]	$800	$360	$1,600	$720	$2,400
Feed [d]	$254	$318	$528	$363	$1,105
Electricity	$316	$129	$316	$129	$316
Fuel	$95	$117	$95	$117	$95
Chemicals	$61	$104	$61	$104	$61
Labor and management	$1,275	$319	$1,275	$319	$1,275
Maintenance	$169	$229	$169	$229	$169
Ice	$104	$50	$127	$50	$316
Oxygen	$17	$0	$17	$0	$17
Telephone & advertisement	$100	$50	$100	$50	$100
Hauling	$0	$47	$0	$47	$0
Legal fees & miscellaneous	$50	$25	$50	$25	$50
Interest on operating cost	$100	$58	$115	$72	$171
Total	$3,341	$1,806	$4,453	$2,239	$6,075

[a] Extensive, semi-intensive and intensive stocking rates are 8,000, 16,000 and 24,000 juveniles per acre, respectively.
[b] Mississippi data for intensive stocking with artificial pond substrate were unavailable.
[c] Assumed juvenile prices are 10¢ and 4.5¢ per head for Kentucky and Mississippi, respectively.
[d] Assumed feed prices are $120 per ton (distiller's grains), $350 per ton (32% crude protein diet), and $500 per ton (40% crude protein shrimp diet) for Kentucky and $250 per ton (32% crude protein diet) for Mississippi.

fixed and variable costs) divided by output volume.

Using cost data from Tables 3 and 4, the total annual cost of prawn farming in Kentucky, based upon a single 1-acre pond, was $5,040 for extensive production, $6,152 for semi-intensive production, and $8,435 for intensive production. Posadas (2004) indicates that the total cost (per acre) for Mississippi prawn farms was almost 50 percent less (Table 5).

Table 5 shows production costs, yield and break-even prices for three stocking densities using data from Kentucky and Mississippi. Survival rates represented poor (40 percent), medium (60 percent) and good (80 percent) years of production. The average survival rate in Kentucky's commercial prawn ponds in 2002 was 45 percent, with a range of 7 to 86 percent. The price of juveniles was $0.10 per head in Kentucky and $0.045 per head in Mississippi.

Table 5 also shows break-even prices with respect to total operating cost, variable costs and total cost. Total operating cost includes only cash expenses related to stocking, feeding, energy, etc. It excludes expenses associated with land, ponds and equipment and it discounts non-cash operating costs such as unpaid labor and management. A typical small-scale farmer selling at this break-even price will not be able to finance pond construction, equipment purchase, or the value of labor and management supplied by family members and friends.

The break-even price computed with respect to total variable cost does account for the value of labor and management; however, this break-even price is not enough for a farmer to pay for land, ponds and equipment. The break-even price with respect to total cost is sufficient to cover all operating (cash and non-cash) and fixed expenses. While a farm can survive in the short term by selling prawns at the break-even price, long-term success requires a greater return.

Table 5 shows that it is cheaper to culture prawns in Mississippi than Kentucky. It also shows that while the break-even price above cash costs and variable costs remains below $3.50 per pound for some scenarios, the break-even price above total cost is consistently above $3.50 per pound (except for the semi-intensive stocking and 80 percent survival scenario in Mississippi). This

Table 5. Break-even prices calculated at three stocking densities using data from Kentucky and Mississippi.

Location	Kentucky			Mississippi	
Stocking density	8,000/ac	16,000/ac	24,000/ac	8,000/ac	16,000/ac
Annual yield[a] (lb/ac/yr)					
40% survival	267	457	960	267	457
60% survival	400	686	1,440	400	686
80% survival	533	914	1,920	533	914
Operating cash costs ($/ac)	$2,032	$3,165	$4,783	$1,487	$1,920
Variable costs ($/ac)	$3,341	$4,453	$6,075	$1,806	$2,239
Total cost ($/ac)	$5,040	$6,152	$8,435	$2,655	$3,088
Break-even prices calculated with respect to					
Operating cash costs:					
40% survival	$7.62/lb	$6.92/lb	$4.98/lb	$5.58/lb	$4.20/lb
60% survival	$5.08/lb	$4.62/lb	$3.32/lb	$3.72/lb	$2.80/lb
80% survival	$3.81/lb	$3.46/lb	$2.49/lb	$2.79/lb	$2.10/lb
Variable costs:					
40% survival	$12.51/lb	$9.74/lb	$6.33/lb	$6.77/lb	$4.90/lb
60% survival	$8.35/lb	$6.49/lb	$4.22/lb	$4.52/lb	$3.27/lb
80% survival	$6.27/lb	$4.87/lb	$3.16/lb	$3.39/lb	$2.45/lb
Total cost:					
40% survival	$18.88/lb	$13.46/lb	$8.79/lb	$9.96/lb	$6.76/lb
60% survival	$12.60/lb	$8.79/lb	$5.86/lb	$6.64/lb	$4.50/lb
80% survival	$9.45/lb	$6.73/lb	$4.39/lb	$4.98/lb	$3.38/lb

[a] Yield was calculated based on the assumption that the average harvest size was 12 per pound, 14 per pound, and 10 per pound for the 8,000, 16,000 and 24,000 per water acre stocking densities, respectively. Posadas (2004) reported an average harvest size of 8 per pound at 8,500 per acre stocking density, but this result was not supported by results from commercial low-density culture in Kentucky.

indicates that while prawns could be sold at wholesale prices to cover operating expenses, earning a profit in the long run will require higher prices. Posadas (2004) described scenarios in which the break-even price above total cost was less than the wholesale price for medium-sized marine shrimp, and in which low-density stocking generated greater profit than more intensive stocking. However, these outcomes were skewed by higher than usual survival (more than 80 percent) and larger than normal average sizes (eight per pound at a stocking density of 8,500 per acre). These scenarios were too specialized to reflect the typical producer.

Lower input prices were partly responsible for making prawn culture less expensive in Mississippi than in Kentucky. However, the Mississippi break-even prices also reflected the economies of scale of the 50-water-acre prawn farm (Posadas, 2004). Since the Mississippi farm size was an extrapolation, and not representative of typical prawn farms in the state, a similar extrapolation is required for Kentucky. To address this issue, we assume a hypothetical Kentucky farm with 50 1-acre ponds where prawns are intensively stocked. Economies of scale calculations reduce the per-acre fixed cost from $2,360 to $1,627, assuming that there was one water pump, two holding tanks, and one seine for every ten ponds. Labor and management costs per acre also diminish from $1,275 to $312 (four laborers and a manager working 4 hours a day for 160 days and an additional 4 hours per pond for harvesting). This reduces the total cost per acre of intensive production from $8,435 to $6,631 and yields break-even prices over total cost of $6.90 per pound, $4.61 per pound, and $3.45 per pound for 40 percent, 60 percent, and 80 percent survival, respectively.

Prawn output prices

The prices producers receive for head-on prawns depend on the buyers—wholesalers, retailers, restaurants or consumers. Wholesalers and processors pay $4 to $7 per pound (Posadas, 2003). A few wholesale buyers in Kentucky and Tennessee have paid from $4.50 to $5.50 per pound in recent years. Retail, restaurant and direct market prices are higher ($6 to $8 per pound in Kentucky) and more volatile than wholesale prices, but a smaller volume is purchased by these buyers.

Some producers are processing prawns into frozen tails to extend the marketing season. The break-even price of frozen tails is generally twice the break-even price of whole prawns plus $1 per pound to cover processing costs. As the freshwater prawn industry matures, prices will likely be differentiated by size (similar to marine shrimp), which should help producers make appropriate, market-driven production choices.

Results from economic models

The question of which production method is most profitable was answered using commercial data collected from Kentucky prawn growers during 2002. Average weight at harvest increased when substrates were used and decreased as stocking density increased. Survival rate increased if substrates were used. Also, average profit increased as stocking density increased, provided producers could sell their total output (which also increased with stocking density). If a producer invested in a single 1-acre pond and equipment to raise prawns intensively over a 10-year period, and had a survival rate of 40 to 60 percent, the growth on the investment would be about 10 percent per year provided juveniles were purchased at $0.07 per head and adult prawns were sold at $5.50 per pound.

Conclusions

Budgets for freshwater prawn production usually seem to underestimate the total costs of production. This has encouraged some producers to sell prawns at prices that result in profits with respect to their operating costs and losses with respect to their total cost. Producers should consider all costs before determining the profitability of their operations. A quick review of break-even prices indicates that most prawn producers realize profit only when they can sell to retail outlets and restaurants or directly to consumers, so they would be wise to focus on developing local markets where they can capitalize on delivering a fresh, or live, product.

The Posadas (2004) report that low-intensity prawn production in Mississippi resulted in a break-even price that was less than the wholesale price for large marine shrimp must not be ignored. Although this scenario hinged on atypically high survival (more than 80 percent) and large average weight (eight prawns per pound or fewer), this technology may have potential for generating profits in wholesale markets. Future research should investigate the combined effect of economies of scale, vertically integrated systems, and other production methods that promote consistently high survival rates on the size distribution and production cost of freshwater prawns.

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