Relationships among Stocking Density, Survival and Yield in Ponds Affected by the Taura Syndrome during Wet and Dry Seasons in Honduras

Work Plan 7, Honduras Study 3C

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Introduction

Relationships among density, mean size, survival and yields of semi-intensively cultured shrimp are not well understood. Shrimp size at harvest may not be proportional to density, and survival of stocked shrimp usually decreases with increasing density. Yields are usually linearly related to survival, but survival is unrelated to treatment. Results of management strategies, especially those related to feeding and growth, are not highly predictable. A better understanding is needed to increase production efficiencies and lower nutrient effluents.

The original objective of this study was to evaluate the relationships among stocking density, mean shrimp size, survival and yield. However, the Taura Syndrome (TS) struck the area after stock-out of the wet season study, severely lowering survivals. Producers naturally became interested in the effect of stocking rate and season on survival under TS conditions. Our study results were therefore appropriated to that end.

Materials and Methods

A completely randomized design was used to test 4 stocking densities of *Penaeus vannamei* in earthen ponds during wet and dry seasons of the year. Juvenile shrimp were stocked at 6, 8, 10, or 12/m^2. The design was tested on two farms during the wet season and on three farms during the dry season. Each treatment was replicated 4 times during the wet season, and 3 times during the dry season on Farm A. On Farm B, each treatment was replicated 2 times during the wet season and only once during the dry season. Farm C stocked one pond at each stocking density.

Shrimp stocked in ponds of all farms had been raised in nurseries from the same source of hatchery-spawned postlarvae. An extra 15% of stocking rate were added to ponds to account for stocking mortality.

During the wet season, commercial grow-out ponds on both farms were used. These ranged from 17 to 36 ha in area. During the dry season, nursery ponds ranging in size from 0.7 to 1.4 ha were stocked. Because of their large size, all wet season ponds could not be stocked simultaneously. Rather, one replicate pond of each treatment was stocked simultaneously in blocks over a period of several weeks. During the dry season, ponds on each farm were stocked simultaneously. Wet season ponds were stocked during 13 June to 20 July 1994 on Farm A, and during 19 July to 9 August 1994 on Farm B. Farm A ponds were harvested after 92 to 107 d, and Farm B ponds were harvested after 95 to 101 d. Dry season ponds were stocked between 27 December 1994 and 12 January 1995 and harvested after 95 to 99 d.

Shrimp were fed an ALCON 20% protein diet based on 75% of feeding tables that decreased the feeding rate as mean shrimp weight increased. The rate adjustment was generally described by the following equation: $Y = 11.74 - 6.79 \text{ Log}_{10}X$, where Y = % of shrimp biomass, X = mean shrimp weight. The feeding tables assumed a weekly mortality of 1.2% during the wet season and 4.2% during the dry season. Feeding rates were calculated for each pond separately during the wet season, and equally for all ponds of a given treatment during the dry season.

Table 1. Production of *Penaeus vannamei* stocked at 4 rates on each of two farms during the wet, and three farms during the dry season of the year in southern Honduras.

Farm	Number of ponds	Stocking density (No./m^2)	Total production (kg/ha)	Mean weight (g)	Survival (%)	Feed conversion (Feed/yield)	Net income ($/ha)
				Wet season			
	4	6	502	16.7	50.5	2.13	3603
	4	8	616	13.7	57	2.38	3795
A	4	10	658	13.9	49.5	2.69	3879
	4	12	757	11.9	52.5	2.55	3986
		Mean	633	14.1	52.4	2.43	3816
	2	6	488	17	45.8	2.28	3404
	2	8	595	17.4	42	2.65	4408
B	2	10	699	16.6	42.3	2.51	4664
	2	12	855	15.7	44.5	2.62	5522
		Mean	659	16.7	43.6	2.51	4500
				Dry season			
	3	6	290	8.8	46	2.67	1169
	3	8	270	8.6	40	3.61	801
A	3	10	334	7.6	43	3.8	53
	3	12	315	9	29	4.76	598
		Mean	302	8.5	39.5	3.71	655
	1	6	303	7.3	69	2.29	611
	1	8	335	6.8	62	2.8	339
B	1	10	427	6.7	64	2.75	339
	1	12	523	5.4	81	2.51	321
		Mean	397	6.6	69	2.59	402
	1	6	253	7.4	57	1.34	340
	1	8	202	6.5	39	2.09	-61
C	1	10	303	6.2	49	2.29	-189
	1	12	238	4.9	41	2.01	-514
		Mean	249	6.3	46.5	1.93	-106

Similar feeding rates were used on the different farms, but actual amounts fed on each farm were calculated separately. Shrimp were sampled by cast net each week from a pre-determined sampling grid for each pond. Feeding rates were adjusted based on weekly shrimp samples. Daily feed was equally divided into morning and afternoon rations (morning and afternoon).

Water was generally exchanged according to the following schedule: the first 2 to 4 weeks no exchange and thereafter, daily exchange at 5% of pond volume. During the dry season, Farm A exchanged water at 5% of pond volume once a week, instead of daily. Water was exchanged by first draining, and then by refilling. Record was kept of exchange frequency and volume.

A limited economic analysis was performed on the data. Variable costs were the sum of seed and feed costs. Total revenue was calculated by pond from the total harvested weight and the price received at the packing plant. Prices varied greatly by shrimp size, so calculations employed a price based on the mean harvested shrimp weight per pond. Juvenile seed and feed cost $9.23/1000 and $0.24/kg, respectively. Shrimp prices per kg of tails ranged from $9.25 to $7.14, decreasing as the mean size decreased.

Water quality variables were monitored to form nutrient budgets for ponds with different stocking rates. Water was analyzed for total settleable solids (American Public Health Association (APHA) et al., 1992), nitrate nitrogen by cadmium column reduction to nitrite (Parsons et al., 1992), total ammonia nitrogen (Parsons et al., 1992), filterable reactive phosphate (Grasshoff et al., 1983), chlorophyll *a* (Parsons et al., 1992), total alkalinity by titration to 4.5 pH endpoint, salinity, and 2-d and 7-d BOD at ambient temperature. Total nitrogen and total phosphorus were determined by nitrate and phosphate analysis, respectively, after simultaneous persulfate oxidation (Grasshoff et al., 1983). Organic phosphorus was calculated from the difference of total phosphorus and filterable reactive phosphate. Dissolved inorganic nitrogen (DIN) was the sum of nitrate, nitrite and total ammonia nitrogen (TAN), and organic nitrogen was the difference of total nitrogen and DIN.

Table 2. Mean production of *Penaeus vannamei* during wet and dry seasons of 1992 to 1994 . Results are means of 3 to 4 replications. Data were collected from the same farm, using 100% hatchery reared animals.

Year	Stocking density (No./m^2)	Production (kg/ha)	Mean weight (g)	Survival (%)	Harvest density (No./m^2)
		Wet Season			
1992	5	1430	24.8	98	4.9
1992	10	2100	21.5	87	8.7
1993	7.5	1258	18.1	96	7.2
1994	6	488	17.0	46	2.8
1994	8	595	17.4	42	3.4
1994	10	698	16.6	42	4.2
1994	12	855	15.7	45	5.4
		Dry Season			
1992	5	419	9.6	89	4.5
1992	10	597	9.7	62	6.2
1993	7.5	360	6.7	74	5.6
1994-5	6	303	7.3	69	4.1
1994-5	8	335	6.8	62	5.0
1994-5	10	427	6.7	64	6.4
1994-5	12	523	5.4	81	9.7

Data were analyzed by ANOVA and linear regression (Haycock et al., 1992). Except where indicated, data from both farms were pooled. Analyses were separate by season. Differences were declared significant at alpha = 0.05.

Results

The Taura Syndrome did not intensify its effects on shrimp during the dry, cool season, as anticipated. Mean wet and dry season survival for pooled data on Farms A and B was 44% and 69%, respectively (Table 1). Survivals during wet and dry seasons would normally have been about 94% and 75%, respectively (Table 2).

Wet season

There was no significant correlation between shrimp stocking density and survival when farm data were pooled (Figure 1). Survival for both farms fell within the same range. Production increased linearly with an increase in stocking density (Figure 2).

Mean shrimp size decreased significantly, with an increase in stocking density on Farm A, but not on Farm B (Figure 3). Net income significantly increased with stocking density on Farm B, but not on Farm A (Figure 4).

Dry season

There was no significant correlation between stocking density and survival (Figure 1). Mean survival differences among farms were greatest at the highest density (Figure 1), where mean survivals at Farms A (39.5%) and C (46.5%) were notably lower than mean survival at Farm B (69%).

Shrimp production increased linearly with an increase in stocking density (Figure 2) when farm data were pooled. However, analysis by farm indicated that the correlation was significant only for Farm B. Production at Farms A and C indicated insignificant change with increasing density.

Mean shrimp size significantly decreased with an increase in stocking density on Farms B and C, but not on Farm A (Figure 3). Net income was not significantly correlated with stocking density at Farms A and B, but significantly decreased with density on Farm C (Figure 4).

Water quality

Analyses of water quality and nutrient budgets are not complete. However, preliminary data indicate that, with minor exceptions, increasing the stocking density from 6 to 12/m^2 had insignificant effect on the export of nutrients from ponds.

Discussion

The Taura Syndrome reduced shrimp survival below normal at all farms during both growing seasons. Mean survivals during the past two years of work in Honduras (Teichert-Coddington and Rodriguez, 1994; Teichert-Coddington and Rodriguez, 1995) ranged from 87 to 98% during the wet seasons, and from 62 to 89% during the dry seasons (Table 2). Mean survivals during the current experiment (Table 1) were almost 50% and 30% lower during the wet and dry seasons, respectively. The incidence of Taura was expected to increase with stocking density, because of the increased frequency of contact among animals. Survival normally decreases at higher densities, even without TS (Teichert-Coddington and Rodriguez, 1995). Results of these experiments indicated no abnormal survival because of TS during either season on any farm. It is possible that stocking rates exceeding 12/m^2 could result in higher mortalities, but such densities are not used in semi-intensive systems characteristic of Honduras.

Seasonal production differences were large as always (Teichert-Coddington et al., 1994). Mean dry season yield for Farms A and B was 349 kg/ha, about half of wet season yield (646 kg/ha). Dry season yield was about normal, but wet season yield was about half of normal. There are concerns that TS affects growth of survivors, in addition to inducing mortality of juveniles. Lesions can be found on adult shrimp, indicating that the disease is present, but subacute. However, the low yields in the current experiment were more likely related to the abnormally low survivals from the Taura Syndrome. Yield reductions in past experiments have been correlated with low survival, probably because growth of surviving animals didn't increase enough to compensate for loss in numbers.

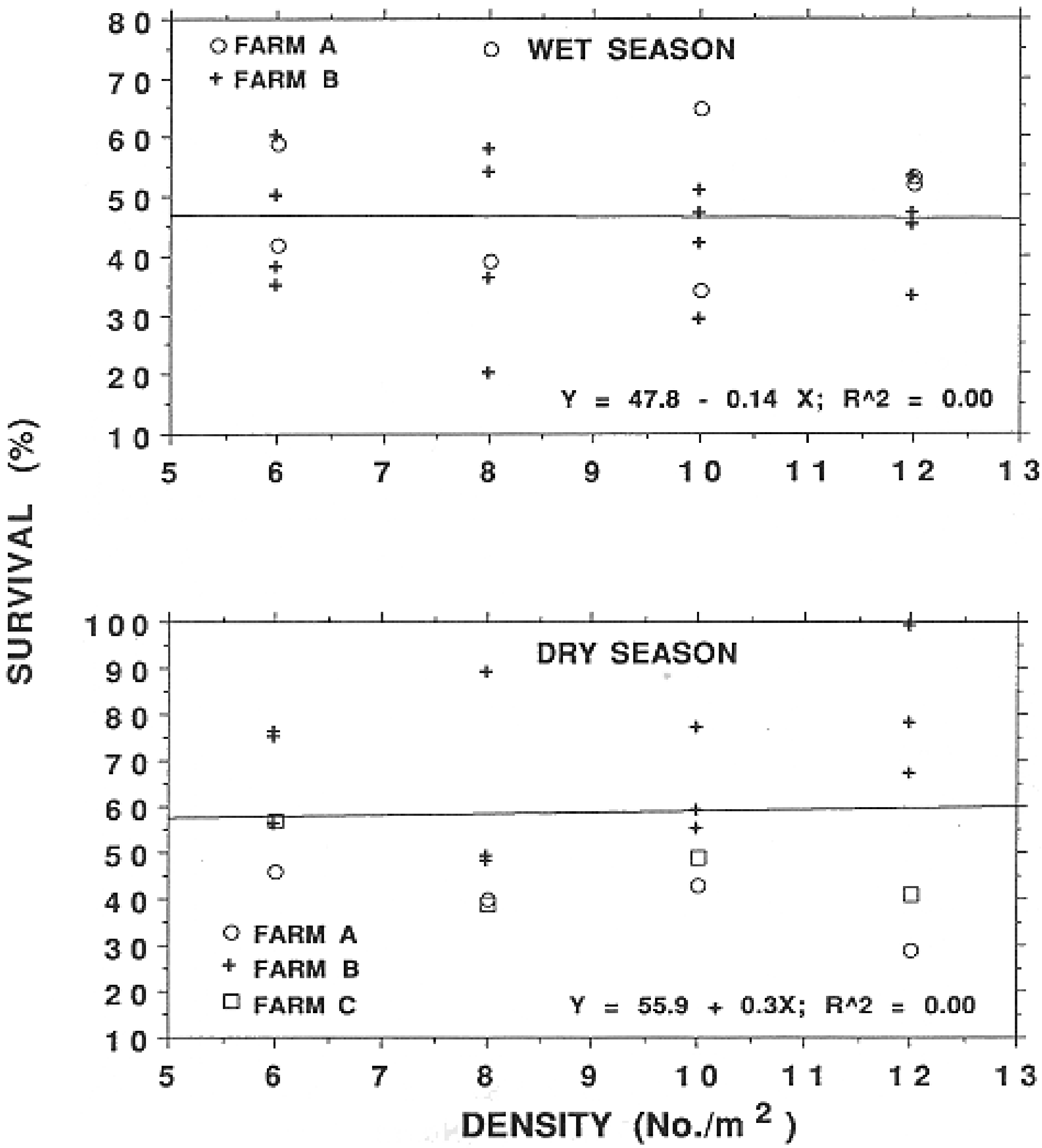

Figure 1. Relationship between shrimp survival and stocking density on different farms and during wet and dry seasons in southern Honduras.

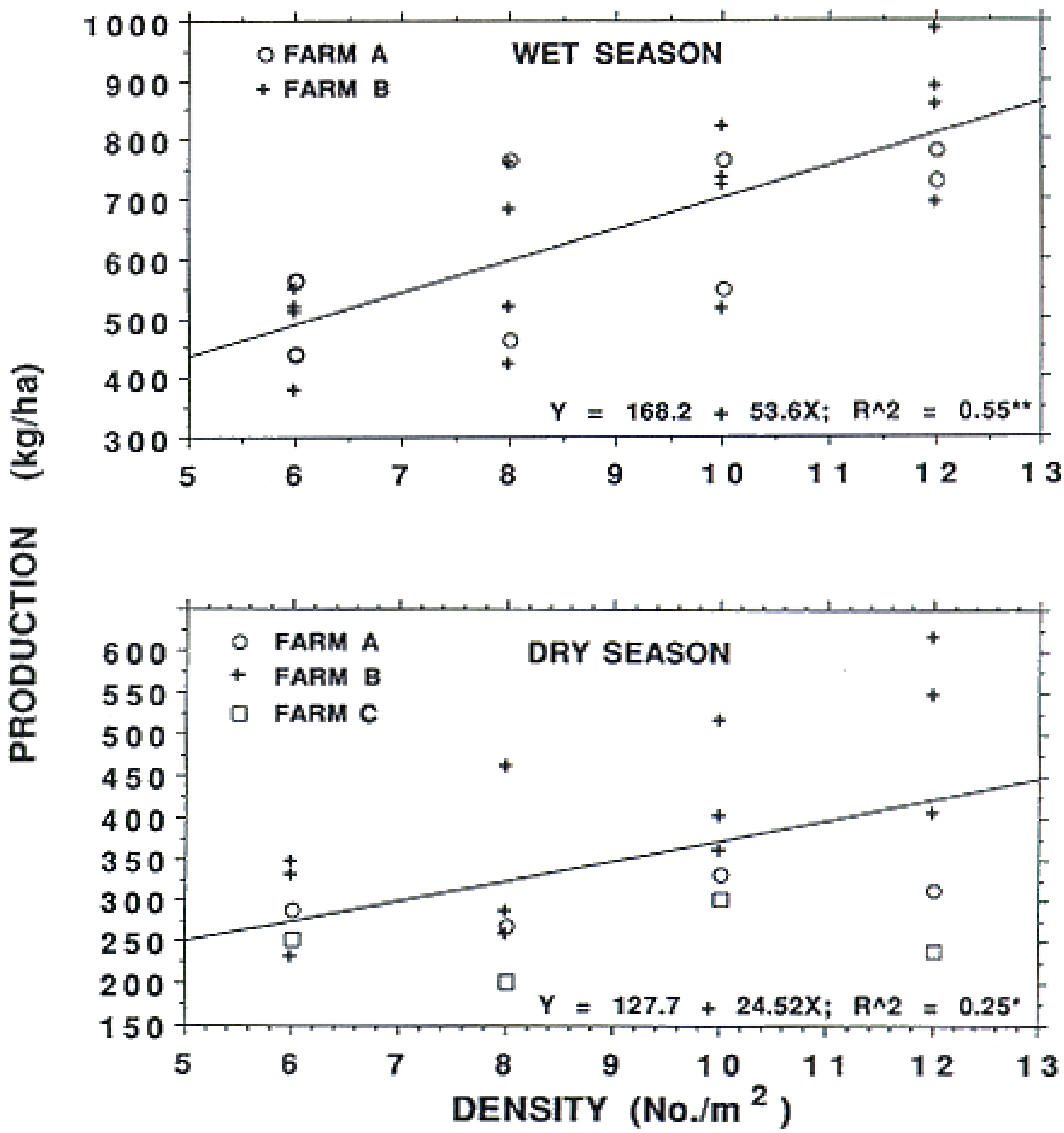

Figure 2. Relationship between shrimp production and stocking density on different farms and during wet and dry seasons in southern Honduras [* significant ($P < 0.05$); ** very significant ($P < 0.01$)].

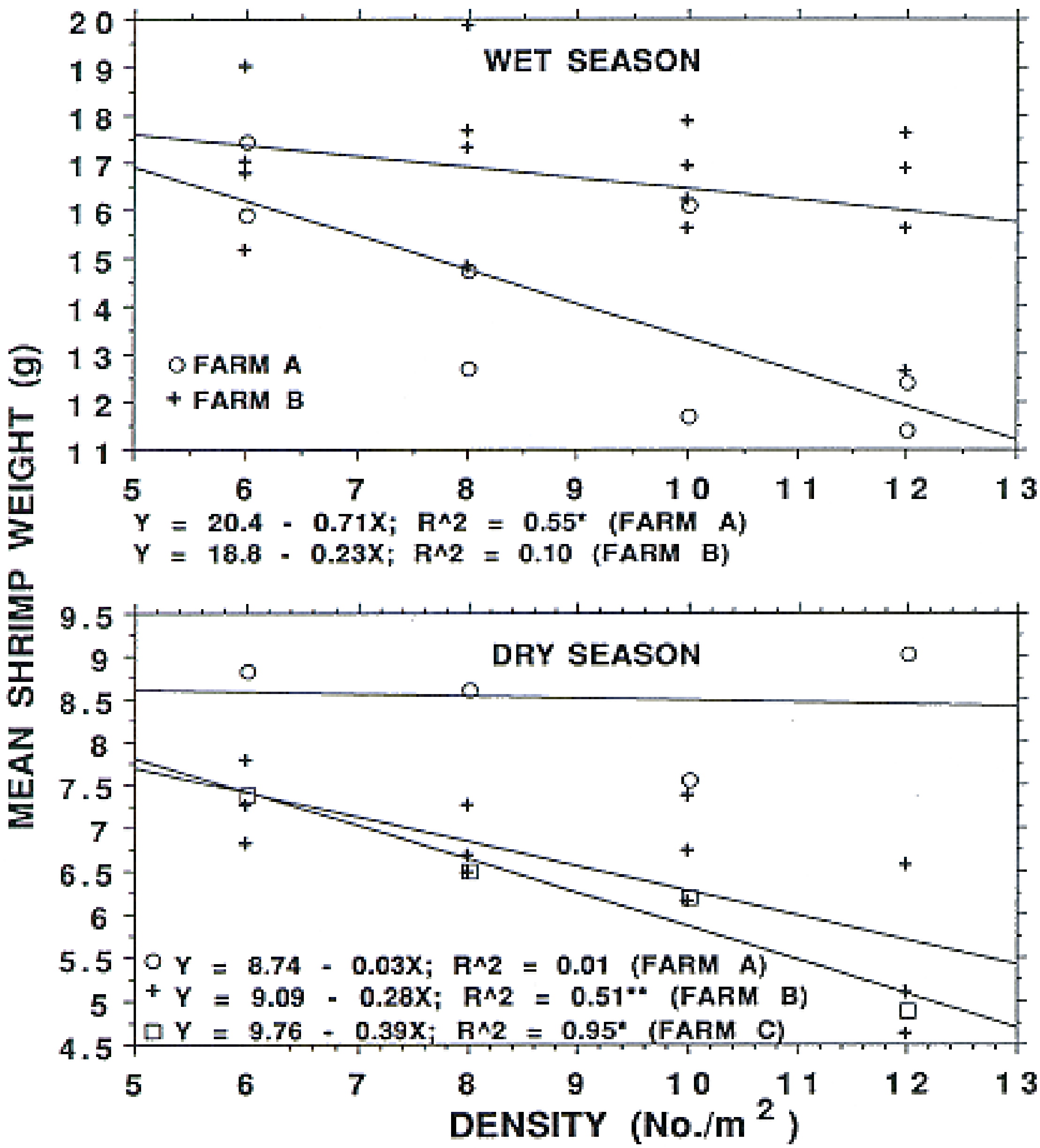

Figure 3. Relationship between mean shrimp weight and stocking density on different farms and during wet and dry seasons in southern Honduras.

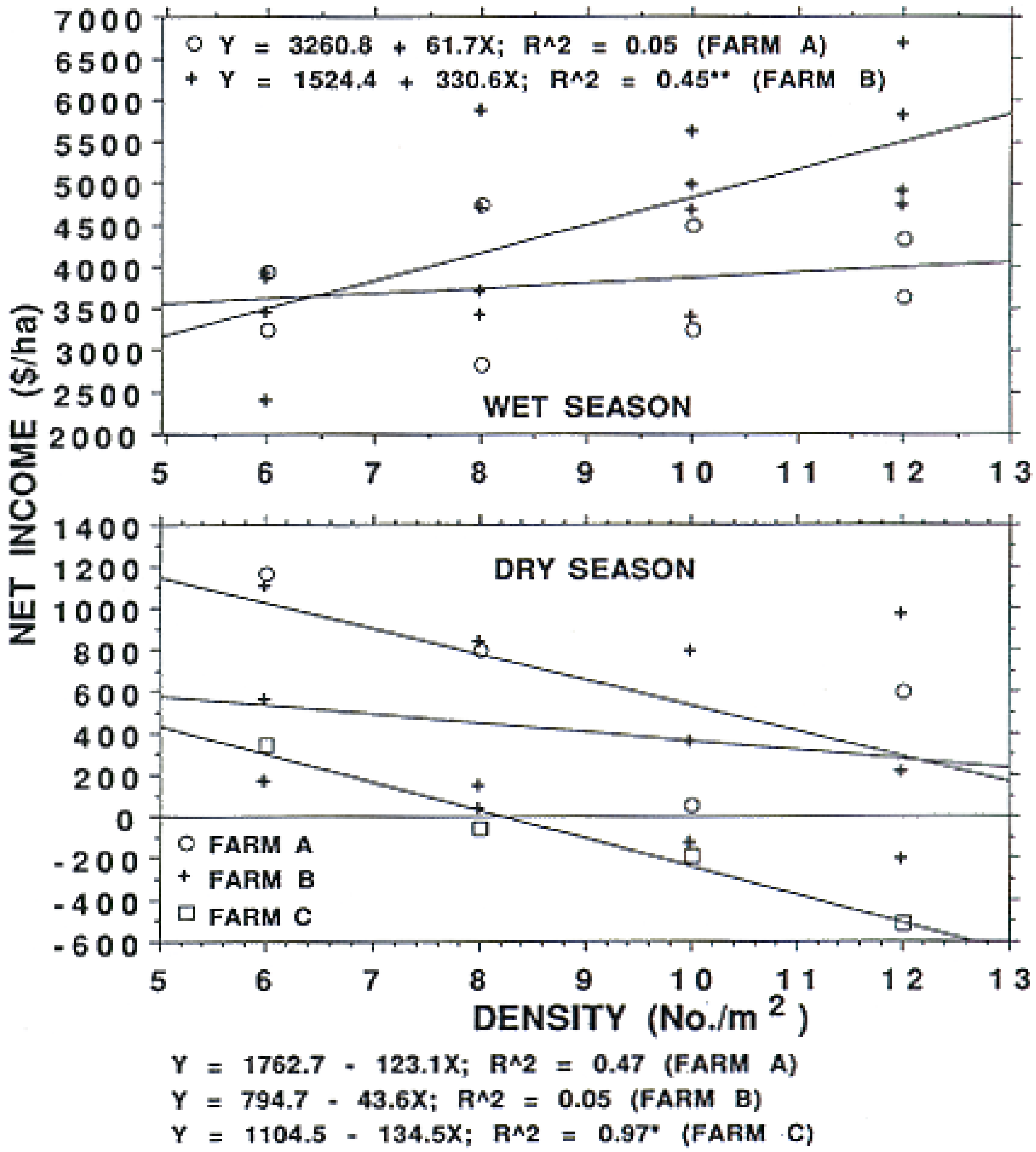

Figure 4. Relationship between net income and stocking density on different farms and during wet and dry seasons in southern Honduras [* significant ($P < 0.05$); ** very significant ($P < 0.01$)].

An objective of this experiment was to evaluate the effect of stocking rate on mean harvest size of shrimp, because growth reduction commonly occurs in cultured animals when stocking rates are increased. Past experiments (Teichert-Coddington and Rodriguez, 1995) indicated that stocking rate had only slight impact on wet season shrimp size and no impact on dry season shrimp size. In the current experiment, stocking rate was only sometimes related to mean harvest size. The results were likely affected by TS, but survivals, albeit abnormally low, were similar across all stocking densities. During the wet season, mean weight of shrimp at Farm A, but not at Farm B, decreased about 0.7 g per animal stocked above $6/m^2$. A dry season reduction of 0.3 to 0.4 g per stocked animal occurred at Farms B and C, but not at Farm A. These data indicate that predictions of harvest size based on stocking rate can not be confidently made. Results are changeable by season and farm. Much more research needs to be done to make management of stocking rates for a particular harvest size more predictable.

Income is related to both biomass and shrimp size, because the price per unit weight of shrimp increases with size. The relationships among stocking rate, yields and harvested mean shrimp size is economically important. On Farm B where most replication of treatments occurred, net income increased with density during the wet season because production increased without a decrease in harvest size. However, dry season net income remained unchanged with increased density despite an increase in production, because mean shrimp size decreased. The loss in size economically compensated the increase in production. Farm A net income showed less correlation to density increase during the wet season, despite increasing production, because mean shrimp size decreased with density. Farm C net income decreased with increased density during the dry season, because mean size decreased while production remained unchanged.

There are strong seasonal effects on both production and net income. The seasonal effects on production are compounded by estuarine eutrophication during the dry season because of reduced estuarine exchange with the Gulf of Fonseca (Teichert-Coddington, 1995). The only way to combat the eutrophication is to reduce farm nutrient effluents to the estuaries. The following processes have been demonstrated during the dry season: shrimp yields decrease drastically; net income decreases with increased stocking density; estuarine water quality significantly degrades. It follows that dry season management should be different from wet season management. Dry season stocking rates might better be minimized to reduce nutrient inputs and outputs, variable costs and economic risk.

The results from this study suggest some management guidelines for ponds affected with TS. Stocking rates can be safely increased to compensate for poor survival, although the cost of additional seed will obviously reduce profits. During the wet season, each farm should determine the number of shrimp that need to be harvested per unit area to be profitable, and over-stock with sufficient animals to account for previously estimated survivals. Mean harvest weight can be manipulated by duration of production cycle. During the dry season, ponds probably should be managed with minimal inputs. Stocking rates should be closely analyzed, because of reasons given above, and because increased seed costs will signify a greater proportion of total variable costs.

Acknowledgments

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Literature Cited

American Public Health Association (APHA), American Water Works Association and Water Pollution Control Federation. 1992. Standard methods for the examination of water and wastewater. American Public Health Association, Washington, D.C., 874 pp.

Grasshoff, K., Ehrhardt, M. and Kremling, K. 1983. Methods of seawater analysis. Verlag Chemie, 419 pp.

Haycock, K., Roth, J., Gagnon, J., Finzer, W. R. and Soper, C. 1992. StatView 4.0. Abacus Concepts, Inc., Berkeley, CA, U.S.A.

Parsons, T. R., Maita, Y. and Lalli, C. M. 1992. A manual of chemical and biological methods for seawater analysis. Pergamon Press, New York, NY, U.S.A., 173 pp.

Teichert-Coddington, D. R. 1995. Estuarine water quality and sustainable shrimp culture in Honduras. In: S. Hopkins and C. Browdy (Eds.), Proceedings of the Special Session on Shrimp Farming, Aquaculture '95, San Diego, CA, U.S.A., World Aquaculture Society, Baton Rouge, LA, U.S.A.

Teichert-Coddington, D. R. and Rodriguez, R. 1994. Inorganic fertilization and feed reduction in commercial production of *Penaeus vannamei* during wet and dry Seasons in Honduras. In: H. S. Egna, J. Bowman, B. Goetze and N. Weidner (Eds.), Twelfth annual technical report 1994, Pond Dynamics/Aquaculture Collaborative Research Program, International Research & Development, Oregon State University, Corvallis, OR; 209.

Teichert-Coddington, D. R. and Rodriguez, R. 1995. Semi-intensive commercial grow-out of *Penaeus vannamei* fed diets containing differing levels of crude protein during wet and dry seasons in Honduras. Journal of the World Aquaculture Society, 26(1): 72-79.

Teichert-Coddington, D. R., Rodriguez, R. and Toyofuku, W. 1994. Causes of cyclical variation in Honduran shrimp production. World Aquaculture, 25(1): 57-61.