Bulletin 985 October 1992

Economic Analysis of

Production of Freshwater Shrimp
(*Macrobrachium rosenbergii*)

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Published by the Department of Information Services, Division of Agriculture, Forestry, and Veterinary Medicine, Mississippi State University. Edited by Keith H. Remy, Publications Coordinator. Cover designed by Beth Carter, Artist.

Acknowledgments

The authors wish to express sincere appreciation to all the people involved in the freshwater shrimp research, who provided production data utilized in this study. Appreciation is also extended to the equipment dealers, and extension service personnel who provided data for this study.

The authors also thank the review and helpful comments provided by: Dr. Louis R. D'Abramo, Dr. Robert J. Martin, Dr. Warren C. Couvillion, and Dr. Carolyn R. Boyle.

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Executive Summary

Increases in per capita consumption of shrimp, generally declining U.S. shrimp commercial landings and a corresponding continued increase in annual imports of shrimp into the United States, and the interest in developing additional aquacultural enterprises, led Mississippi Agricultural and Forestry Experiment Station (MAFES) researchers to investigate the potential of the commercial culture of freshwater shrimp. The general objective of this study was to assess various management strategies used in culture of freshwater shrimp (*Macrobrachium rosenbergii*) at Mississippi State University from 1984 to 1990. Management strategies developed and evaluated for 7 years, 1984 to 1990, were used in a synthetic firm approach to assess the economics of freshwater shrimp production in Mississippi.

Performance of different production strategies and their effects on net revenues in the hill areas of east-central Mississippi were studied. All production costs were estimated for a specified farm size, utilizing published price and production data and suggestions from researchers, extension service specialists, consultants, and equipment dealers to the aquaculture industry.

Estimated net revenues for all farm strategies were negative. Size-grading was generally found to be associated with slightly higher net revenues, when compared among equal stocking densities. Overall, strategies with the highest net revenues were generally associated with high stocking densities and small size of stocked animals.

Economic analysis of production of freshwater shrimp
(Macrobrachium rosenbergii)

Introduction

Researchers at the Mississippi Agricultural and Forestry Experiment Station (MAFES), devoted great effort from 1984 to 1990 to develop biological, economical, and managerial strategies for the commercial cultivation of freshwater shrimp (*Macrobrachium rosenbergii*) in Mississippi.

Interest in development of freshwater shrimp as a new aquaculture enterprise was fueled primarily by two key factors. One factor was the need for additional profitable enterprises for Mississippi farmers, particularly in the hill areas of the state where production of catfish was not generally economically feasible. Another factor was the steady increase in consumption of shrimp. The U.S. annual per capita consumption of shrimp in all preparations increased from 1.3 pounds in 1979 to 2.3 pounds in 1989, a 77 percent increase (Figure 1). Meanwhile, the U.S. commercial landings of shrimp have varied widely from year to year for the last 20 years, but have generally trended downward (Figure 2).

The continuous increase in the U.S. annual per capita consumption of shrimp, along with the steady decline of U.S. commercial landing of shrimp, has created a strong dependency on foreign supplies. The total amount of shrimp imported into the United States increased from slightly more than 219 million pounds in 1980 to almost 504 million pounds in 1989 – a 124 percent increase (Figure 3). The value of imported shrimp during the same period increased 139 percent, to more than $1.7 billion (USDC, 1990 and 1982).

An important source of shrimp worldwide is aquaculture. In 1990, production of farm raised shrimp was approximately 1.46 billion pounds (whole shrimp), which accounted for 25 percent of the total shrimp that entered the world market. This figure represents a considerable increase from the 2 percent of farmed shrimp that entered the global market in 1980 (Aquaculture Digest, 1991).

Review of Literature

In tropical areas, commercial freshwater shrimp farming is practiced year-round. In most cases, selective harvest of market size animals is implemented (Smith et al., 1981). Malecha (1983) described the traditional (seine and cull) and nontraditional (mul-

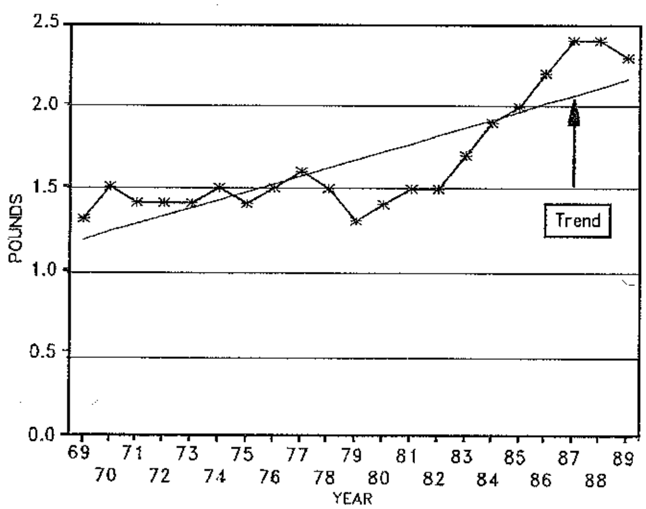

Figure 1. Annual per capita consumption of shrimp (all preparations), United States, 1969-1989. Source: USDC, Fisheries of the United States, 1990.

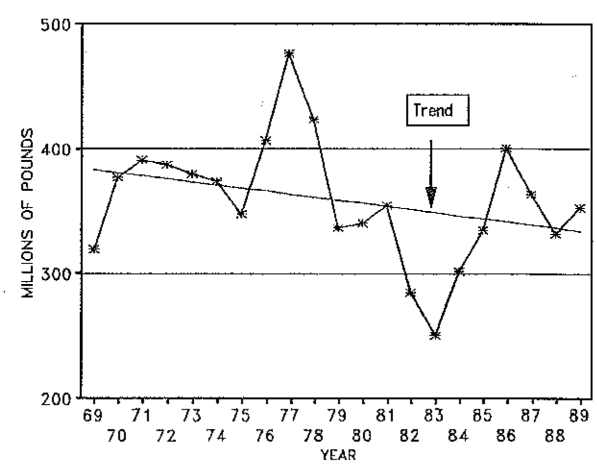

Figure 2. Commercial landings of shrimp, United States, 1969-1989. Source USDC, Fisheries of the United States, various issues.

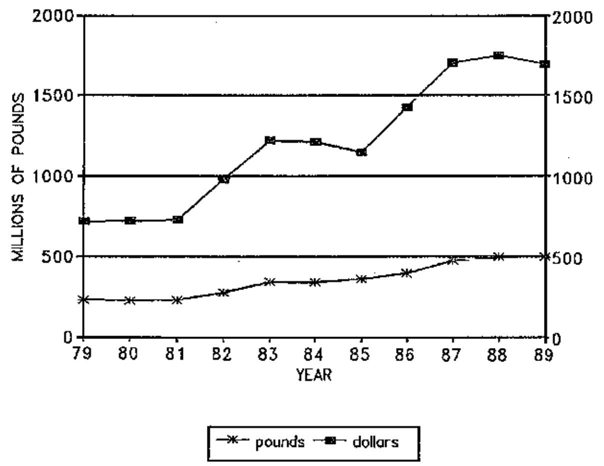

Figure 3. Annual imports of shrimp, United States, 1979-1989. Source: USDC, Fisheries of the United States, various issues.

tiphased) systems being used in Hawaii. In the former technique, postlarvae or small juveniles are restocked after a specific growout/seining period and cull harvest of marketable animals. The later technique incorporates pond drain-down between growing cycles. The cultivation of freshwater shrimp in temperate regions is restricted to somewhere between 6 and 7 months (Brody, 1980; Smith et al., 1981; and New, 1990).

Stocking of freshwater shrimp should be performed when the pond water temperature is at least 20 °C (68 °F) to avoid stress and possible death. Freshwater shrimp become stressed at 18 °C (65 °F) and die at 15 °C (60 °F) (Wellborn, 1985). In Mississippi, the growout season extends from early May to late September/early October when pond water temperatures usually remain above 20 °C (68 °F) (Wax et al., 1987). Researchers have developed a series of managerial practices to overcome the biological and economic consequences that the considerably shorter temperate growing season imposes on the farming of freshwater shrimp.

Cohen (1985) suggested that among various fish, mollusks, and crustaceans the strongest candidate to help diversify Mississippi's aquaculture industry was the freshwater shrimp. This conclusion was reached through consideration of production and marketing objectives.

One management technique that results in market size individuals within the restricted growing season is stocking of juveniles instead of new postlarval shrimp. This procedure can also reduce stocking mortality and increase yield (Willis, 1977; Brody et al., 1980; Smith et al., 1981).

Initial stocking density strongly influences final yield. Average harvest weight and initial stocking densities are inversely related (Willis et al., 1977; Smith et al., 1981 and D'Abramo et al., 1989). A higher average harvest weight will increase net revenue because shrimp size and price are positively related. In the marine shrimp industry, price is structured in such a way that larger shrimp sell for higher prices (Fuller et al. 1988a).

Size grading, or separation of juveniles into weight classes, has proven to be an important technique to enhance not only pond yield, but also reduce the percentage of small, low value individuals. This management practice has proven to influence the level of net returns (Ra'anan and Cohen, 1983; Karplus et al., 1986, 1987; D'Abramo et al., 1991; Fuller and Kelly, 1991a, b, and c).

The study of D'Abramo et al. (1991) indicated that adequate pond management and size-grading technology will reduce freshwater shrimp heterogenous individual growth (HIG). HIG results in a large range of size for the freshwater shrimp. Managing to minimize HIG could be an important mechanism to achieve higher returns to land and management.

Fuller et al. (1988b) stated that local (U.S.) sources of freshwater shrimp seed stock were lacking. Smith (1990) estimated that the cost of producing seed stock in Mississippi is considerably lower than commercial prices. He estimated that the cost of producing seed stock locally is $8.64 per 1,000 postlarvae (pl's), compared to the commercial price of $20-50 per 1,000 pl's.

Results of an investigation performed by Fuller et al. (1986) could be used to predict tail yields of freshwater shrimp. This procedure, in conjunction with the recent developments in grow-out technology, would be beneficial in assessing potential revenues.

D'Abramo et al. (1991) stated that the growth of a freshwater shrimp industry in tropical regions has been frustrated by the limited knowledge of the biology of this crustacean. Application of recently derived information concerning shrimp behavior and biology has resulted in an increase in mean harvest weight and total production.

Clardy et al. (1985) developed three scenarios to study costs and revenues for freshwater shrimp production in Mississippi. In the same study, alternative management techniques, such as the effect of alternative stocking on yields and revenues, and the effect of feed and feeding strategies on cost, were recommended for additional investigation.

Fuller et al. (1988a, and 1988b), using specific management procedures and assumptions, concluded from economic analysis of production data that commercial freshwater shrimp culture was not economically feasible in Mississippi. Research to estimate optimum size of seed stock, and determine optimum stocking rates and alternative feeding methods were highlighted as principal areas of future investigation needed to be implemented in order to assess future economic feasibility of the freshwater shrimp enterprise.

The effect of size-grading on the production of freshwater shrimp in the hill area of Mississippi was described by Fuller and Kelly (1991c). Implementation of size-grading did not result in an economically feasible commercial enterprise when all costs of production were included. Size-grading techniques did not increase net returns sufficiently to cover all costs. Additional research to estimate the optimal ratio of upper and lower graded shrimp resulting in maximum net return was recommended. A brief review of the most significant management strategies, results, and economic implications derived from the freshwater shrimp research at MAFES from 1984 to 1990 is presented in Appendix Table 1.

In geographic areas where freshwater shrimp grow-out is practiced year-round, profitable operations have been reported. Freshwater shrimp farms of all sizes in Thailand (in 1980) were very profitable (New, 1991). Shang and Fujimura (1977) conducted a detailed study of cost and returns from freshwater shrimp farming in Hawaii. At the existing average farm price of $3.00 per pound, profitable farms were identified as those of 10 acres or larger with an average annual production of 3,000 pounds per acre. Smaller farms were only profitable when operated as a family venture because under this situation, labor cost was not included.

Objectives

The general objective of this study was to review and summarize freshwater shrimp research at Mississippi State University for the years 1984 to 1990, and to assess results in an economic framework.

Specific objectives were to:

(1) Describe alternative treatments and managerial techniques for freshwater shrimp culture employed at MSU from 1984 to 1990.

(2) Aggregate data for the 7 years of research (1984 to 1990) in a manner that will allow for meaningful interpretation of results.

(3) Conduct an economic analysis of selected management techniques utilized at MSU.

(4) Based on results from (3), describe the most efficient production scheme for freshwater shrimp culture, using current production practices and average ex-vessel prices for Gulf shrimp.

Methods and Procedures

Data for 7 years (1984 to 1990) of shrimp research at MSU were compiled in an orderly manner, by year and general management strategies. Objective one was accomplished by evaluating meaningful published and unpublished data dealing with the freshwater shrimp research at MSU from 1984 to 1990.

To achieve objective 2, data for the 7 years of research (1984 - 1990) were arranged so that interpretation of results was rather direct. Data were organized according to particular management parameters (i.e. stocking rate, stocking weight, size-grading, etc.) over the 7-year period.

Objective 3 was accomplished by developing detailed cost-returns of different freshwater shrimp farming scenarios where management practices of importance were identified and studied in detail.

In objective 4, the appropriate grow-out practices identified in objective 3 were evaluated. Costs of production estimates generated in the Department of Agricultural Economics (MSU) were utilized to assess the most efficient freshwater shrimp production practice.

Experiments and Results by Year

During the 7 years of research (1984 to 1990), MAFES researchers conducted experiments related to freshwater shrimp in four different locations: (1) MSU Leveck Animal Research Center (South Farm) Aquaculture Unit (MSU), (2) Coastal Aquaculture Unit (Gulfport), (3) Blackjack aquaculture facilities (MSU), and (4) Delta Branch Experiment Station (Stoneville). Earthen ponds ranging in size from 0.10 to 0.18 acre used at the South Farm facility, from 0.16 to 0.87 acre at the Blackjack facility, and from 0.25 to 0.27 acre at the Coastal Aquaculture Unit, were used. A 4-acre pond was used at the Delta Branch Experiment Station.

A total of 132 ponds were utilized throughout the years to conduct diverse experiments to determine and/or evaluate the following:

(1) The commercial compatibility of the freshwater shrimp with either channel catfish fry or large channel catfish (polyculture);

(2) The effects of stocking weight on the survival, mean individual weight, and yield of freshwater shrimp grown with catfish fry (polyculture);

(3) The effect of specially designed "mesa" ponds on the production and survival of shrimp (monoculture);

(4) The effects of stocking density on the survival weight, size frequency distribution, and yield of freshwater shrimp (monoculture);

(5) The utilization of the existing hill area topography and resources in the production of freshwater shrimp (monoculture);

(6) Different diet composition and feeding regimens (monoculture); and

(7) Size-grading as an alternative management prac-

tice for freshwater shrimp (monoculture), among others.

During the performance of this research, MAFES personnel observed that some experimental designs, such as polyculture trials, and some feeding regimes were not appropriate for freshwater shrimp production. In lieu of the fact that some experimental designs did not engender further research, only the trials corresponding to the monoculture research of the freshwater shrimp at the South Farm and Coastal Aquaculture Unit, were incorporated into this study.

1984

Ten ponds ranging in size from 0.10 to 0.14 acre were dedicated exclusively to freshwater shrimp monoculture research at the MAFES South Farm Aquaculture Unit. A stocking density of 32,000 juveniles per water surface acre was employed, following the stocking rate suggested by Dan Cohen and Ziva Ra'anan of Aquaculture Production Technology, Jerusalem, Israel (D'Abramo et al., 1984).

Two pond designs were employed: a conventional layout (Clardy et at., 1985) and a special design incorporating a raised area or "mesa" (top of the mesa was about 18 inches below the water surface), to increase the slope area or pond bottom surface area (D'Abramo et al., 1984).

Stocking use of 75-day-old postlarvae was planned for the 1984 research, but due to technical problems with the seed stock supplier 15-, 40-, and 75- day-old postlarvae were delivered (26.2, 44.1, and 29.7 % of the total number, respectively). The postlarvae were held in indoor tanks (for 8 days) until they were stocked into grow-out ponds after water temperature reached 19 °C (66 °F). The mean wet weight of the 15-, 40-, and 75-day-old juveniles were 0.03, 0.24, and 0.52 grams, respectively, when stocked. The large variation in stocking weights combined with low survival (associated with poor water quality) prevented meaningful comparison of growth and survival between the regular and special design ponds (D'Abramo et al., 1984).

Shrimp samples were taken every 3 weeks throughout the grow-out period to estimate a mean weight of the pond population. These data were used to estimate, percentage of body weight to be fed, and to calculate feed conversion ratios.

The crustaceans were fed a specially manufactured sinking feed. A 25 percent crude protein diet (denoted S) was fed in eight ponds; and a 32 percent crude protein diet (denoted CD) was feed in two ponds (Table 1). Ingredient composition of the two diets is provided in Appendix Table 2. One half of the total amount of feed was distributed between 10:00 a.m. and 12:00 noon and the reminder between 8:00 and 9:00 p.m. The recommended feeding schedule proposed by Ra'anan was followed (Appendix Table 3). Pond management procedures previous to and during the grow-out cycle consisted of pond fertilization, predaceous insect control, and monitoring dissolved oxygen (D.O.), ammonia, nitrates, nitrites, temperature, and pH. Grow-out periods ranged from 130 to 145 days.

Results from the monoculture research conducted in 1984 were inconsistent among ponds (Table 1). Survival ranged from 0 to 88.9 percent, with a mean of 44.5 percent (high pH during the cycle was believed to have caused significant mortality in many ponds). Feed conversions ranged from a ratio of 0 to 24.9

Table 1. Pond summary of the freshwater shrimp research, 1984.

Pond Description		Mean Stocking Weight	Treatment Stocking Rate	Feed Schedule/Diet	Mean Harvest Weight	Survival	Growout Days	Biomass Produced	Total Fed	Feed Conv.	Yield
Number	Size										
	(acre)	(grams)	(per acre)		(grams)	(percent)		(lb)	(lb)		(lb/acre)
7	0.10	0.03	32,000	O/CD	24.94	88.88	145	156.19	396.94	2.54	1,564
9	0.11	0.03	32,000	O/CD	23.00	76.09	140	139.51	353.53	2.53	1,270
40*	0.13	0.03	32,000	O/S	25.47	33.25	137	77.69	366.27	4.69	600
26	0.14	0.03	32,000	O/S	30.78	2.23	130	6.48	161.18	24.87	48
27	0.14	0.24	32,000	O/S	23.68	85.25	131	196.96	543.47	2.76	1,424
36	0.14	0.24	32,000	O/S	50.13	11.96	131	56.88	447.80	7.87	423
37*	0.14	0.27	32,000	O/S	0	0	0	–	138.89	–	–
38*	0.15	0.24	32,000	O/S	41.48	21.35	137	91.20	650.33	7.13	625
30	0.13	0.52	32,000	O/S	28.05	75.12	138	188.49	639.04	3.39	1,487
39*	0.14	0.52	32,000	O/S	28.79	50.98	130	139.84	620.90	4.44	1,036

O = Original Feed Schedule
S = Shrimp Diet
CD = Crustacean Diet
* = Mesa Pond
0.03 gram = 1 ounce

pounds of feed per pound of harvested gain. High feed conversions were associated with ponds having low survival. Average harvest weight ranged from 0 to 50.1 grams (mean = 27.6). Average yield was 848 pounds per acre, ranging from 0 to 1,564 pounds per acre.

Proportional distribution of the 10 ponds based on survival would yield the following results. Survival in five of the ten monoculture ponds was greater than 50 percent, ranging from 51.0 to 88.9 percent (mean = 75.3 %). Harvest weight ranged from 23.0 to 28.8 grams (mean = 25.7), average yield was 1,356 pounds per acre (ranging from 1,036 to 1,565 pounds per acre). Feed conversion ratios ranged from 2.5 to 4.4 pounds of feed per pound of shrimp harvested (mean = 3.1).

The remaining five ponds had a survival ranging from 0 to 33.3 percent (mean = 13.8 %). Harvest weight ranged from 25.5 to 50.1 grams (mean = 37.0) and the average yield was 424 pounds per acre, (ranging from 0 to 625 pounds lb/A). The mean feed conversion was estimated to be 11.1 pounds of feed per pound of shrimp harvested (ranging from 2.53 to 24.9 lb/lb).

Meaningful analysis between regular and "mesa" ponds and between diets, was difficult due to the high mortality caused by poor water quality in some ponds and large variation in the size of the stocked juveniles. These differences did not allow for statistical comparison of the results.

A positive relation between survival rate and yield, and a negative relation between mean harvested weight and total yield were evident. It was concluded that freshwater shrimp production would be unprofitable based on 1984 results and that further research was needed to reduce cost of seed stock and feed, which represented a large portion of the total cost. Recommended research for the future included further evaluation of stocking densities, weight/size, pond design, and feeding strategies.

1985

Trials in 1985 were designed to expand the understanding of the effect of stocking density on the survival, mean harvest weight, size distribution, and total yield of the freshwater shrimp. Four stocking densities were used: 16,000, 24,000, 32,000, and 48,000 juveniles per water surface acre. Twelve earthen ponds, ranging in size from 0.15 to 0.17 acre and located at the MAFES South Farm Aquaculture Unit, were utilized. Four of the ponds were the "mesa" type.

The postlarvae utilized for research conducted in 1985 were kept in an indoor nursery system for 42 to 48 days, utilizing the same system management used in 1984 (D'Abramo et al., 1985). Stocking mean wet weight was 0.714 gram. Sampling, feeding strategies and pond management were similar to those used in 1984. The ingredient composition and proximate analysis of feed (diet S) used are shown in Appendix Table 4.

Survival results for the monoculture ponds were very consistent (Table 2). Shrimp populations in all ponds showed more than 80 percent survival (mean = 86.9 %). Feed conversions ranged from a ratio of 2.8 to 4.3 pounds of feed per pound of harvested gain (mean = 3.5). Average harvest weight per animal in stocking density treatments of 16,000, 24,000, 32,000,

Table 2. Pond summary of the freshwater shrimp research, 1985.

Pond Description Number	Size	Mean Stocking Weight	Treatment Stocking Rate	Feed Schedule/Diet	Mean Harvest Weight	Survival	Growout Days	Biomass Produced	Total Fed	Feed Conv.	Yield
	(acre)	(grams)	(per acre)		(grams)	(percent)		(lb)	(lb)		(lb/acre)
35	0.16	0.174	16,000	O/S	25.44	80.86	135	115.12	370.35	3.22	726
36	0.16	0.174	16,000	O/S	26.52	80.70	141	119.80	417.39	3.48	755
29	0.17	0.174	24,000	O/S	26.31	83.41	141	195.81	707.54	3.61	1,161
32	0.17	0.174	24,000	O/S	22.21	83.33	135	164.93	529.25	3.21	979
37*	0.16	0.174	24,000	O/S	18.73	92.19	135	144.66	469.69	3.25	913
40*	0.16	0.174	24,000	O/S	26.00	91.20	141	199.25	560.25	2.81	1,255
28	0.15	0.174	32,000	O/S	20.86	86.56	138	189.22	716.64	3.79	1,274
30	0.17	0.174	32,000	O/S	19.69	83.16	140	194.25	763.12	3.93	1,155
38*	0.16	0.174	32,000	O/S	19.17	90.74	138	194.36	659.06	3.39	1,227
39*	0.16	0.174	32,000	O/S	21.01	92.60	140	217.64	751.37	3.45	1,372
27	0.16	0.174	48,000	O/S	17.07	87.76	139	250.75	1,064.75	4.25	1,586
33	0.17	0.174	48,000	O/S	15.00	89.87	139	239.33	973.28	4.07	1,426

O = Original Feed Schedule
S = Shrimp Diet
* = Mesa Pond
0.03 gram = 1 ounce

and 48,000 juveniles per water surface acre was 26.0, 23.3, 20.2, 16.0 grams, respectively.

Mean yield associated with stocking density treatments of 16,000, 24,000, 32,000, and 48,000 juveniles per water surface acre was 741, 1,077, 1,257, and 1,506 pounds per acre, respectively. Survival associated with the same stocking density treatments was 80.8, 87.5, 88.3, and 88.8, respectively. Grow-out periods ranged from 135 to 141 days.

Results indicated that survival and total yield increased as stocking density increased. A decrease in the average whole body weight per animal as stocking density increased was observed, which could be viewed as a density-dependent growth factor. No major difference was observed between conventional and "mesa" ponds (D'Abramo et al., 1985, and 1986b).

Reduction of the total amount of animals with comparatively low harvest weight (eg. ≤ 19 grams) could be achieved by utilizing low stocking densities (eg. 16,000 juveniles/acre). Even though total yield is reduced when lower stocking densities are used, the net revenue from this strategy is likely to increase due to the production of larger animals to be marketed (increase in mean harvest weight), and a decrease in operation costs (eg. amount feed and number of nursed juveniles utilized decrease with decreasing stocking densities).

Fuller et al. (1988a) concluded that, under the given results for the 1985 research combined with particular economic assumptions, commercial freshwater shrimp production was not economically feasible. Research that would lead to increased net revenue was identified. A goal of increase in net revenue was defined by manipulating stocking densities to maximize the final harvested weight and minimize the size variation among male morphotypes, instead of maximizing the final/overall yield (D'Abramo et al., 1985, and 1989; Fuller et al., 1988a).

1986

The research design used in 1986 was based on the results obtained from investigations conducted during the previous 2 years. The research was designed to investigate the effect of greater stocking weight of nursed juveniles upon harvest weight, survival, yield, and net revenue. Three stocking densities were used; 16,000, 24,000, and 32,000 nursed juveniles per water surface acre (D'Abramo et al., 1988). The 48,000 stocking rate was not included because of the proportionately large number of smaller size shrimp harvested at this density in previous research. Nine earthen ponds, all of the conventional type, located at the MAFES South Farm Aquaculture Unit and ranging in size from 0.15 to 0.17 acre, were used for this research.

Postlarvae obtained from two different sources were nursed for 66 to 76 days (D'Abramo et al., 1986a). Eight of the nine ponds were stocked with postlarvae averaging 0.75 gram. Postlarvae averaging 1.07 grams were stocked in one of the nine ponds. Sampling, feeding, and pond management practices were similar to those used during the previous years. Shrimp in all nine ponds were fed a 25 percent crude protein diet (denoted type S, in Appendix Table 5).

Survival of the stocked shrimp from the 1986 season ranged from 54.3 to 89.6 percent (mean = 70.3%) (Table 3). Ponds with lower survival were associated with poor water quality. Feed conversion ranged from 3.6 to 6.5 pounds of feed per pound of shrimp harvested (mean = 5.0). Average harvest weight associated with stocking density treatments of 16,000, 24,000,

Table 3. Pond summary of the freshwater shrimp research, 1986.

Pond Description: Number	Pond Description: Size	Mean Stocking Weight	Treatment Stocking Rate	Feed Schedule/Diet	Mean Harvest Weight	Survival	Growout Days	Biomass Produced	Total Fed	Feed Conv.	Yield
	(acre)	(grams)	(per acre)		(grams)	(percent)		(lb)	(lb)		(lb/acre)
28	0.15	0.75	16,000	O/S	34.50	78.60	135	139.48	501.59	3.60	956
36	0.16	0.75	16,000	O/S	44.30	55.00	137	133.29	513.29	3.85	859
37	0.17	0.75	16,000	O/S	30.09	54.30	142	93.47	604.59	6.47	576
30	0.17	0.75	24,000	O/S	26.38	75.70	135	172.91	800.29	4.63	1,057
31	0.17	0.75	24,000	O/S	25.28	55.20	137	118.76	764.90	6.44	738
35	0.16	0.75	24,000	O/S	32.99	67.20	141	181.28	928.13	5.12	1,173
25	0.17	0.75	32,000	O/S	26.34	74.10	136	225.09	1,097.73	4.88	1,377
29	0.17	0.75	32,000	O/S	22.27	82.90	137	212.43	1,117.55	5.26	1,302
34	0.16	1.07	32,000	O/S	22.07	89.60	138	211.16	1,046.85	4.96	1,395

O = Original Feed Schedule
S = Shrimp Diet
0.03 gram = 1 ounce

and 32,000 juveniles per water surface acre were 36.3, 28.2, and 23.6 grams, respectively; mean yield for the same stocking densities were 797, 989, and 1,358 pounds per acre. Growout period in the ponds ranged from 135 to 142 days.

Density dependent growth factors were evident by the decrease in the average whole body weight per animal as stocking density increased. A comparison of 1985 and 1986 yield data from ponds with survival greater than 70 percent, indicates that final mean wet weight of shrimp from stocking densities of 16,000, 24,000, and 36,000 per acre increased 32.8, 13.2, and 16.8 percent, respectively, evidently the result of an increase of mean stocking weight from 0.17 to 0.75 gram. The increase in mean stocking weight translated into increases of the mean overall yield of 22.5, 3.5, and 8.0 percent, respectively, for the same three stocking densities.

Economic analysis based on 1986 research results showed that commercial freshwater shrimp production would not be profitable. However, the research resulted in a better understanding of the relationship between stocking weight and density, and the final harvest weight, and yield. The need for additional evaluation of seed stock production and alternative feeding schedules was recognized for their potentially positive contribution toward achieving economic success.

1987

Research during 1987 was designed to study the effects of stocking density, alternative feeding strategies, and stocking size of juveniles on survival, harvest weight, and yield. Stocking densities studied were 12,000, 16,000, and 20,000 juveniles per water surface acre. Eighteen ponds ranging in size from 0.90 to 0.17 acre and located at the MAFES South Farm Aquaculture Unit were utilized in the study. Animals in 12 of 18 ponds were fed following 1984-1986 feeding schedules. A new feeding schedule (Appendix Table 6) was employed in two ponds, and no commercial feed was provided to the animals in the remaining four ponds. The four ponds receiving no supplemental feed were only treated with a liquid inorganic fertilizer (10-34-0) when needed (Secchi disc reading >30 cm) to maintain a good phytoplankton bloom. Appendix Table 7 provides the ingredient composition and proximate analysis of the 25 percent crude protein feed (type S) used in all ponds except the four that were only fertilized.

Postlarvae for the research conducted in 1987 were kept in an indoor nursery facility, following the procedures in previous years management. The mean weight of juveniles stocked into ponds was 0.25 gram. The growout season in the ponds ranged from 121 to 148 days. High mortality in some of the ponds was attributed to high pH. Results for those ponds in which shrimp were fed a pelleted diet according to the 1984-1986 feed schedule (except for pond B33, which was excluded from the averages because it had almost 100 percent mortality at the beginning of the growing season), were as follows: average survival rates of 49.4, 37.6, 36.5 percent; average harvest weights of 46.4, 39.8, and 44.0 grams; feed conversion of 4.1, 13.1, and 8.0 pounds of feed per pound of harvested gain; and yields of 604, 494, and 642 pounds per water surface acre for 12,000, 16,000, 20,000 stocked juveniles per water surface acre, respectively. For the ponds assigned the new feeding schedule, the results were as follows: mean survival of 69.0 percent, mean harvest weight of 30.0 grams, feed conversion ratio of 2.44 pounds of feed per pound of shrimp harvested, and a yield of 729 pounds per water surface acre (Table 4).

Individuals in ponds that received no supplemental feed had a survival ranging from 2.3 to 74.1 percent (mean = 21.5%), with a mean harvest weight of 49.5 grams (ranging from 17.0 to 71.6) and yields ranging form 18 to 439 pounds per water surface acre (mean = 147 lb/A). These results demonstrated that maintenance of a good phytoplankton bloom cannot effectively substitute, as a supplemental feed for juveniles stocked at 16,000 per water-surface acre.

When comparing the results from the new feed schedule (about 60% reduction in the amount of feed employed) with the 1984-1987 schedule (for ponds with survival greater than 65%), survival and average harvest weights were comparable. Feed conversion (Table 4) was improved by 31 percent (from 3.5 to 2.4).

There was an evident effect of stocking weight and density upon harvest weight and yield. Results suggested that a reduced feed strategy might have some economical advantage, and that future research should focus on determining the most profitable stocking strategy and feeding schedules.

1988

Research during 1988 focused mainly on stocking density and improvement of feeding strategies. Trials evaluating stocking of size-graded individuals and its effect on shrimp culture were initiated.

Sixteen ponds located at the MAFES South Farm Aquaculture Unit and ranging in area from 0.11 to 0.18 acre, and six 0.25-acre ponds at the Coastal Aquaculture Unit (located at Gulfport) were employed in the study. The Coastal Unit ponds were used as part of a joint research effort between Hawaii Aquaculture Company, Inc. and MAFES. The effect of size-grading on mean individual weight and yield was the focal point of the research conducted in 1988. Size-grading was utilized to minimize heterogeneous individual growth (HIG) or the wide size variation typically

Table 4. Pond summary of the freshwater shrimp research, 1987.

Pond Description		Mean Stocking Weight	Treatment		Mean Harvest Weight	Survival	Growout Days	Biomass Produced	Total Fed	Feed Conv.	Yield
Number	Size		Stocking Rate	Feed Schedule/Diet							
	(acre)	(grams)	(per acre)		(grams)	(percent)		(lb)	(lb)		(lb/acre)
A33	0.17	0.25	12,000	O/S	43.78	52.80	147	102.93	440.65	4.28	612
A35	0.16	0.25	12,000	O/S	49.00	46.00	139	94.38	376.52	3.99	596
B33	0.17	0.25	12,000	O/S	6.12	1.00	64	Negative	36.44	Negative	2
A31	0.18	0.25	16,000	O/S	42.18	20.20	142	52.54	530.73	10.10	301
B35	0.17	0.25	16,000	O/S	34.80	80.20	148	165.90	589.64	3.55	985
B37	0.17	0.25	16,000	O/S	42.10	24.90	140	61.44	520.72	8.48	370
B34	0.17	0.25	16,000	O/S	37.06	72.50	142	159.61	541.23	3.39	948
B31	0.17	0.25	16,000	O/S	48.21	4.90	143	12.63	528.73	41.86	83
A34	0.17	0.25	16,000	O/S	34.34	22.70	146	45.28	512.46	11.32	275
B32	0.16	0.25	20,000	O/S	54.49	22.00	139	82.80	614.66	7.42	529
B38	0.18	0.25	20,000	O/S	34.70	71.10	147	193.76	727.56	3.75	1,087
A37	0.17	0.25	20,000	O/S	42.73	16.50	148	50.97	648.46	12.72	311
A27	0.09	0.25	16,000	RF/S	31.85	74.90	141	74.98	157.08	2.09	842
B36	0.16	0.25	16,000	RF/S	28.10	62.10	143	97.05	267.53	2.78	615
B27	0.11	0.25	16,000	NF	17.00	74.10	140	47.29	0.00	0.00	439
A36	0.16	0.25	16,000	NF	56.65	2.30	141	6.08	0.00	0.00	47
A38	0.16	0.25	16,000	NF	71.57	3.40	146	12.17	0.00	0.00	85
A32	0.15	0.25	16,000	NF	52.61	6.30	121	16.18	0.00	0.00	18

O = Original Feed Schedule
S = Shrimp Diet
RF = Reduced Feed Schedule
NF = No Feed
0.03 gram = 1 ounce

characteristic of a population of harvested freshwater shrimp. By reducing the number of small shrimp present in the harvested population the economic value of a given harvest increases.

Size-grading is the physical separation of cultured juvenile shrimp into size categories. This separation was performed by placing nursed juveniles (nursed in an indoor system as described previously) in a 5x5-mm nylon net and allowing the animals to passively grade themselves. Initially, a 5x5-mm sorting net was used and only a small portion of the population remained within the net. Then, a 4x4-mm sorting net was used to grade the remaining animals. With the 4x4-mm sorting net, the majority of the animals were retained within the net. Subsequently, manual size grading by means of visual inspection was performed. The two large groups of animals derived from passive and manual grading were combined, yielding one-third (of the total) upper-graded and two-thirds lower-graded populations (mean wet weight of 0.30 and 0.14 gram, respectively). The ungraded or control group had a mean wet weight of 0.33 gram (D'Abramo et al., 1991). The mean wet weight of the ungraded population (control group) was obtained by allowing the animals to nurse for a longer period of time and/or by decreasing the stocking density during the nursing period. Researchers hypothesized that by using upper-graded and ungraded populations with similar mean stocking weights the "evident stocking weight" advantage that the upper-graded group would have had over the ungraded group (control) would be nullified. This procedure thereby allowed for a more accurate evaluation of the grading versus nongrading strategy.

Unsorted juveniles were stocked at 12,000 juveniles per water surface acre in two ponds, at 16,000 per acre in five ponds, and at 20,000 per acre in four ponds, all located at the MAFES South Farm Aquaculture Unit; and at 12,000 juveniles per acre in two ponds at the Coastal Aquaculture Unit. All graded juveniles were stocked at 12,000 juveniles per water surface acre. Ponds utilized for the size grading experiment were located at the Coastal Aquaculture Unit. All three treatments used for the size grading investigation (upper and lower sorted and unsorted) were replicated at least once.

All shrimp were fed a 28 percent crude protein pellet. A shrimp feed (denoted S in Appendix Table 8) and a shrimp feed with Nutribinder, (denoted SN in Appendix Table 8) were utilized. Nutribinder is a specially processed milo derivative. When included as a feed ingredient under certain manufacturing conditions, it aids in producing a more waterstable feed. Feeds with high water stability are recognized for potentially beneficial effects such as maintaining desirable water quality, stable pond ecology, and physical characteristics of the feed. The feeding schedule used for all treatments was similar to the reduced schedule used in 1987.

Pond management consisted of liming, fertilization, control of predaceous air-breathing insects, crush corn application (to control high pH), and frequent monitoring of D.O., salinity, pH, temperature, ammonia, nitrite, and nitrates. The total daily feed ration was distributed in two equal amounts, between 7:00 and 8:00 a.m., and between 3:00 and 4:00 p.m.

Results for the monoculture research conducted in 1988 at the South Farm Aquaculture Unit were as follows. Survival ranged from 44.1 to 65.3 percent (mean = 58.3%), 46.7 to 73.8 percent (mean = 62.8%), and 59.8 to 70.0 percent (mean = 65.5%) for 12,000, 16,000, and 20,000 juveniles per water surface acre, respectively. Mean harvest weights ranged from 32.3 to 39.0 grams (mean = 35.6), 24.3 to 38.2 grams (mean = 31.3), and 24.1 to 29.8 grams (mean = 27.2) for 12,000, 16,000, and 20,000 juveniles per water surface acre stocking densities, respectively. As expected, average size of shrimp harvested decreased with increasing stocking densities. Mean feed conversions were 3.1, 3.3, and 3.5 pounds of feed per pound of gain for stocking densities of 12,000, 16,000, and 20,000 stocking densities, respectively. Yield increased with increasing stocking density; 547, 694, and 789 pounds per acre for stocking densities of 12,000, 16,000, and 20,000 juveniles per acre water surface, respectively.

Results for the monoculture research conducted in 1988 at the Coastal Aquaculture Unit were as follows: mean survival for the ungraded, upper-graded and lower-graded treatments were 76.7, 83.8, and 76.5 percent, respectively. Mean harvest weights were 32.7, 44.9, and 34.1 grams for the ungraded, upper-graded, and lower-graded treatments, respectively. Mean feed conversion for the ungraded, upper-graded, and lower-graded treatments were 3.15, 2.35, and 3.10 pounds of feed per pound of harvested gain, respectively. Average yields for ungraded, upper-graded, and lower-graded treatments were 748, 1,089 and 830 pounds per acre, respectively. A summary of the results for the 1988 research is contained in Table 5.

When comparing the upper-graded and lower-graded with the ungraded treatment of the same general characteristics (eg. density, grow-out period, climatic conditions, and management), both the upper- and lower-graded treatments out-performed the control group. D'Abramo et al. (1991) estimated that mean yields for upper and lower-graded treatments were, respectively, 45.6 and 11.0 percent higher than the ungraded. Mean wet weight of animals harvested from the upper-graded treatments, was 37.3 and 31.7 percent higher than the ungraded and lower-graded treatments, respectively. There was also a con-

Table 5. Pond summary of the freshwater shrimp research, 1988.

Pond Description		Treatment		Mean	Feed	Mean						
Number	Size	Size Grading	Stocking Rate	Stocking Weight	Schedule/ Diet	Harvest Weight	Survival	Growout Days	Biomass Produced	Total Fed	Feed Conv.	Yield
	(acre)		(per acre)	(grams)		(grams)	(percent)		(lb)	(lb)		(lb/acre)
A31	0.18	UN	12,000	0.33	RF/S	34.90	63.90	139	104.63	267.04	2.55	591
B32	0.15	UN	12,000	0.33	RF/S	39.00	65.30	144	99.76	351.98	3.53	674
A34	0.17	UN	12,000	0.33	RF/S	36.00	44.10	145	69.91	249.34	3.57	412
A37	0.17	UN	12,000	0.33	RF/S	32.30	59.70	138	85.23	243.01	2.85	512
CAU6	0.25	UN	12,000	0.33	RF/SN	35.60	80.70	169	186.64	522.60	2.80	848
CAU9	0.25	UN	12,000	0.33	RF/SN	29.80	73.10	169	141.89	496.60	3.50	648
B31	0.18	UN	16,000	0.33	RF/S	38.20	46.70	138	111.18	394.82	3.55	629
A32	0.15	UN	16,000	0.33	RF/S	34.30	72.20	137	129.28	302.49	2.34	875
A35	0.16	UN	16,000	0.33	RF/S	35.40	70.80	143	139.59	408.31	2.92	885
B36	0.16	UN	16,000	0.33	RF/S	24.30	48.40	145	64.51	316.16	4.90	416
A33	0.17	UN	16,000	0.33	RF/SN	26.70	66.90	147	105.14	397.60	3.78	632
B35	0.16	UN	16,000	0.33	RF/SN	30.30	53.10	140	88.93	376.98	4.24	567
A36	0.16	UN	16,000	0.22	RF/S	30.90	73.80	133	127.47	292.22	2.29	806
B37	0.17	UN	16,000	0.22	RF/S	29.90	70.40	136	124.91	311.57	2.49	744
B28	0.11	UN	20,000	0.33	RF/S	29.80	70.00	139	99.58	327.62	3.29	923
B34	0.17	UN	20,000	0.33	RF/S	27.80	68.10	137	139.44	462.01	3.31	838
A38	0.16	UN	20,000	0.33	RF/S	27.00	59.80	144	111.57	408.16	3.36	715
B38	0.18	UN	20,000	0.33	RF/S	24.10	64.00	147	119.80	465.19	3.88	681
CAU10	0.25	33% UP	12,000	0.30	RF/SN	45.70	77.90	169	233.47	607.01	2.60	1,033
CAU8	0.25	33% UP	12,000	0.30	RF/SN	44.10	89.70	169	259.63	545.24	2.10	1,144
CAU5	0.25	67% LO	12,000	0.14	RF/SN	30.80	78.50	169	158.97	476.92	3.00	801
CAU7	0.25	67% LO	12,000	0.14	RF/SN	37.30	74.40	169	182.61	584.35	3.20	859

UN = Ungraded
UP = Upper-graded
LO = Lower-graded
CAU = Coastal Aquaculture Unit

RF = Reduced Feed Schedule
S = Shrimp Diet
SN = Shrimp Diet With Nutribinder
0.03 gram = 1 ounce

siderable shift in the population distribution of the upper-graded treatment; that is, an average of 8.6 percent small males ($\leq$ 19.0 g) was found in the upper-graded compared to 30.8 percent in the ungraded population.

Economic analysis for a synthesized 163-acre farm showed returns to land and management of $48,201 for the upper-graded juveniles and $12,905 for the ungraded juveniles (D'Abramo et al., 1991). The results clearly showed the economic benefits derived from size grading. Size grading apparently disturbed (changed) the social structure of the stocking population when compared to that of the ungraded population. As a consequence, mean harvest weight and yield increased. Also, a significant reduction in feeding rate was found to have no adverse effect on production (i.e. harvest weight and total yield). Future research in distributions (percentage of upper and lower) resulting from size grading along with improvement of the feeding schedule is needed to determine their effect on net returns.

1989

The main area of study for research conducted in 1989 was the evaluation of different strategies for size-grading of juveniles prior to stocking. This research was a continuation of the size-grading trials that were initiated in 1988 at the Coastal Aquaculture Unit. Separating juveniles into size classes decreased the proportion of small animals composing the population; consequently, the average harvest weight increased. Emphasis in evaluating grading effects at stocking densities of 16,000 juveniles per water surface acre was the most important investigation. Two feeds with similar ingredient composition but different water stability properties were evaluated (Appendix Table 9).

Shrimp postlarvae were nursed following procedures previously outlined. Juveniles were size-graded with a 4x4-mm sorting net. Those animals which passively graded through the net were classified as lower-graded (30% of the population). Those shrimp that remained within the sorting net (that did not passively exit from the net) were classified as upper-graded (70% of the population). Mean wet weights of the upper-graded and lower-graded populations were 0.14 and 0.10 gram, respectively. The average weight of the ungraded population (control group) equalled the average weight of the upper-graded group because of a longer period of time and/or lower stocking density for the nursing phase of the control group. Researchers hypothesized that by having the mean wet weight of both upper-graded and ungraded populations as close as possible the "evident stocking weight" advantages of the upper-graded group versus the ungraded group (control) would be eliminated. This procedure would therefore allow for a more accurate evaluation of the grading strategies.

Ponds located at the South Farm and Coastal Aquaculture Units were utilized to compare the effects of grading versus nongrading techniques upon production. Pond management consisted of monitoring D.O., temperature, pH, ammonia, nitrate, nitrite, and control of predaceous air-breathing insects.

Results of the research conducted in 1989 are depicted in Table 6. The 70 percent upper-graded treatment at a stocking density of 16,000 juveniles per water surface acre out-performed all other treatments in average harvest weight and yield. A reduction in the amount of small, low market value males and a corresponding increase in mean harvest weight were achieved. No obvious advantage in the use of the water stable diet was observed.

Economic evaluation of the results of this size-grading procedure showed that freshwater shrimp production still remained economically not feasible; however, size-grading did increase estimated net returns in some scenarios of exclusive shrimp production (Fuller et al., 1991a, 1991b, and 1991c). Under the assumption that shrimp production is a supplemental crop to an existing farm operation, estimated net returns were positive (Fuller et al., 1991c). Researchers concluded that future studies should attempt to identify the grading combination and optimum feed level that will result in maximum profit.

1990

The research conducted in 1990 was exclusively devoted to a followup evaluation of side-grading as an effective management practice. Postlarvae were nursed in an indoor system for approximately 30 days. Size-grading was conducted as previously outlined.

All ponds employed for the size-grading study were located at the South Farm Aquaculture Unit. Fifteen ponds ranging in size from 0.16 to 0.18 acre were stocked at a density of 16,000 juveniles per water surface acre. There were five treatments each consisting of different populations of nursed juveniles, 70 percent upper-graded, 30 percent lower-graded, 30 percent upper-graded, 70 percent lower-graded, and a control or ungraded treatment, with mean wet weights at stocking of 0.21, 0.10, 0.40, 0.15, and 0.16 gram, respectively. Each treatment was run in triplicate.

Pond management consisted of fertilization, control of predaceous airbreathing insects, ground corn application (to control high pH) and routine monitoring of D.O., pH, nitrates, and nitrites. Sampling techniques and feeding were similar to the methods utilized during the previous 2 years. A modified feed

Table 6. Pond summary of the freshwater shrimp research, 1989.

Pond Description		Treatment		Mean	Feed	Mean						
Number	Size	Size Grading	Stocking Rate	Stocking Weight	Schedule/ Diet	Harvest Weight	Survival	Growout Days	Biomass Produced	Total Fed	Feed Conv.	Yield
	(acre)		(per acre)	(grams)		(grams)	(percent)		(lb)	(lb)		(lb/acre)
A31	0.18	UN	16,000	0.14	RF/PFC	31.40	81.40	136	161.66	368.21	2.28	903
A35	0.16	UN	16,000	0.14	RF/PFC	34.80	72.10	135	140.65	327.03	2.33	885
B32	0.16	UN	16,000	0.14	RF/PFC	36.00	84.60	143	171.10	376.72	2.20	1,074
A36	0.16	UN	16,000	0.14	RF/S	32.40	73.60	132	133.73	347.24	2.60	841
A28	0.11	UN	16,000	0.14	RF/SN	29.80	72.00	146	82.01	242.39	2.96	752
A33	0.17	UN	16,000	0.14	RF/SN	29.50	71.70	134	125.82	326.79	2.60	746
B31	0.17	UN	16,000	0.14	RF/SN	27.40	78.10	134	127.29	340.06	2.67	755
CAU5	0.26	UN	16,000	0.14	RF/S	34.70	85.90	161	272.42	669.95	2.46	1,051
CAU8	0.25	UN	16,000	0.14	RF/S	36.30	84.20	163	267.88	639.09	2.39	1,078
A32	0.15	70% UP	12,000	0.14	RF/S	39.20	74.60	141	115.34	257.65	2.23	744
A38	0.16	70% UP	12,000	0.14	RF/S	34.90	77.10	133	113.34	244.20	2.15	712
B35	0.17	70% UP	12,000	0.14	RF/S	38.30	80.50	139	138.32	294.58	2.13	816
A29	0.11	70% UP	16,000	0.14	RF/S	32.40	77.40	142	96.80	248.46	2.57	885
A37	0.17	70% UP	16,000	0.14	RF/S	35.20	81.10	132	170.75	357.74	2.10	1,007
B30	0.11	70% UP	16,000	0.14	RF/S	30.10	84.20	140	97.86	254.21	2.60	894
B29	0.11	70% UP	16,000	0.14	RF/S	33.00	62.20	141	78.95	230.42	2.92	724
B33	0.17	70% UP	16,000	0.14	RF/S	30.40	58.90	138	106.66	367.64	3.45	632
CAU7	0.25	70% UP	16,000	0.14	RF/S	39.00	70.25	162	240.50	676.30	2.81	966
CAU9	0.25	70% UP	16,000	0.14	RF/S	36.70	78.70	162	253.73	678.46	2.67	1,019
B28	0.11	30% LO	12,000	0.10	RF/S	37.70	84.90	142	114.90	162.50	1.41	847
B36	0.16	30% LO	12,000	0.10	RF/S	35.70	76.50	135	115.04	233.29	2.03	723
B38	0.18	30% LO	12,000	0.10	RF/S	39.60	50.20	134	94.05	232.54	2.47	526
A34	0.17	30% LO	16,000	0.10	RF/S	27.90	85.40	139	142.22	332.41	2.34	840
B34	0.17	30% LO	16,000	0.10	RF/S	29.10	80.70	141	140.23	362.35	2.58	828
B37	0.17	30% LO	16,000	0.10	RF/S	30.70	80.00	131	146.47	328.99	2.25	867
CAU6	0.27	30% LO	16,000	0.10	RF/S	26.50	63.90	161	160.41	636.31	3.97	597
CAU10	0.25	30% LO	16,000	0.10	RF/S	28.60	81.30	161	204.52	526.41	2.57	820

UN = Ungraded
UP = Upper-graded
LO = Lower-graded
CAU = Coastal Aquaculture Unit
RF = Reduced Feed

S = Shrimp Diet
SN = Shrimp Diet with Nutribinder
PFC = Delta Feed (ingredient composition same as S)
0.03 gram = 1 ounce

Table 7. Pond summary of the freshwater shrimp research, 1990.

Pond Description		Treatment		Mean	Feed	Mean						
Number	Size	Size Grading	Stocking Rate	Stocking Weight	Schedule/ Diet	Harvest Weight	Survival	Growout Days	Biomass Produced	Total Fed	Feed Conv.	Yield
	(acre)		(per acre)	(grams)		(grams)	(percent)		(lb)	(lb)		(lb/acre)
A31	0.18	UN	16,000	0.16	RF/S2	26.00	82.60	126	135.34	272.95	2.02	758
A38	0.16	UN	16,000	0.16	RF/S2	23.40	52.30	135	68.17	295.94	4.32	432
B34	0.17	UN	16,000	0.16	RF/S2	25.00	86.90	135	129.30	315.63	2.44	766
B33	0.17	70% UP	16,000	0.21	RF/S2	29.30	76.20	127	132.63	275.31	2.08	788
B37	0.17	70% UP	16,000	0.21	RF/S2	29.50	77.60	132	136.02	308.33	2.27	807
A34	0.17	70% UP	16,000	0.21	RF/S2	26.90	84.40	136	134.88	319.42	2.37	801
A35	0.16	30% LO	16,000	0.10	RF/S2	29.10	73.70	133	120.46	267.00	2.22	757
A37	0.17	30% LO	16,000	0.10	RF/S2	29.70	64.80	134	114.81	280.58	2.44	679
B36	0.16	30% LO	16,000	0.10	RF/S2	26.00	81.00	133	118.28	269.95	2.28	743
A32	0.15	30% UP	16,000	0.40	RF/S2	34.60	82.40	131	148.72	324.14	2.18	1,006
B38	0.18	30% UP	16,000	0.40	RF/S2	36.50	87.10	138	199.32	413.29	2.07	1,121
A36	0.16	30% UP	16,000	0.40	RF/S2	33.40	86.30	126	160.43	318.76	1.99	1,017
B35	0.17	70% LO	16,000	0.15	RF/S2	24.40	94.70	125	137.65	273.70	1.99	815
B31	0.17	70% LO	16,000	0.15	RF/S2	25.40	59.70	138	90.04	288.84	3.21	535
A33	0.17	70% LO	16,000	0.15	RF/S2	27.00	86.10	133	138.49	325.49	2.35	820

UN = Ungraded
UP = Upper-graded
LO = Lower-graded

RF = Reduced Feed Schedule
S2 = Modified S Feed
0.03 gram = 1 ounce

(denoted as S in Appendix Table 10) of 32 percent crude protein was provided to all ponds in all treatments. The total daily amount of feed was distributed in two equal parts, one in the morning and the second in the afternoon.

Growing season ranged from 125 to 138 days. Table 7 depicts the results from the different treatments at the culmination of the growing season. The mean harvest weights of the 30 percent upper-graded (34.8 grams) and 70 percent upper-graded (28.6 grams) treatments were 36.5 and 12.2 percent greater than that of the ungraded treatment (25.5 grams). Average survival and feed conversion were also significantly higher and lower, respectively, for the 30 percent upper-graded treatment. Average yield for the 30 percent upper-graded (1,048 lb/A) was 31 and 38 percent greater than the 70 percent upper-graded and ungraded treatment yields, respectively. The total amount of small males in the graded treatments was significantly lower than in the ungraded treatments.

Economic Analysis of Research Results

Production data obtained from the 1984 through 1990 experiments were incorporated into a synthetic firm approach to calculate an estimated cost for a selected production system. The synthetic firm approach was used to develop budgets from technical coefficients (input-output) along with price data and suggestions from professionals in the field (researchers, extension service specialists, consultants, suppliers, and dealers) and previous studies on the economic feasibility of freshwater shrimp production in Mississippi, which includes among others Fuller et al. (1991 a, b, and c, and 1988a and b); Smith (1990); D'Abramo et al. (1991); Leventos, (1986); Moore, (1986); and Clardy et al. (1985).

The technical production data obtained from MAFES research were considered suitable to estimate the "best" net revenue from the different managerial strategies evaluated during the 7 years of research. Research results, in terms of mortality, size of shrimp harvested, and total yield, varied widely over the seven years. Therefore, results selected for inclusion in economic analysis were those believed to be consistently under commercial conditions.

The Synthetic Firm

The synthesized firm consisted of 42 land acres located on heavy clay soils with topography suitable for developing a shrimp farm. Shrimp pond design and site selection were conducted as a joint project between MSU researchers and Soil Conservation Service (SCS) specialists. SCS personnel surveyed and made topographic maps of the area used in this study. Land requirements for this operation were as follows: 10 water surface acres for five production ponds of 2 water surface acres each, 8.40 water surface acres for a water storage reservoir, 4.49 acres for levees, 1 acre for service area; and 18.11 acres for miscellaneous (Appendix Table 11).

The geographic location assumed for this study was the east central hill area of Mississippi. The hill area topography allowed for the design of a water supply or storage pond, in which sufficient water can be collected from the surrounding watershed to fill a series of production ponds and to satisfy water needs (evaporation and seepage) during the growout season. Miscellaneous land requirement includes land surrounding the water reservoir. This land is needed to provide runoff area for water collection and to ensure that no chemicals or pollutants detrimental to freshwater shrimp production enter the water storage pond.

Stocking rates and size were varied according to different treatments. Appendix Table 12 shows the number and respective year for each pond from which data were derived to be used in the analyses. These ponds were selected (from the data available from 1984 to 1990, Tables 1-7) because they represented typical production results (for each year) of the freshwater shrimp research period of 1984 to 1990. Survival and yield were used to identify treatments with results that were not characteristic of a given year, and these treatments were eliminated from analysis.

Estimated cost for seed stock (juveniles) was based upon a stocking weight dependent price (Appendix Table 13). The cost for juveniles was estimated using results from Smith (1990) and Leventos (1986).

Feed conversion ratios and total amount of feed for each treatment were based on results from the freshwater shrimp research from 1984 to 1990 (Tables 1 through 7). Two feeding schemes were utilized ("old" and "new" feed schedules as shown in Appendix Tables 3 and 6). Feeding rates were based on the average wet weight of the animal population in the experimental pond (obtained from triweekly samples and survival estimates), percentages of body weight to be fed, and calculated conversion ratios obtained from two generalized growth curves.

The type of feed utilized for this study was a 25 percent crude protein sinking pellet. It was assumed that feed was delivered to the farm in bulk form by the feed producer and stored in a 4-ton feed bin. Other assumptions included a growing season of approximately 153 days (early May to late September) with all shrimp harvested and marketed at the end of the growout period.

Ponds

Design of the five, 2-acre production ponds was based on SCS recommendations. Specifications for levee were: 14-foot crown with 3:1 slope for all interior and exterior levees; and an average of 4 feet of water depth and 2 feet of freeboard. Pond design allowed for a slight sloping of the bottom towards the drainage area. All ponds had access to a drainage ditch and harvest basin. Drain pipes and water level control pipes consist of 10-inch, and 6-inch PVC pipes, respectively. Filling and draining of the ponds were accomplished by gravity flow. Each pond can be filled or drained independently. All weather access was provided on graveled levee crowns. Bermudagrass was employed as vegetative coverage to avoid erosion. Schematic diagrams of pond and levee design are shown in Appendix Figures 1 and 2.

Water Supply

A water storage reservoir of 8.4 water surface acres was included in the synthesized farm for water supply. The water-supply pond had designed capacity to hold 1 acre-foot of water for each acre-foot of water in the production ponds. Stored water is delivered to the ponds via gravity flow. Production ponds could be filled in 24 to 48 hours. A sufficient amount of water should be available to replace water loss due to seepage and evaporation and to supply additional freshwater when needed to improve water quality.

Feed and Feeding

Feeding frequency was twice daily (morning and afternoon). A 25 percent crude protein sinking pelleted feed that had soybean meal, fish meal, rice bran, vitamins, and minerals as its main ingredients (Diet "S", Appendix Table 9) was used.

Feeding was done with a 500-pound capacity tractor-powered feeder (smallest size available commercially). This type of feeder allows for better distribution of feed through the pond and, consequently, better feed utilization.

Feed was stored in a 4-ton feed bin. Total feed requirement and conversion ratios for each treatment were based on feeding schedules and total feed utilized during the 1984-1990 shrimp research.

Disease Prevention and Water Quality Control

The disease prevention and water quality control program, which reflect strategies utilized in experiments, was developed in consultation with MAFES researchers. This program encompasses potential problems that producers might face under Mississippi's environmental characteristics, and focuses on water quality management, temperature, predaceous insect treatment, and phytoplankton control.

Predaceous insect treatment consisted of application of a diesel oil treatment (4 gallons per water surface acre) one or two days before the stocking of juveniles. This procedure effectively kills predaceous air-breathing insects.

D.O. levels and water temperature were carefully monitored in each production pond in early morning and late evening. Electric paddlewheels were operated 10 hours a day in each pond. During detrimentally low D.O. concentrations, a portable PTO-driven paddlewheel was used for aeration.

Other water quality parameters such as ammonia, nitrate, nitrite, and pH were monitored weekly. Total alkalinity was measured prior to stocking and at different stages during the growout period. Desired levels of water quality parameters for freshwater shrimp production are well documented (New, 1990; Wellborn, 1985; Malecha, 1983).

The synthetic farm was equipped with an oxygen meter set (includes oxygen meter, probe, cable, and membrane kit) and an emergency oxygen kit. Also included were test kits to check levels of ammonia, nitrate, nitrite, pH, and alkalinity. A boat, outboard motor, and trailer were also included for chemical application, removal of unwanted filamentous algae, and water collection.

Harvesting and Hauling

Harvesting of the pond was accomplished by draining via gravity flow. The 10-inch PVC draining pipe could be raised and lowered to meet desired water flow.

Drained water would be directed through a harvest basin (10.7x5.3x5.3 feet with an 8-inch thick wall) adjacent to the levee and then exited to a ditch. A harvest basket would be placed in the harvest basin to catch the shrimp that exit the pond. Once the desired amount of shrimp entered the harvest basket, the water flow would momentarily be stopped while the basket was lifted by a backhoe to transfer the animals to a live-haul truck (owned by the custom crew). Then the harvest basket would be returned to the harvesting basin to repeat the process. Shrimp that remained in the pond after complete drainage were harvested by hand. Harvested shrimp were assumed to be transported to the processing facility by live-haul trucks owned by the custom crew.

Revenue Estimation

Total revenues per acre for each treatment included in the economic analysis were calculated by determining headless shrimp yield times headless shrimp prices by tail count. Headless shrimp yields were estimated by using the regression analysis model of

Fuller et al. (1986). Headless shrimp prices represented a 5-year average (1986-1990) for the northern Gulf of Mexico ex-vessel prices for the months of July, August, September, and October. These prices are provided in Appendix Table 14.

Estimated Investment Requirements

Investment requirements were divided into five categories: land, pond construction, feeding, disease and water quality, and miscellaneous equipment. Some degree of farm complementarity was assumed in this farm situation. That is, some of the equipment used in shrimp farming was shared by another farming activity (such as cattle production). Farm complementarity is evident by the amount of equipment required for the shrimp operation. Such is the case of miscellaneous equipment, where one-half tractor, service building, farm/shop equipment, and clipper and one-quarter truck are allocated to the shrimp operation (allowing other farm operations to utilize the equipment). All of these capital items are needed to initiate production. The total investment requirement of $93,041 was the same for all strategies. A detailed list of the items that comprise investment requirements is shown in Table 8.

Table 8. Estimated investment requirements for a 10-water-acre freshwater shrimp farm, hill area of Mississippi, 1991.

Item	Dollars	Percent of Total
Land	25,200	27.08
Pond Construction		
Earth moving	24,959	26.83
Piping & fixtures[1]	13,425	14.43
Concrete	441	0.47
Cinder blocks[2]	520	0.56
Gravel	1,225	1.32
Vegetative cover	412	0.44
Subtotal	40,982	44.05
Feeding Equipment		
Feeder	1,650	1.77
Feed bin	850	0.91
Subtotal	2,500	2.68
Disease & Water Quality		
Boat	700	0.75
Motor	510	0.55
Trailer	600	0.64
Subtotal	1,810	1.94
Miscellaneous Equipment		
Tractor (1/2 Tractor)	7,000	7.52
Truck (1/4 Truck)	3,775	4.06
Service building (1/2 Service bldg.)	1,750	1.88
Farm/shop equipment (1/2 Farm/shop equip).	1,000	1.07
Oxygen meter, probe, cable and membrane kit	905	0.97
Emergency oxygen kit	61	0.07
Seines	170	0.18
Harvesting basket	250	0.27
5 ft Clipper (1/2 clipper)	388	0.42
Electric floating paddlewheels	4,550	4.89
PTO-driven paddlewheel	1,700	1.83
Other	1,000	1.07
Subtotal	22,549	24.24
Total Investment	**93,041**	**100.00[3]**
Investment per water surface acre	9,304	
Investment per land acre	2,215	

[1] A detailed description of piping & fixtures is presented in Appendix Table 15.

[2] Includes construction cost.

[3] Subject to rounding error.

Land

The value for land was estimated at $600 per acre by farm management specialists who assess land values in the region. The total investment required for land was $25,200, which represented 27.08 percent of the total estimated investment requirement.

Pond Construction

Pond construction costs included earth moving, piping and fixtures, concrete, cinder blocks, gravel, and vegetative cover. Concrete and cinder blocks were used to construct the harvest basin, which is the structure that allows collection of shrimp when the pond is drained by gravity flow. Gravel and vegetative cover were used to provide all-weather access and to protect the pond from erosion, respectively. Earth moving cost was established at 80 cents per cubic yard.

Pond construction was estimated at $40,982, or 44.05 percent of the total investment requirement. A detailed explanation of the quantities and prices for volume of earth moved, gravel and concrete, cinder blocks, and vegetative cover are presented in Appendix Tables 16 and 17.

Feeding

A PTO-driven, tractor-pulled feeder, and a 4-ton feed bin are used in this farm situation. The feeder was assumed to be necessary for proper distribution of feed throughout the pond, thereby maximizing feed utilization. Total investment required for feeding equipment was $2,500 or 2.69 percent of the total investment requirement.

Disease Prevention and Water Quality Control

The investment required for the boat, outboard motor, and boat trailer was $1,810. The boat, outboard motor, and boat trailer were mainly used for chemical application. Disease prevention and water quality control represented the smallest percentage (1.94) of the total estimated investment requirement.

Miscellaneous Equipment

Miscellaneous equipment is equipment that could be utilized in more than one area in the production process and includes the following items: one-half of a tractor, service building, farm/shop equipment, 5-foot clipper; one-quarter ton truck; and oxygen meter, probe, cable and membrane kit, emergency oxygen kit, seines, harvesting basket, electric floating paddlewheel, and others. The total investment for miscellaneous equipment was $22,549 (24.24 % of the total estimated investment requirement).

Estimated Annual Ownership Costs

Annual ownership costs are incurred once the durable goods are purchased. These are added costs whether or not the assets (equipment/materials) are used in the production process. Annual ownership costs are frequently referred to as "fixed costs." They include depreciation, interest on investment, taxes, and insurance. Total annual ownership costs for this farm situation were $14,813. These costs are presented in Table 9.

Depreciation

Depreciation is the annual loss in the value of facilities and equipment throughout their life expectancy due to use in the production process or obsolescence. The useful life for facilities and equipment was obtained from information provided by manufacturers, dealers, suppliers, and published material. The straight-line method with zero salvage value was employed to calculate annual depreciation.

Pond depreciation was calculated employing a pond levee life expectancy of 10 years. Depreciation cost for ponds was $4,098. The depreciation for feeding equipment, disease prevention and water quality control, and miscellaneous equipment was calculated by summing the depreciation of each item or separate component in each category; these costs were $373, $232, and $3,012, respectively. The total annual depreciation was $7,715. Appendix Table 18 shows the expected useful life and the annual depreciation for facilities and equipment.

Interest on Investment

Interest on investment is the cost of capital. An annual interest rate of 11 percent was charged on the total value of land (nondepreciable item). All other items were to be charged 11 percent interest rate on half of the original investment (depreciable items). The total annual cost of interest on investment for this operation was $6,515.

Table 9. Estimated annual ownership costs for a 10-water-acre freshwater shrimp farm, hill area of Mississippi, 1991.

Item	Dollars	Percent of Total
Depreciation[1]		
Ponds	4,098	27.66
Feeding (feeder & feed bin)	373	2.52
Disease & water quality (boat, motor, trailer)	232	1.57
Miscellaneous equipment	3,012	20.33
Subtotal	7,715	52.08
Interest on Investment[2]		
Land	2,772	18.71
Pond construction	2,254	15.22
Feeding (feeder & feed bin)	138	0.93
Disease & water quality (boat, motor, trailer)	100	0.68
Miscellaneous equipment	1,247	8.42
Subtotal	6,511	43.96
Taxes and insurance	587	3.96
Total annual ownership costs	**14,813**	**100.00**
Annual ownership costs/water surface area	1,481	

[1] Calculated by straight line method with zero salvage value.
[2] Charged at 11% on the total value of land and one-half the investment of all other depreciable items.

Taxes and Insurance

A tax rate of $1.54 per acre of total land used (i.e. 42 acres) was applied to determine land taxes. This tax rate was obtained from the 1990 average rates of five Mississippi counties representing hill areas (Kemper, Oktibbeha, Clay, Lowndes, Monroe, and Noxubee). The tax rate of each of the six counties was obtained as follows. The use-value for cultivable land in the Upper Coastal Plain region and the Black Belt region for 1990 was estimated at $125 per acre for all classes of land. Then, the tax base (assessed value) was determined by multiplying the assessment ratio by the use value (the assessment ratio is a percentage, which is used to convert use-value into assessed value; in Mississippi it's 15%). Finally, the tax rate was determined for each county. The tax rate is an expression of the property tax due for a given amount of assessed valuation. Tax rates are expressed in mills per dollar of assessed value. The tax rate for each county was determined by multiplying the assessed value by the mills representative of that specific county. Insurance costs were estimated by a reputable insurance company to be $522 per year with a $250 deductible. The insurance coverage included fire, hail, and malicious misdemeanors. For this farm situation, total cost for taxes and insurance was $587.

Estimated Annual Operating Costs

Annual operating costs are incurred when the production process occurs. These costs are commonly known as "variable costs," and in this farm situation are composed of costs for repairs and maintenance, fuel, chemicals, test kits, juvenile shrimp, feed, labor, harvesting and hauling, liability insurance, and interest on operating capital (Table 10). Prices for other selected inputs used in shrimp production are presented in Appendix Tables 13 and 16, respectively.

Repairs and Maintenance

Yearly repair and maintenance costs (over the life expectancy of the item) were determined as a percentage of the initial purchase price. These estimates were derived from information provided by manufacturers, dealers, suppliers, and published material (Appendix Table 18). Repairs and maintenance costs (includes vegetative cover, feeding equipment, disease prevention and water quality control, and miscellaneous equipment) for this farm situation were $2,438. Operating costs for repair and maintenance varied among alternative management strategies, from 6.10 percent to 22.46 percent of the total estimated annual operating costs.

Fuel

Estimates of fuel utilization were determined from MAFES budgets and other published data. Three types of fuel were purchased: diesel to operate the tractor, gasoline to operate the outboard motor and truck, and electricity to power the floating paddlewheels.

One hour of operation of the 35-hp tractor, would consume approximately 2 gallons of diesel fuel per hour for clipping or grass mowing, feeding, and PTO-driven paddlewheels. It was estimated that annual grass mowing and feeding would require 22 and 153 hours, respectively.

Electric paddlewheels were utilized 10 hours per day throughout the entire growing season (153 days). It was assumed that electricity usage for a one-hp electric floating paddlewheel was 0.63 Kwh per hour of operation, considering 85 percent efficiency. The PTO-driven paddlewheel would be employed if emergency aeration were needed. The total amount of emergency paddlewheel aeration to be utilized was estimated to be approximately 10 percent of the total electric paddlewheel aeration hours.

The rate of gasoline consumption for the outboard motor was estimated to be 2 gallons per hour of operation. The outboard motor was employed 22 hours during the growing season. Estimation of the fuel cost of transportation was based on the average annual miles driven by the pickup truck (15,000), and an estimated mileage of 20 miles per gallon of gasoline.

The total amount of fuel required (including electricity, gasoline, and diesel) for clipping, feeding, outboard motor, PTO-driven paddlewheel, transportation, and electric floating paddlewheels was $1,440 (Appendix Table 19). Operating costs for fuel ranged from 3.6 percent to 13.26 percent of the total estimated annual operating costs.

Chemicals

The total annual chemical expense solely includes the cost of diesel fuel utilized in the control of predaceous air-breathing insects. A total of 40 gallons of diesel fuel were utilized at a total cost of $32.

Test Kits

The type of test kits employed to analyze water quality were: alkalinity, ammonia, nitrate, nitrite, and pH. The estimated annual cost for the test kits was $58.

Seed Stock

In this study, the cost of seed stock (nursed juveniles) is associated with the mean individual weight of the animals purchased. Larger seed stock command higher prices. For the sizes assumed for this analysis, costs were estimated by extrapolating from previous work done by Smith (1990) and Leventos (1986).

Leventos (1986) estimated that the cost of producing postlarvae was $7.74 per 1,000 shrimp. The total cost of postlarvae production and then nursing postlarvae to 0.50-gram and 0.25-gram mean individual weight were estimated to be $38.25 and $23.23, per 1,000 individuals, respectively. Smith (1990) updated the cost of producing postlarval shrimp to $8.64 per 1,000 shrimp. Postlarvae can be cultured until the desired size juveniles for stocking are obtained (this is known as the nursery phase). In this study, it was assumed that the nursery phase took place indoors, in tanks where water quality, feeding, and water temperature were closely monitored. The advantages of using nursed juveniles instead of postlarvae for stocking ponds are increase in mean harvest weight and final yield, decrease in mortality, and ability to better utilize the restricted growing season in temperate regions.

By subtracting the cost of producing postlarvae ($7.74) from the $38.25 and $23.23 cost of producing juveniles (0.50 gram and 0.25 gram, respectively) and then adding the updated cost of producing postlarvae of $8.64, the final cost of producing 0.50-gram and 0.25-gram juveniles was estimated to be $0.039 and $0.024 per shrimp, respectively. From these two cost points, the value of juveniles of different sizes was extrapolated.

Since juveniles were stocked at different sizes and densities, the estimated cost of juveniles changed among treatments or strategies. Overall, cost of

Table 10. Estimated annual operating costs for a 10-water-acre freshwater shrimp farm for alternative management practices, hill area of Mississippi, 1991.

Item	UN 12,000[1] @ 0.25[2]	Percent of total	UN* 12,000 @ 0.33	Percent of total	UN* 16,000 @ 0.14	Percent of total	UN* 16,000 @ 0.16	Percent of total	UN* 16,000 @ 0.17	Percent of total	UN* 16,000 @ 0.22	Percent of total	UN 16,000 @ 0.25	Percent of total
	($)	(%)	($)	(%)	($)	(%)	($)	(%)	($)	(%)	($)	(%)	($)	(%)
Repairs & Maintenance														
Vegetative cover	445	3.39	445	3.37	445	3.49	445	3.58	445	3.34	445	3.40	445	2.91
Feeding equipment	252	1.92	252	1.91	252	1.97	252	2.03	252	1.89	252	1.92	252	1.65
Disease and water quality	128	0.97	128	0.97	128	1.00	128	1.03	128	0.96	128	0.98	128	0.84
Miscellaneous equipment	1,613	12.28	1,613	12.22	1,613	12.64	1,613	12.99	1,613	12.10	1,613	12.31	1,613	10.54
Fuel														
Clipping	36	0.27	36	0.27	36	0.28	36	0.29	36	0.27	36	0.27	36	0.24
Feeding	248	1.89	248	1.88	248	1.94	248	2.00	248	1.86	248	1.89	248	1.62
Outboard motor	13	0.10	13	0.10	13	0.10	13	0.10	13	0.10	13	0.10	13	0.08
PTO-driven paddlewheel	620	4.72	620	4.70	620	4.86	620	4.99	620	4.65	620	4.73	620	4.05
Transportation	218	1.66	218	1.65	218	1.71	218	1.76	218	1.63	218	1.66	218	1.42
Electric floating paddlewheel	305	2.32	305	2.31	305	2.39	305	2.46	305	2.29	305	2.33	305	1.99
Chemicals	32	0.24	32	0.24	32	0.25	32	0.26	32	0.24	32	0.24	32	0.21
Test kits	58	0.44	58	0.44	58	0.45	58	0.47	58	0.43	58	0.44	58	0.38
Juveniles	2,880	21.93	3,480	26.37	2,720	21.31	3,040	24.48	3,040	22.80	3,520	26.87	3,840	25.09
Feed (25% protein sinking)	2,902	22.09	2,311	17.51	2,584	20.25	1,977	15.92	2,878	21.58	2,141	16.34	3,885	25.38
Labor	2,515	19.15	2,515	19.06	2,515	19.71	2,515	20.25	2,515	18.86	2,515	19.20	2,515	16.43
Harvesting & hauling	242	1.84	276	2.09	359	2.81	305	2.46	296	2.24	310	2.37	387	2.53
Liability insurance	200	1.52	200	1.52	200	1.57	200	1.61	200	1.50	200	1.53	200	1.31
Interest on operating capital	429	3.27	446	3.38	414	3.24	414	3.33	439	3.29	445	3.40	513	3.35
Total operating cost[a]	**13,135**	**100.00**	**13,196**	**100.00**	**12,761**	**100.00**	**12,419**	**100.00**	**13,336**	**100.00**	**13,099**	**100.00**	**15,307**	**100.00**

UN =Ungraded
UP = Upper-graded
LO = Lower-graded
[1] Stocking density per water surface acre
[2] Stocking weight in grams
* Reduced feed schedule
[a] Subject to rounding error
0.03 gram = 1 ounce

(continued)

Table 10. Estimated annual operating costs for a 10-water-acre freshwater shrimp farm for alternative management practices, hill area of Mississippi, 1991 (continued).

Item	UN* 16,000[1] @ 0.25[2]	Percent of total	UN* 16,000 @ 0.33	Percent of total	UN 16,000 @ 0.75	Percent of total	UN 20,000 @ 0.25	Percent of total	UN* 20,000 @ 0.33	Percent of total	UN 24,000 @ 0.17	Percent of total	UN 24,000 @ 0.75	Percent of total
	($)	(%)	($)	(%)	($)	(%)	($)	(%)	($)	(%)	($)	(%)	($)	(%)
Repairs & Maintenance														
Vegetative cover	445	3.33	445	2.99	445	2.19	445	2.58	445	2.69	445	2.74	445	1.63
Feeding equipment	252	1.89	252	1.70	252	1.24	252	1.46	252	1.52	252	1.55	252	0.92
Disease and water quality	128	0.96	128	0.86	128	0.63	128	0.74	128	0.77	128	0.79	128	0.47
Miscellaneous equipment	1,613	12.08	1,613	10.85	1,613	7.95	1,613	9.36	1,613	9.74	1,613	9.93	1,613	5.91
Fuel														
Clipping	36	0.27	36	0.24	36	0.18	36	0.21	36	0.22	36	0.22	36	0.13
Feeding	248	1.86	248	1.67	248	1.22	248	1.44	248	1.50	248	1.53	248	0.91
Outboard motor	13	0.10	13	0.09	13	0.06	13	0.08	13	0.08	13	0.08	13	0.05
PTO-driven paddlewheel	620	4.64	620	4.17	620	3.06	620	3.60	620	3.74	620	3.82	620	2.27
Transportation	218	1.63	218	1.47	218	1.07	218	1.26	218	1.32	218	1.34	218	0.80
Electric floating paddlewheel	305	2.28	305	2.05	305	1.50	305	1.77	305	1.84	305	1.88	305	1.12
Chemicals	32	0.24	32	0.22	32	0.16	32	0.19	32	0.19	32	0.20	32	0.12
Test kits	58	0.43	58	0.39	58	0.29	58	0.34	58	0.35	58	0.36	58	0.21
Juveniles	3,840	28.75	4,640	31.22	8,640	42.59	4,800	27.85	5,800	35.01	4,560	28.07	12,960	47.46
Feed (25% protein sinking)	2,036	15.24	2,699	18.16	3,826	18.86	4,727	27.43	3,171	19.14	4,013	24.70	6,143	22.49
Labor	2,515	18.83	2,515	16.92	2,515	12.40	2,515	14.59	2,515	15.18	2,515	15.48	2,515	9.21
Harvesting & hauling	337	2.52	319	2.15	363	1.79	435	2.52	316	1.91	431	2.65	446	1.63
Liability insurance	200	1.50	200	1.35	200	0.99	200	1.16	200	1.21	200	1.23	200	0.73
Interest on operating capital	460	3.44	522	3.51	774	3.82	590	3.42	599	3.62	557	3.43	1,077	3.94
Total operating cost[a]	**13,356**	**100.00**	**14,863**	**100.00**	**20,286**	**100.00**	**17,234**	**100.00**	**16,568**	**100.00**	**16,244**	**100.00**	**27,309**	**100.00**

UN = Ungraded
UP = Upper-graded
LO = Lower-graded
[1] Stocking density per water surface acre
[2] Stocking weight in grams
* Reduced feed schedule
[a] Subject to rounding error
0.03 gram = 1 ounce

(continued)

Table 10. Estimated annual operating costs for a 10-water-acre freshwater shrimp farm for alternative management practices, hill area of Mississippi, 1991 (continued).

Item	UN 32,000[1] @ 0.03[2]	Percent of total	UN 32,000 @ 0.17	Percent of total	UN 32,000 @ 0.24	Percent of total	UN 32,000 @ 0.52	Percent of total	UN 32,000 @ 0.75	Percent of total	UN 32,000 @ 1.07	Percent of total	UN 48,000 @ 0.17	Percent of total
	($)	(%)	($)	(%)	($)	(%)	($)	(%)	($)	(%)	($)	(%)	($)	(%)
Repairs & Maintenance														
Vegetative cover	445	2.87	445	2.31	445	2.24	445	1.68	445	1.33	445	1.11	445	1.81
Feeding equipment	252	1.63	252	1.31	252	1.27	252	0.95	252	0.75	252	0.63	252	1.03
Disease and water quality	128	0.83	128	0.67	128	0.64	128	0.48	128	0.38	128	0.32	128	0.52
Miscellaneous equipment	1,613	10.42	1,613	8.39	1,613	8.11	1,613	6.08	1,613	4.82	1,613	4.04	1,613	6.57
Fuel														
Clipping	36	0.23	36	0.19	36	0.18	36	0.14	36	0.11	36	0.09	36	0.15
Feeding	248	1.60	248	1.29	248	1.25	248	0.94	248	0.74	248	0.62	248	1.01
Outboard motor	13	0.08	13	0.07	13	0.07	13	0.05	13	0.04	13	0.03	13	0.05
PTO-driven paddlewheel	620	4.01	620	3.22	620	3.12	620	2.34	620	1.85	620	1.55	620	2.53
Transportation	218	1.41	218	1.13	218	1.10	218	0.82	218	0.65	218	0.55	218	0.89
Electric floating paddlewheel	305	1.97	305	1.59	305	1.53	305	1.15	305	0.91	305	0.76	305	1.24
Chemicals	32	0.21	32	0.17	32	0.16	32	0.12	32	0.10	32	0.08	32	0.13
Test kits	58	0.37	58	0.30	58	0.29	58	0.22	58	0.17	58	0.15	58	0.24
Juveniles	3,520	22.74	6,080	31.61	7,360	37.02	12,800	48.27	17,280	51.60	23,360	58.48	9,120	37.15
Feed (25% protein sinking)	4,200	27.13	5,289	27.50	4,540	22.84	5,476	20.65	7,629	22.78	7,652	19.16	7,242	29.50
Labor	2,515	16.25	2,515	13.08	2,515	12.65	2,515	9.48	2,515	7.51	2,515	6.30	2,515	10.24
Harvesting & hauling	567	3.66	503	2.62	570	2.87	505	1.90	536	1.60	558	1.40	436	2.45
Liability insurance	200	1.29	200	1.04	200	1.01	200	0.75	200	0.60	200	0.50	602	0.81
Interest on operating capital	460	3.29	678	3.53	729	3.67	1,052	3.97	1,359	4.06	1,694	4.24	901	3.67
Total operating cost[a]	**15,479**	**100.00**	**19,232**	**100.00**	**19,881**	**100.00**	**26,516**	**100.00**	**33,486**	**100.00**	**39,947**	**100.00**	**24,549**	**100.00**

UN = Ungraded
UP = Upper-graded
LO = Lower-graded
[1] Stocking density per water surface acre
[2] Stocking weight in grams
* Reduced feed schedule
[a] Subject to rounding error
0.03 gram = 1 ounce

(continued)

Table 10. Estimated annual operating costs for a 10-water-acre freshwater shrimp farm for alternative management practices, hill area of Mississippi, 1991 (continued).

Item	33% UP* 12,000[1] @ 0.30[2]	Percent of total	70% UP* 12,000 @ 0.14	Percent of total	30% UP 16,000 @ 0.40	Percent of total	70% UP* 16,000 @ 0.14	Percent of total	70% LO* 16,000 @ 0.21	Percent of total	30% LO* 12,000 @ 0.10	Percent of total	67% LO* 16,000 @ 0.10	Percent of total
	($)	(%)	($)	(%)	($)	(%)	($)	(%)	($)	(%)	($)	(%)	($)	(%)
Repairs & Maintenance														
Vegetative cover	445	3.30	445	3.93	445	2.88	445	3.41	445	3.57	445	4.10	445	3.74
Feeding equipment	252	1.87	252	2.22	252	1.63	252	1.93	252	2.02	252	2.32	252	2.12
Disease and water quality	128	0.95	128	1.13	128	0.83	128	0.98	128	1.03	128	1.18	128	1.07
Miscellaneous equipment	1,613	11.95	1,613	14.24	1,613	10.44	1,613	12.37	1,613	12.93	1,613	14.86	1,613	13.54
Fuel														
Clipping	36	0.27	36	0.32	36	0.23	36	0.28	36	0.29	36	0.33	36	0.30
Feeding	248	1.84	248	2.19	248	1.60	248	1.90	248	1.99	248	2.28	248	2.08
Outboard motor	13	0.10	13	0.11	13	0.08	13	0.10	13	0.10	13	0.12	13	0.11
PTO-driven paddlewheel	620	4.59	620	5.47	620	4.01	620	4.76	620	4.97	620	5.71	620	5.21
Transportation	218	1.62	218	1.92	218	1.41	218	1.67	218	1.75	218	2.01	218	1.83
Electric floating paddlewheel	305	2.26	305	2.69	305	1.97	305	2.34	305	2.44	305	2.81	305	2.56
Chemicals	32	0.24	32	0.28	32	0.21	32	0.25	32	0.26	32	0.29	32	0.27
Test kits	58	0.43	58	0.51	58	0.38	58	0.44	58	0.46	58	0.53	58	0.49
Juveniles	3,240	24.00	2,040	18.01	5,280	34.16	2,720	20.86	2,987	23.94	1,800	16.58	2,040	17.13
Feed (25% protein sinking)	2,691	19.94	1,942	17.15	2,519	16.30	2,831	21.71	2,075	16.63	1,720	15.84	2,481	20.83
Labor	2,515	18.63	2,515	22.21	2,515	16.27	2,515	19.29	2,515	20.16	2,515	23.17	2,515	21.12
Harvesting & hauling	436	3.23	303	2.68	419	2.71	382	2.93	319	2.56	314	2.89	332	2.79
Liability insurance	200	1.48	200	1.77	200	1.29	200	1.53	200	1.60	200	1.84	200	1.68
Interest on operating capital	448	3.32	358	3.16	555	3.59	422	3.24	414	3.32	339	3.12	374	3.14
Total operating cost[a]	**13,498**	**100.00**	**11,326**	**100.00**	**15,457**	**100.00**	**13,038**	**100.00**	**12,478**	**100.00**	**10,856**	**100.00**	**11,909**	**100.00**

UN = Ungraded
UP = Upper-graded
LO = Lower-graded
[1] Stocking density per water surface acre
[2] Stocking weight in grams
* Reduced feed schedule
[a] Subject to rounding error
0.03 gram = 1 ounce

(continued)

Table 10. Estimated annual operating costs for a 10-water-acre freshwater shrimp farm for alternative management practices, hill area of Mississippi, 1991 (continued).

Item	30% LO* 16,000[1] @ 0.10[2]	Percent of total	70% LO* 16,000 @ 0.15	Percent of total
	($)	(%)	($)	(%)
Repairs & Maintenance				
Vegetative cover	445	3.71	445	3.60
Feeding equipment	252	2.10	252	2.04
Disease and water quality	128	1.07	128	1.03
Miscellaneous equipment	1,613	13.45	1,613	13.04
Fuel				
Clipping	36	0.30	36	0.29
Feeding	248	2.07	248	2.01
Outboard motor	13	0.11	13	0.11
PTO-driven paddlewheel	620	5.17	620	5.01
Transportation	218	1.82	218	1.76
Electric floating paddlewheel	305	2.54	305	2.47
Chemicals	32	0.27	32	0.26
Test kits	58	0.48	58	0.47
Juveniles	2,400	20.01	2,880	23.28
Feed (25% protein sinking)	2,210	18.43	2,071	16.74
Labor	2,515	20.97	2,515	20.33
Harvesting & hauling	316	2.63	327	2.64
Liability insurance	200	1.67	200	1.62
Interest on operating capital	385	3.21	408	3.30
Total operating cost[a]	**11,994**	**100.00**	**12,369**	**100.00**

UN = ungraded
UP = Upper-graded
LO = Lower-graded
0.03 gram = 1 ounce

[1] Stocking density per water surface acre
[2] Stocking weight in grams
* Reduced feed schedule
[a] Subject to rounding error

juveniles varied among strategies from 17.1 percent to 58.5 percent of the total annual operating costs. The charges associated with different juvenile sizes are provided in Appendix Table 13.

Feed

A specially formulated 25 percent crude protein sinking feed was estimated to cost $234 per ton delivered. Feed conversion ratios and total amount of feed used fluctuated among treatments. Costs of feed ranged from 15.24 to 29.50 percent of the total annual operating costs. Strategies that included reduced feed schedules generally showed lower costs.

Labor

Labor requirements were satisfied by employing hired help for feeding, water quality monitoring, mowing, and general maintenance. The estimated annual cost associated with labor was based on an hourly wage rate of $5.00. This hourly wage rate includes fringe benefits and workers compensation. The estimated total amount of labor hours was 503, resulting in a labor cost of $2,515.

Harvesting and Hauling

It was assumed that harvesting was done by draining water by gravity flow. Rapid flow of water out of the pond was achieved by a design consisting of a gentle increase of the slope of the pond bottom towards the draining pipe and harvest basin area. As the water and shrimp exit the pond, the animals are captured in the harvest basin. This harvesting technique considerably decreases the amount of labor needed, when compared to seine harvest.

It was assumed that harvesting and hauling costs per pound for freshwater shrimp would be the same as that of catfish: that is, 3 cents for harvesting, and 1 cent for hauling. These charges were typical of customs rates charged in the Mississippi Delta and are considered reasonable for this study. Harvesting and hauling costs differed among treatments ranging from 1.40 percent to 3.66 percent of the total annual operating costs.

Liability Insurance

The costs of a general liability insurance policy was estimated to be $200 per year by a reputable insurance firm.

Interest on Operating Capital

The annual cost of interest on operating capital was estimated by charging a rate of 11 percent for 6 months on the cost of juveniles and 3 months on all other operating costs. Interest on operating capital differed across management strategies.

Estimated Annual Net Revenue

The computed net revenues for all strategies were negative, based on an average 5-year price (Appendix Table 14) for headless gulf shrimp. The smallest and largest net losses were $2,239 and $28,383, respectively (Table 11). Sensitivity analysis of annual net revenue, under various price situations for whole shrimp, showed that at an average price for whole shrimp of $3.50 per pound all of the "graded" strategies had positive net revenues, ranging from $356 to $9,804 (Table 12).

Effect of Management Strategies on Net Revenue

Multiple regression analysis was used to analyze the effect of variations in stocking size, stocking density and grading strategies on net revenue. The only variable that was significant (P= 0.05) was stocking size and the sign of the coefficient was negative, as expected.

A simple regression model containing net revenue as the dependent variable and stocking size as the only independent variable explained 64 percent of the variation in the revenue. The regression coefficient was significant (P= 0.05) and negative.

Among the variables studied, size of animals stocked was the most important in determining net revenue. As stocking size increased, net revenue

Table 11. Estimated net returns for a 10-water-acre freshwater shrimp farm for alternative management practices, hill area of Mississippi, 1991.

Strategy			Revenue[1]	Estimated Annual Cost			Net Revenue
				Ownership Cost	Operating Cost	Total	
			($)	($)	($)	($)	($)
UN,	12,000[2]	@ 0.25[3]	14,711	14,813	13,135	27,948	-13,237
UN*,	12,000	@ 0.33	14,634	14,813	13,196	28,009	-13,375
UN*,	16,000	@ 0.14	18,840	14,813	12,761	27,574	- 8,734
UN*,	16,000	@ 0.16	14,419	14,813	12,419	27,232	-12,813
UN,	16,000	@ 0.17	16,513	14,813	13,336	28,149	-11,636
UN*,	16,000	@ 0.22	16,710	14,813	13,099	27,912	-11,202
UN,	16,000	@ 0.25	18,800	14,813	15,307	30,120	-11,320
UN*,	16,000	@ 0.25	15,172	14,813	13,356	28,169	-12,997
UN*,	16,000	@ 0.33	17,783	14,813	14,863	29,676	-11,892
UN,	16,000	@ 0.75	20,086	14,813	20,286	35,099	-15,013
UN,	20,000	@ 0.25	22,972	14,813	17,234	32,047	- 9,075
UN*,	20,000	@ 0.33	16,286	14,813	16,568	31,381	-15,095
UN,	24,000	@ 0.17	20,701	14,813	16,244	31,057	-10,356
UN,	24,000	@ 0.75	23,689	14,813	27,309	42,122	-18,433
UN,	32,000	@ 0.03	26,710	14,813	15,479	30,292	- 3,582
UN,	32,000	@ 0.17	23,285	14,813	19,232	34,045	-10,760
UN,	32,000	@ 0.24	32,455	14,813	19,881	34,694	- 2,239
UN,	32,000	@ 0.52	27,215	14,813	26,516	41,429	-14,114
UN,	32,000	@ 0.75	26,042	14,813	33,486	48,299	-22,258
UN,	32,000	@ 1.07	26,377	14,813	39,947	54,760	-28,383
UN,	48,000	@ 0.17	24,400	14,813	24,549	39,362	-14,962
33% UP*,	12,000	@ 0.30	20,069	14,813	13,498	28,311	- 8,242
70% UP*,	12,000	@ 0.14	17,303	14,813	11,326	26,139	- 8,836
30% UP*,	16,000	@ 0.40	22,828	14,813	15,457	30,270	- 7,441
70% UP*,	16,000	@ 0.14	20,217	14,813	13,038	27,851	- 7,634
70% UP*,	16,000	@ 0.21	16,890	14,813	12,478	27,291	-10,400
30% LO*,	12,000	@ 0.10	17,013	14,813	10,856	25,669	- 8,656
67% LO*,	12,000	@ 0.14	16,875	14,813	11,909	26,722	- 9,847
30% LO*,	16,000	@ 0.10	15,838	14,813	11,994	26,807	-10,970
70% LO*,	16,000	@ 0.15	15,390	14,813	12,369	27,182	-11,793

UN = Ungraded
UP = Upper-graded
LO = Lower-graded
[1] Calculated by multiplying headless freshwater shrimp yields by marine shrimp prices
[2] Stocking density per water surface acre
[3] Stocking weight, in grams
* Reduced feed schedule
0.03 gram = 1 ounce

decreased, a situation explained mainly by the cost for the largest size seed stock (1.07 grams) being more than six times the cost of the smallest size (0.03 gram) (Appendix Table 13).

Summary, Conclusions, and Limitations

Summary

Increases in per capita consumption of shrimp, generally declining U.S. shrimp commercial landings and a corresponding continued increase in annual imports of shrimp into the U.S., and the interest in developing additional aquacultural enterprises, led MAFES researchers to investigate the potential of commercial culture of freshwater shrimp. Numerous experiments were conducted by an interdisciplinary research team during a 7-year period, 1984 to 1990. Different management strategies, such as stocking density, stocking weight, and grading techniques, were evaluated in the expectation of increasing mean harvest weight and yield and decreasing variation in size.

The purpose of this study was to evaluate how different management strategies affect net revenue of a potential freshwater shrimp operation. A synthetic firm approach was utilized to develop a budget and net revenue estimates for a production situation in the hill area of Mississippi. The synthesized farm situation consisted of a total of 42 acres of land, with 10 water surface acres in shrimp production ponds and a water storage reservoir of 8.40 acres for water supply. All ponds were assumed to be 2 water acres in size. The remaining 23.60 acres were devoted to levees, watershed area, service, and miscellaneous uses.

Relevant production data from MAFES research for 1984 through 1990 were sorted by management

Table 12. Estimated net returns for a 10-water-acre freshwater shrimp farm for alternative management practices and selected product prices, hill area of Mississippi, 1991.

Strategy	Price							
	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
UN, 12,000[1] @ 0.25[2]	-18,888	-15,868	-12,848	-9,828	-6,808	-3,788	-768	2,252
UN*, 12,000 @ 0.33	-17,659	-14,209	-10,759	-7,309	-3,859	-409	3,041	6,491
UN*, 16,000 @ 0.14	-14,104	-9,614	-5,124	-634	3,856	8,346	12,836	17,326
UN*, 16,000 @ 0.16	-15,802	-11,992	-8,182	-4,372	-562	3,248	7,058	10,868
UN, 16,000 @ 0.17	-16,809	-13,029	-9,249	-5,469	-1,689	2,091	5,871	9,651
UN*, 16,000 @ 0.22	-16,287	-12,412	-8,537	-4,662	-787	3,088	6,963	10,838
UN*, 16,000 @ 0.25	-15,615	-10,780	-5,945	-1,110	3,725	8,560	13,395	18,230
UN*, 16,000 @ 0.25	-15,539	-11,329	-7,119	-2,909	1,301	5,511	9,721	13,931
UN*, 16,000 @ 0.33	-17,721	-13,736	-9,751	-5,766	-1,781	2,204	6,189	10,174
UN, 16,000 @ 0.75	-21,479	-16,939	-12,399	-7,859	-3,319	1,221	5,761	10,301
UN, 20,000 @ 0.25	-15,742	-10,307	-4,872	563	5,998	11,433	16,868	22,303
UN*, 20,000 @ 0.33	-19,546	-15,601	-11,656	-7,711	-3,766	179	4,124	8,069
UN, 24,000 @ 0.17	-14,902	-9,517	-4,132	1,253	6,638	12,023	17,408	22,793
UN, 24,000 @ 0.75	-25,397	-19,822	-14,247	-8,672	-3,097	2,478	8,053	13,628
UN, 32,000 @ 0.03	-9,037	-1,952	5,133	12,218	19,303	26,388	33,473	40,558
UN, 32,000 @ 0.17	-15,190	-8,905	-2,620	3,665	9,950	16,235	22,520	28,805
UN, 32,000 @ 0.24	-13,334	-6,214	906	8,026	15,146	22,266	29,386	36,506
UN, 32,000 @ 0.52	-22,499	-16,189	-9,879	-3,569	2,741	9,051	15,361	21,671
UN, 32,000 @ 0.75	-28,199	-21,499	-14,799	-8,099	-1,399	5,301	12,001	18,701
UN, 32,000 @ 1.07	-33,835	-26,860	-19,885	-12,910	-5,935	1,040	8,015	14,990
UN, 48,000 @ 0.17	-16,772	-9,242	-1,712	-5,818	13,348	20,878	28,408	35,938
33% UP*, 12,000 @ 0.30	-11,976	-6,531	-1,086	-4,535	9,804	15,249	20,694	26,139
70% UP*, 12,000 @ 0.14	-14,784	-10,999	-7,214	-3,429	356	4,141	7,926	11,711
30% UP*, 16,000 @ 0.40	-14,550	-9,310	-4,070	1,170	6,410	11,650	16,890	22,130
70% UP*, 16,000 @ 0.14	-13,541	-8,771	-4,001	769	5,539	10,309	15,079	19,849
70% UP*, 16,000 @ 0.21	-15,306	-13,311	-7,316	-3,321	674	4,669	8,664	12,659
30% LO*, 12,000 @ 0.10	-13,894	-9,969	-6,044	2,119	1,806	5,731	9,656	13,581
67% LO*, 12,000 @ 0.14	-14,272	-10,122	-5,972	-1,822	2,328	6,478	10,628	14,778
30% LO*, 16,000 @ 0.10	-14,942	-10,987	-7,032	-3,077	878	4,833	8,788	12,743
70% LO*, 16,000 @ 0.15	-14,912	-10,822	-6,732	-2,642	1,448	5,538	9,628	13,718

UN = Ungraded
UP = Upper-graded
LO = Lower-graded
[1] Stocking density per water surface acre
[2] Stocking weight in grams
* Reduced feed schedule
0.03 gram = 1 ounce

strategies used (grading vs. nongrading, stocking density, and stocking weight). This procedure allowed for estimation of production costs and net revenues for all the relevant strategies used. These revenues were calculated by multiplying headless freshwater shrimp yields by headless marine shrimp prices for specific tail count categories. Prices used were average ex-vessel prices for the Northern Gulf of Mexico for the years 1986 through 1990 during July, August, September, and October.

Estimated investment requirements for the synthesized farm situation were $93,041. Estimated annual ownership cost for all management strategies was $14,813. Annual operating costs varied among strategies, ranging from $10,856 to $39,947. Higher annual operating costs were usually associated with strategies utilizing greater stocking densities and stocking weights. Strategies where a size-grading management practice was employed showed lower annual operating costs.

Net revenues for all management strategies were negative. Smaller negative net revenues were associated with small size, ungraded juveniles stocked at high densities (32,000 per acre), followed by 30 and 70 percent upper-graded juveniles at stocking densities of 16,000 per surface water acre. When comparing grading versus nongrading strategies at 12,000 and 16,000 per surface water acre stocking densities, grading strategies proved helpful in increasing mean harvest weight which increased net revenue.

Sensitivity analysis was performed to study the effects of different whole shrimp prices on net revenue. At a whole shrimp price of $3.50 per pound, all of the strategies that utilized size-grading produced positive net revenues, and more than half of the ungraded strategies also had positive net revenues.

Conclusions

Based on research conducted by MAFES, and the use of 5-year average northern Gulf of Mexico prices for headless marine shrimp, freshwater shrimp production is not an economically feasible activity if all production costs are to be included. Net revenues derived from size-grading strategies were less negative than most of the ungraded strategies at similar stocking densities. Less negative net revenue was associated with strategies in which greater stocking densities and small stocking weights were employed. More research is needed to establish the most profitable size grading strategy.

Little is known about the nature of demand for freshwater shrimp. Average ex-vessel prices for marine shrimp tails used in the analysis are considerably lower than observed prices for limited quantities of whole freshwater shrimp sold in retail seafood markets and may not reflect actual prices that commercial producers might receive. Also, size-grading techniques might lead to the development of a market for whole freshwater shrimp that is completely different from the marine shrimp tail market.

The lack of reliable sources of seed stock locally has partially frustrated achieving commercial success of freshwater shrimp production in Mississippi. Further research is also needed to reduce costs of juveniles and feed. Size-grading shows promising economic improvement for freshwater shrimp production. Appropriate proportional division of upper and lower size-graded shrimp could have a positive effect on mean harvest weight, which could potentially increase net revenues. Effects of grading procedures at high stocking densities are not known. Therefore, more research is needed in this area. Size of the animals to be stocked appears to be the most important independent variable in determining net revenue.

The sensitivity analysis shown in Table 12 yields positive net revenues for all graded strategies for an average whole shrimp price of $3.50. At a price of $4.00 per pound, all but two strategies would produce positive net returns. When whole shrimp prices (instead of northern Gulf of Mexico ex-vessel prices for headless shrimp) are considered, it is evident that some strategies would produce positive net revenues. Utilizing whole shrimp prices and selling the product at the farm gate or pond bank, could be an appropriate strategy for a small shrimp farmer located in the hill area of Mississippi, provided that a local market for freshwater shrimp exists. Fuller and Kelly (1991c) indicated that potential demand for freshwater shrimp in particular geographic areas or ethnic populations could result in prices significantly higher that those for marine shrimp. Localized demand for freshwater shrimp should be studied in order to assist in estimating market potential for farm gate or pond bank sales of freshwater shrimp produced by small farmers.

Alternative production strategies, such as sex reversal (to create monosex populations) and its effect on net revenue, needs to be studied. Reduction of feed used/improvement of feed conversion and seed stock production also require further investigation.

Limitations

The costs presented in this study were based on a synthetic firm operation. Some of the costs utilized in this analysis might not be the same as the costs incurred in a commercial operation. The synthetic firm developed for this study utilized hill area topography, and production costs will change when a different topographic area is considered. This study also assumed that equipment was used for other farm activities as well as shrimp farming.

Most of the projected costs for production of juveniles were extrapolated and might not reflect actual costs. Cost of juveniles according to size (weight) and grading charges must be further evaluated, so that the potential of shrimp farming can be more satisfactory assessed. Additional investigation of harvesting and hauling costs for freshwater shrimp would also result in a more comprehensive and accurate assessment of the viability of commercial production of freshwater shrimp production in the hill areas of Mississippi.

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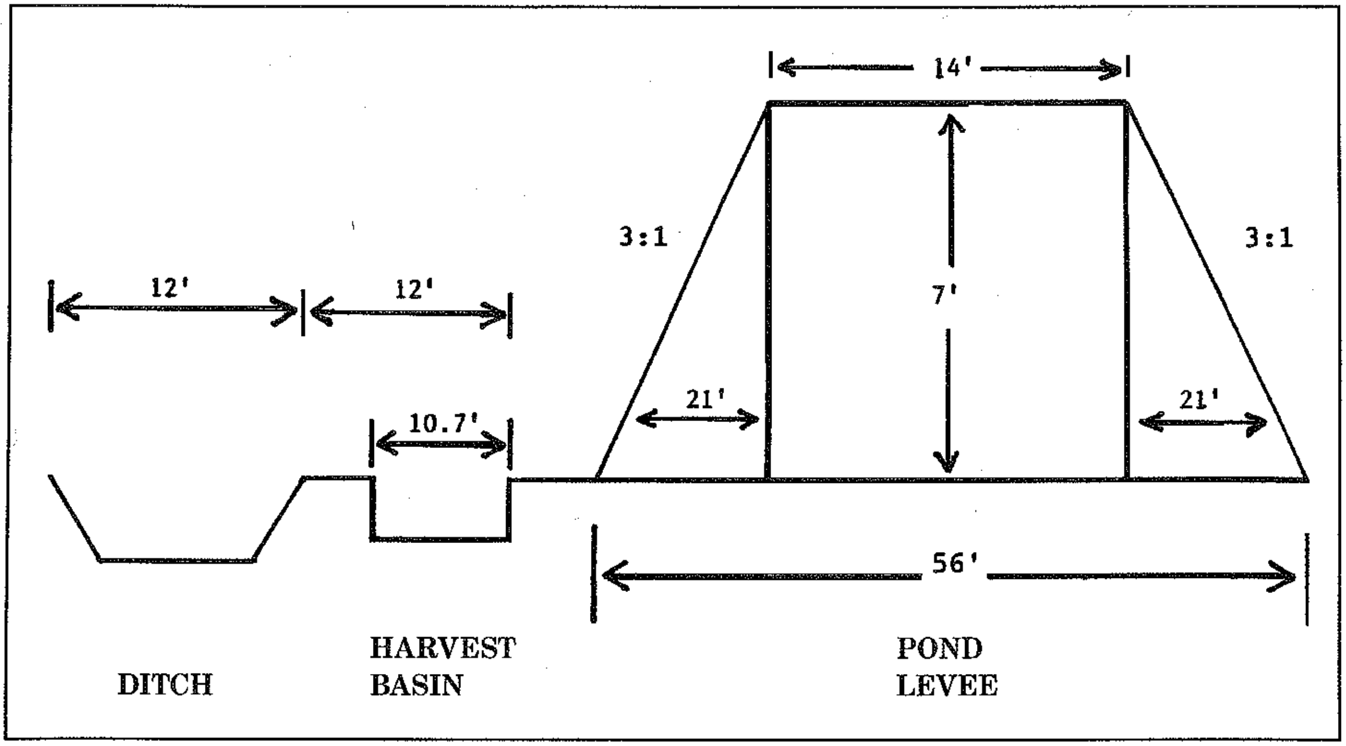
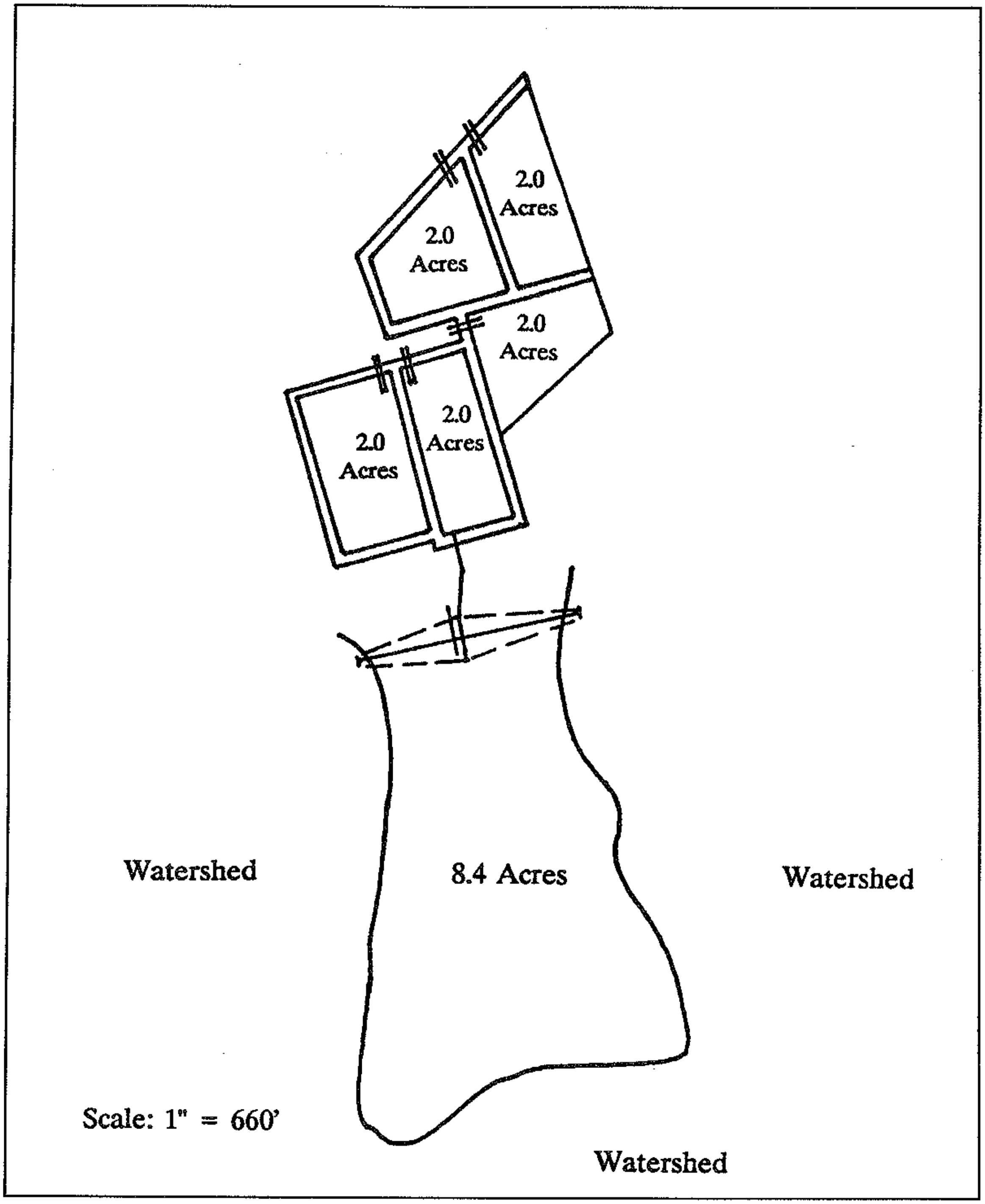
Appendix



Appendix Figure 1. Schematics of the cross section of ditch, harvest basin, and levee with a berm.



Appendix Figure 2. Schematics of a freshwater shrimp production facility with five 2-water-surface-acre production ponds and a water supply reservoir with 8.4 water-surface acres.

Appendix Table 1. Summary of the most significant management strategies, results, and economic implications derived from the freshwater shrimp research at MAFES, 1984-1990.

1984	• Single stocking density studied • Market size achieved in one growing season • Freshwater shrimp production unprofitable based upon results
1985	• Multiple stocking densities studied • Mean yield increased with increasing stocking densities • Density dependent growth factors in evidence, mean harvest weight decreased with increasing stocking densities • Freshwater shrimp production unprofitable under given results • Lower stocking densities economically more attractive
1986	• Effect of stocking weight of juveniles upon mean harvest weight were investigated • Greater stocking weight of juveniles translates into significant increases in mean harvest weight and total yield • Freshwater shrimp production unprofitable based upon results
1987	• New (reduced) feeding schedule studied • Reduction in total amount fed of 60 percent was successfully achieved • Reduced feed strategy could prove to be economically advantageous • Growth rate at stocking densities of 16,000 per water surface acre will be lower when no supplemental feed is provided
1988	• Continuation of the evaluation of the effects of feeding schedules and stocking densities • Feeding rates had been successfully reduced without inflicting in considerable reductions on the overall production • Effect of size grading juveniles prior to stocking was evaluated • Size grading proved to be an effective management practice that increases mean harvest weight and total yield • Proportion of small low price individuals was significantly reduced • Upper-graded animals outperformed both lower-graded and ungraded (control group) • Economic analysis for a synthesized 163-acre farm showed positive returns to land and management for some grading strategies
1989	• Evaluation of size grading as an alternative management strategy continuous • Size grading again is shown to be an effective management practice in increasing net returns
1990	• The mean harvest weight of the 30 and 70 percent upper-graded populations stocked into ponds were 36.5 and 12.2 percent greater than that of the ungraded stocked population • Average yield for the 30 percent upper-graded population was 31 and 38 percent greater than the 70 percent upper-graded and ungraded population yields, respectively.

Appendix Table 2. Ingredient composition and proximate analysis of diets S and CD fed to freshwater shrimp, 1984.

	Diet S	Diet CD
	% Dry Weight	% Dry Weight
Soybean meal	17	25
Fish meal	15	12
Rice bran	33	15
Corn screenings	21.75	–
Wheat	13	–
Shrimp meal	–	25
Nutribinder	–	15
Corn distillers dried grains with solubles	–	4.3
Tuna oil	–	3.0
Phytosterol premix[a]	–	0.5
Trace Mineral premix[b]	0.1	–
Vitamin premix[c]	0.1	0.2
Choline	.05	–
Moisture (%)	12.4	13.9
Ash (%)	5.1	10.6
Crude protein (%)	25.9	32.3
Fat (%)[d]	4.2	8.4
Crude fiber (%)	2.8	4.6
Nitrogen-free extract (%)	9.6	30.2

[a] Phytosterol premix contains: B-sitosterol, 63.2%; campesterol, 32.2%; stigmasterol, 4.6%

[b] Trace mineral premix contains: Mn, 10.0%; Zn, 10.0%; Fe, 7.0%; Cu, 0.7%; I, 0.24%; Co, 0.10%; Ca (carrier)

[c] Vitamin premix contains: thiamin, 1.01%; riboflavin 1.32%; pyridoxine, 0.9%; nicotinic acid, 8.82%; folic acid, 0.22%; vitamin B12, 0.001%; pantothenic acid, 3.53%; menadione, 0.2%; ascorbic acid, 33.07%; vitamin A, 4,409,200 (IU)/kg; vitamin D3, 2,204,600 (IU)/kg; vitamin E, 66,138 (IU)/kg; athoxyquin, 0.66%.

[d] Acid Hydrolysis.

Source: D'Abramo et al., 1984.

Appendix Table 3. Feed schedule used for culture of freshwater shrimp, Mississippi, 1984-1987 (old feed schedule).

Average Wet Weight From	To	Estimated survival	Body weight fed
grams		%	%
Stocking Size	1	100	20
1	2	100	15
2	5	95	12
5	10	90	9
10	15	85	8
15	20	80	7
20	25	78	6
25	30	75	5
30	Up	75	3

Source: Adapted from D'Abramo et al., 1984.

Appendix Table 4. Ingredient composition and proximate analysis of diets S and CD fed to freshwater shrimp, 1985.

	Diet S		Diet CD
	% Dry Weight		% Dry Weight
Soybean meal	17		25
Fish meal	15		12
Rice bran	33		15
Corn screenings	21.75		–
Wheat	13		–
Shrimp meal	–		25
Nutribinder	–		15
Corn distillers dried grains with solubles	–		4.3
Tuna oil	–		3.0
Phytosterol premix[a]	–		0.5
Trace mineral premix[b]	0.1		–
Vitamin premix[c]	0.1		0.2
Choline	0.05		–
	Batch A	Batch B	
Moisture (%)	10.8	9.7	11.4
Ash (%)	6.6	10.1	11.5
Crude protein	26.4	28.3	33.4
Fat (%)[d]	5.2	8.5	9.3
Crude fiber (%)	5.1	5.3	4.8
Nitrogen-free extract (%)	46.0	38.1	29.6

[a] Phytosterol premix contains: B-sitosterol, 63.2%; campesterol, 32.2%; stigmasterol, 4.6%.

[b] Trace mineral premix contains: Mn, 10.0%; Zn, 10.0%; Fe, 7.0%; Cu, 0.7%; I, 0.24%; Co, 0.10%; Ca (carrier).

[c] Vitamin premix contains: thiamin, 1.01%; riboflavin 1.32%; pyridoxine, 0.9%; nicotinic acid, 8.82%; folic acid, 0.22%; vitamin B12, 0.001%; pantothenic acid, 3.53%; menadione, 0.2%; ascorbic acid, 33.07%, vitamin A, 4,409,200 (IU)/kg; vitamin D3, 2,204,600 (IU)/kg; vitamin E, 66,138 (IU)/kg; ethoxyquin, 0.66%.

[d] Acid hydrolysis.

Appendix Table 5. Ingredient composition and proximate analysis (mean ± SE of 4 separate batches) of diet S fed to freshwater shrimp, 1986.

	% Dry Weight
Soybean meal	17
Fish meal	15
Rice bran	33
Corn screenings	21.75
Wheat	13
Trace mineral premix[a]	0.1
Vitamin premix[b]	0.1
Choline	0.05
	% Weight (as fed)
Moisture	12.8 ± 1.2
Ash	10.8 ± 1.7
Crude protein	27.5 ± 0.6
Fat[c]	8.7 ± 1.4
Crude fiber	7.3 ± 1.2
Nitrogen-free extract	32.9 ± 6.3

[a] Trace mineral premix contains: Mn, 10.0%; Zn, 10.0%; Fe, 7.0%; Cu, 0.7%; I, 0.24%; Co, 0.10%; Ca (Carrier).
[b] Vitamin premix contains: thiamin, 1.01%; riboflavin, 1.32%; pyridoxine, 0.9%; nicotinic acid, 8.82%; folic acid, 0.22%; vitamin B12, 0.001%; pantothenic acid, 3.53%; menadione, 0.2%; ascorbic acid, 33.07%; vitamin A, 4,409,200 (IU)/kg; vitamin D3, 2,204,600 (IU)/kg; vitamin E, 66.138 (IU)/kg; ethoxyquin, 0.66%.
[c] Acid hydrolysis.

Source: D'Abramo et al., 1989.

Appendix Table 6. New feed schedule used for freshwater shrimp research, 1987-1990.

Mean Wet Weight (grams)	Daily Feeding Rate[a] (%)
< 5	0
5-15	7
15-25	5
> 25	3

[a] (as-fed weight of feed/wet biomass of shrimp x 100).
Source: Adapted from D'Abramo et al., 1991.
0.03 gram = 1 ounce

Appendix Table 7. Ingredient composition of diet S fed to freshwater shrimp, 1987.

	% Dry Weight
Soybean meal	17
Fish meal	15
Rice bran	33
Corn screenings	21.75
Wheat	13
Trace mineral premix[a]	0.1
Vitamin premix[b]	0.1
Choline	0.05

[a] Trace mineral premix contains: Mn, 10.0%; Zn, 10.0%; Fe, 7.0%; Cu, 0.7%; I, 0.24%; Co, 0.10%; Ca (Carrier).
[b] Vitamin premix contains: thiamin, 1.01%; riboflavin, 1.32%; pyridoxine, 0.9%; nicotinic acid, 8.82%; folic acid, 0.22%; vitamin B12, 0.001%; pantothenic acid, 3.53%; menadione, 0.2%; ascorbic acid, 33.07%; vitamin A, 4,409,200 (IU)/kg; vitamin D3, 2,204,600 (IU)/kg; vitamin E, 66.138 (IU)/kg; ethoxyquin, 0.66%.

Appendix Table 8. Ingredient composition of diet S and diet SN fed to freshwater shrimp, 1988.

	Diet S	Diet SN
	% Dry Weight	% Diet Weight
Soybean meal	17	17
Fish meal	15	15
Rice bran	33	33
Corn screenings	21.75	21.75
Wheat	13	–
Nutribinder	–	13
Trace mineral premix[a]	0.1	0.1
Vitamin premix[b]	0.1	0.1
Choline	0.05	0.05

[a] Trace mineral premix contains: Mn, 10.0%; Zn, 10.0%; Fe, 7.0%; Cu, 0.7%; I, 0.24%; Co, 0.10%; Ca (Carrier).
[b] Vitamin premix contains: thiamin, 1.01%; riboflavin, 1.32%; pyridoxine, 0.9%; nicotinic acid, 8.82%; folic acid, 0.22%; vitamin B12, 0.001%; pantothenic acid, 3.53%; menadione, 0.2%; ascorbic acid, 33.07%; vitamin A, 4,409,200 (IU)/kg; vitamin D3, 2,204,600 (IU)/kg; vitamin E, 66.138 (IU)/kg; ethoxyquin, 0.66%.

Appendix Table 9. Ingredient composition of diets S and SN fed to freshwater shrimp, 1989.

	Diet S	Diet SN
	% Dry Weight	% Dry Weight
Cereal feed	22.5	22.5
Wheat, soft-10	32	17
Wheat, midds	10	10
Fish meal	18	18
Soybean meal	17	17
Trace mineral premix[a]	0.1	0.1
Vitamin premix[b]	0.4	0.4
Nutribinder	–	1.5

[a] Trace mineral premix contains: Mn, 10.0%; Zn, 10.0%; Fe, 7.0%; Cu, 0.7%; I, 0.24%; Co, 0.10%; Ca (Carrier).

[b] Vitamin premix contains: thiamin, 1.01%; riboflavin, 1.32%; pyridoxine, 0.9%; nicotinic acid, 8.82%; folic acid, 0.22%; vitamin B12, 0.001%; pantothenic acid, 3.53%; menadione, 0.2%; ascorbic acid, 33.07%; vitamin A, 4,409,200 (IU)/kg; vitamin D3, 2,204,600 (IU)/kg; vitamin E, 66.138 (IU)/kg; ethoxyquin, 0.66%.

Appendix Table 10. Ingredient composition of diet S2 fed to freshwater shrimp, 1990.

	% Dry Weight
Soybean meal	17
Fish meal	15
Wheat midds	13
Meat, bone & blood meal	10
Rice bran	33
Corn screenings	11.75
Trace mineral premix[a]	0.1
Vitamin premix[b]	0.1
Choline	0.05

[a] Trace mineral premix contains: Mn, 10.0%; Zn, 10.0%; Fe, 7.0%; Cu, 0.7%; I, 0.24%; Co, 0.10%; Ca (Carrier).

[b] Vitamin premix contains: thiamin, 1.01%; riboflavin, 1.32%; pyridoxine, 0.9%; nicotinic acid, 8.82%; folic acid, 0.22%; vitamin B12, 0.001%; pantothenic acid, 3.53%; menadione, 0.2%; ascorbic acid, 33.07%; vitamin A, 4,409,200 (IU)/kg; vitamin D3, 2,204,600 (IU)/kg; vitamin E, 66.138 (IU)/kg; ethoxyquin, 0.66%.

Appendix Table 11. Land requirement for a 10-water-acre freshwater/shrimp farm, hill area of Mississippi, 1991.

Item	Acres
Production ponds	10.00
Storage pond	8.40
Levees	4.49
Service	1.00
Miscellaneous	18.11
Total land requirement	**42.00**

Appendix Table 12. Selected ponds utilized to estimate net revenues for a 10-water-acre freshwater shrimp farm, for alternative management practices, hill area of Mississippi, 1991.

Year	Pond Number	Year	Pond Number	Year	Pond Number	Year	Pond Number
1984	27	1986	29	1988	B34	1989	CAU7
1984	30	1986	34	1988	A38	1989	CAU9
1984	39	1987	A33	1988	B28	1989	B28
1984	7	1987	A35	1988	CAU10	1989	B36
1984	9	1987	B35	1988	CAU8	1989	A34
1985	35	1987	B34	1988	CAU5	1989	B34
1985	36	1987	B38	1988	CAU7	1989	B37
1985	29	1987	A27	1989	A31	1989	CAU10
1985	32	1987	B27	1989	A35	1990	A31
1985	37	1987	A36	1989	B32	1990	B34
1985	40	1987	A38	1989	A36	1990	B33
1985	28	1987	A32	1989	A28	1990	B37
1985	30	1988	A31	1989	A33	1990	A34
1985	38	1988	B32	1989	B31	1990	A35
1985	39	1988	CAU6	1989	CAU5	1990	A37
1985	27	1988	CAU9	1989	CAU8	1990	B36
1985	33	1988	A32	1989	A32	1990	A32
1986	28	1988	A35	1989	A38	1990	B38
1986	36	1988	A33	1989	B35	1990	A36
1986	30	1988	A36	1989	A29	1990	B35
1986	35	1988	B37	1989	A37	1990	A33
1986	25	1988	B28	1989	B30		

Appendix Table 13. Weight-dependent prices assumed for individual freshwater shrimp seed stock (juveniles)[1].

Weight	Price
(grams)	($)
0.03	0.011
0.10	0.015
0.14	0.017
0.15	0.018
0.16	0.019
0.17	0.019
0.21	0.022
0.22	0.022
0.24	0.023
0.25	0.024
0.30	0.027
0.33	0.029
0.40	0.033
0.50	0.039
0.52	0.040
0.75	0.054
1.07	0.073

[1] Prices were estimated from studies completed by Smith (1990) and Leventos (1986).

0.03 gram = 1 ounce

Appendix Table 14. Five-year average ex-vessel prices of headless marine shrimp by count category for the northern Gulf of Mexico during July, August, September, and October 1986-1990.

Tail count (number/lb)	Price ($/lb)
< 16	6.98
16-20	6.09
21-25	5.10
26-30	4.32
31-35	3.63
36-40	3.15
41-50	2.75
51-60	2.49
> 60	2.35

Source: U.S.D.C., Shrimp Statistics Report, various issues.

Appendix Table 16. Number of units of equipment and other input components required for a 10-water-acre freshwater shrimp farm, hill area of Mississippi, 1991.

Item/Units	Number required
Land, acre	42.00
Earth moving, cu yd	31,199.00
Concrete, cu ft	94.04
Gravel, cu yd	126.00
Cinder block	260.00
Tractor, 35 hp	.50
Truck, 3/4 ton, 4x4	.25
Clipper, 5 ft	.50
Service building, 20x40 ft	.50
Farm/shop equipment	.50
Feeder, 500 lbs	1.00
Feed bin, 4-ton	1.00
Boat, motor, and trailer	1.00
Oxygen meter	1.00
Oxygen probe	1.00
Oxygen cable, 25 feet	1.00
Oxygen meter membrane & KCL kit	1.00
Emergency oxygen kit	1.00
Harvest basket	1.00
Miscellaneous equipment	10.00
Test kits:	
Alkalinity	1.00
Ammonia	1.00
Nitrate	1.00
Nitrite	1.00
pH	1.00
Electric floating paddlewheels	5.00
PTO-driven paddlewheel	1.00
Seine, 1-in mesh, 6x100 ft	1.00
Vegetative covering, acre	4.49

Appendix Table 15. Estimated piping and fixtures investment requirements for a 10-water-acre freshwater shrimp farm, hill area of Mississippi, 1991.

Item	Quantity	Unit	Price ($)	Total ($)
6-inch schedule 40 pvc pipe	70	ft	2.27	158.90
8-inch schedule 40 pvc pipe	1,460	ft	3.53	5,153.80
8-inch schedule 80 pvc pipe	80	ft	9.41	752.80
10-inch schedule 40 pvc pipe	300	ft	7.54	2,262.00
45° elbow for 8-inch pvc pipe (schedule 80)	2	each	111.60	223.20
90° elbow for 6-inch pvc pipe (schedule 40)	5	each	30.26	151.30
8-inch Tee's (schedule 80)	4	each	116.40	665.60
8-inch alfalfa line	5	each	78.30	391.50
10-inch line gate	5	each	550.05	2,750.25
6-inch female threaded coupling (connection)	5	each	19.90	99.50
6-inch male threaded coupling (connection)	5	each	13.46	67.30
6-inch schedule 40 pvc pipe (drain pipe)	330	ft	2.27	749.10
Total Cost				**13,425.00**[1]

[1] Rounded to the nearest fifth.

Appendix Table 17. Prices of other selected inputs used in producing freshwater shrimp, hill area of Mississippi, 1991.

Item	Unit	Price ($)
Land	Acre	600.00
Earthmoving	Cubic yard	0.80
Concrete	Cubic feet	1.76
Gravel[1]	Cubic yard	9.72
Cinder blocks[2]	Each	2.00
Test Kits:		
Alkalinity	Each	16.95
Ammonia	Each	11.78
Nitrate	Each	9.75
Nitrite	Each	9.66
pH measurement	Each	9.66
Diesel fuel	Gallon	.81
Gasoline	Gallon	1.16
Electricity	Kwh	.063
Pelleted feed (25% protein)	Ton	234.00
Vegetative cover:		
Establishment	Acre	91.72
Maintenance	Acre	99.06

[1] Includes delivery cost (within 20 mile radius).

[2] Includes construction costs.

Appendix Table 19. Estimated annual energy cost for a 10 water-acre shrimp farm by activity, hill area of Mississippi, 1991.

Activity	Fuel Cost
	($)
Clipping	36
Feeding	248
Outboard Motor	13
PTO-driven paddlewheel	620
Transportation–	218
Electric floating paddlewheels±	305
Total energy cost	**1,440**

– Transportation expenses for truck were calculated at a cost of 1.16 dollars per gallon of gasoline at a mileage of 20 miles per gallon, assuming 15,000 miles per year.

± Based on the maximum amount of electric paddlewheel aeration (10 hours per day) at 85 percent efficiency rate.

Appendix Table 18. Cost, estimated economic life, and other selected data for equipment and facilities for a 10-water-acre freshwater shrimp farm, hill area of Mississippi, 1991.

Item	New cost	Repairs as a % of new cost	Est. Life	Average Investment	Annual Deprec.	Interest on average investment at 11%	Annual repairs & Maint.
	($)	(%)	(yr)	($)	($)	($)	($)
Tractor, 35 hp	14,000	75	12	7,000	1,167	770	875
Truck, 3/4-ton, 4x4	15,100	35	4	7,550	3,775	831	1,321
Clipper, 5 ft	776	20	6	388	129	43	26
Service building, 20x40 ft	3,500	50	20	1,750	175	193	88
Farm/shop equipment	2,000	50	5	1,000	400	110	200
Feeder, 500 lb tractor pull	1,650	75	5	825	330	91	248
Feed bin, 4-ton	850	10	20	425	43	47	4
Oxygen meter	545	202	10	273	55	30	110
Oxygen meter probe	193	55	2	97	97	11	53
Oxygen meter cable, 25-ft	155	300	3	78	52	9	155
Oxygen meter membrane & KCL kit	12	25	1	12	12	1	3
Emergency oxygen kit	61	100	2	31	31	3	31
PTO-driven paddlewheel, 10-in	1,700	25	10	850	170	94	43
Electric floating paddlewheels (1hp)	910	50	10	455	91	50	46
Miscellaneous equipment[a]	100	25	5	50	20	6	5
Chemical boat (14-ft, 38-in bottom)	700	75	10	350	70	39	53
Outboard motor, 3.3 - 3.5 hp	510	50	5	255	102	28	51
Boat trailer (12-in wheels)	600	40	10	300	60	33	24
Seine, 1 in. mesh, 6 x 100 ft	170	25	5	85	34	9	9
Harvesting basket	250	10	10	125	25	14	3

[a] Per water surface acre.

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