Project Number: 1640-512-5261

Project Title: Improved Feed Management for Shrimp Use Automation Feeders.

Organization: Auburn University

Principal Investigator Name: D. Allen Davis

Project Status - What key activities were undertaken and what were the key accomplishments during the life of this project? Please use this field to clearly and concisely report on project progress. The information included should reflect quantifiable results (expand upon the KPIs) that can be used to evaluate and measure project success. Technical reports, no longer than 4 pages, may be included in this section.

Project Goal: To develop science-based information on feed management alternatives for the culture of Pacific white shrimp under semi-intensive pond production conditions. Then transfer and promote adaptation by the industry to improve commercial feed management practices and consequently reduce production costs.

Background: Pacific white shrimp (*Litopenaeus vannamei)* are one of the most commonly farmed species in the United States. The cost of labor and the lack of quality observation of the feeding habits of shrimp in a pond setting are two of the major concerns for shrimp farmers and can have major impacts on the profitability of a farm. In order to produce shrimp competitively on the world market, American farmers should explore options for reducing labor costs through automation of feeding and monitoring. Timer feeders have been used successfully to reduce the labor and to increase the number of feedings each day. The grazing nature of shrimp results in improved growth when increasing the number of feedings with the same daily ration. The AQ1 feeding system improves on the timer feeder by incorporating a hydrophone that can monitor the feeding response each time feed is added to the pond and the computer system will analyze that to determine when and how much to feed. In addition to reducing the labor, this has the potential to improve the use of the feed by only applying feed during periods of active feeding.

Methods: To evaluate the efficacy of four feed management strategies a trial was performed in an outdoor pond system at the Alabama Department of Conservation and Natural Resource Division Claude Peteet Mariculture Center, Gulf Shores, AL. Post larvae were obtained on May 11th and transported from the Florida hatchery to our facility. Over the nursery period they were monitored for mortality. Two nursery tanks were found to have some mortality after stocking which would indicate weak larvae or stress occurring during the shipping process. The PLs were cultured under typical conditions with normal water quality parameters being observed. At the conclusion of the two-week nursery period we harvested the nursery tanks, quantified juvenile shrimp and distributed them to the culture ponds. We found very poor survival in the nursery system which in turn has resulted in lower than planed densities in the ponds. Thus, we were only able to stock 17 shrimp per meter or about ½ the planned density. Albeit, this is a lower density, this was an adequate density to complete the research and demonstrate the applicability of the feed management.

The ponds used for the production trial were approximately 0.1 ha in surface area and lined with 1.52 mm high-density polyethylene lining with a 25 cm layer of sandy-loam soil on the bottom. All ponds were aerated with a 1hp Aquarian™ (Air-O-Lator, Kansas City, MO, USA) and a 1 or 2 hp Aire-O_2 (Aire-O_2, Aeration Industries International, Inc. Minneapolis, MN, USA) as backup and/or supplemental aeration to maintain DO above 3 mg/L. Ponds were filled using brackish water from the (11-13 ppt), filtered through a 250 um sock to prevent predators, from the Intracoastal Canal between Mobile and Perdido Bay, Alabama and water exchange was minimized. Inorganic liquid fertilizers (1697 ml of 32-0-0 and 303 ml of 10-34-0) were added to the pond two weeks before stocking and reapplied at half the rate one and a half weeks later. Ponds that had a Sechi disk reading of more than 50 cm at the time of stocking received another treatment at half of the original strength.

The four treatments used to evaluate the potential for automation were a Standard Feeding Protocol (SFP), SFP that included a 15% increase in daily ration for the final 8 weeks of growth, timer feeding using the same ration as the SFP, and the AQ1 SF200 acoustic feeding system (AQ1 Systems, Tasmania, Australia) fed ad libitum using a hydrophone and computer software to monitor the feeding activity. The SFP was calculated based on an expected weight gain of 1.3g/wk, a feed conversion of 1.2, and a survival of 75% during the culture period. The SFP and SFP+15 treatments were fed by hand twice daily (0800 and 1600 h). The solar timer feeders (FIAP, Ursensollen, Germany) treatment received feed 6 times daily (0800, 1000, 1200, 1400, 1600, and 1800 h). Timer and AQ1 treatments were non-randomly assigned to ponds due to constraints to the power supply and the SFP and SFP+15 treatments were randomly assigned to the remaining ponds. Shrimp were fed with the high soy sinking feed (35% CP and 7% Lipid) manufactured by Zeigler, Inc. (Gardners, PA, USA), proximate composition Table 1.

Ponds were monitored at least three times a day (dissolved oxygen, temperature, salinity, and pH), just before sunrise (0500 - 0530h), during the day (1400 – 1430 h), and at sunset (1900 – 2000 h) using an YSI ProPlus meter (Yellow Spring Instrument Co., Yellow Springs, OH, USA). Secchi disk readings and total ammonia nitrogen (TAN) were monitored on a weekly basis. Water samples were taken in the morning at the bank and TAN was determined using an Orion ammonia electrode probe (Thermo Fisher Scientific Inc., Waltham, MA, USA). Water quality samples were also analyzed at weeks 0, 4, and weekly from 8-16 for the following parameters: chlorophyll *a*, total ammonia nitrogen, nitrite-nitrogen, nitrate-nitrogen, total nitrogen, total phosphorus, soluble reactive phosphorus, total suspended solids, total suspended volatile solids, turbidity, conductivity, salinity, and biological oxygen demand. Samples were collected and shipped overnight to Auburn, Alabama for off-site analysis. Shrimp sampling was conducted weekly using two 5-foot cast nets (monofilament net, 1.22 m radius and 0.95 cm opening). Approximately 60 shrimp in each pond were collected to determine the average weight and as a check on the health of shrimp.

The shrimp were harvested over two days at the end of the 16 week culture period. The ponds were drained by about two thirds before the pond was due to be harvested and an aerator placed above the catch basin to ensure adequate DO levels. The remaining water was drained and the shrimp were pumped out of the catch basin using a hydraulic fish pump equipped with a 25 cm diameter suction pipe (Aqualife-Life pump, Magic Valley Heli-arc and Manufacturing, Twin Falls, ID, USA). The pump was placed in the catch basin and shrimp pumped, de-watered, and collected into a hauling truck. Shrimp were rinsed, weighed in bulk and 150 were randomly selected to measure individual weights and size distribution. The value of the shrimp was estimated using the size distribution and the local price for each size class. One replicate from the Timer treatment was excluded due to a low DO induced mortality. Statistical analyses were conducted using SAS 9.3 (SAS Institute, Cary, NC, USA). Data were analyzed using one-way analysis of variance to determine if significant differences existed among treatments, followed by the Student-Neuman-Keuls multiple range test to determine the differences between treatment means. Significant differences among treatments were determined at a probability level of $P < 0.05$.

Results:

Post larvae were obtained from a commercial supplier and ran through our standard nursery operation. Unfortunately, at the conclusion of the nursery period survival of PLs was exceptionally poor. After talking with several commercial producers this seemed to be a common problem. Due to the poor survival of the PLs we could not reach our targeted stocking density but were able to stock all ponds at 17.2 shrimp/m^2.

Over the 16-week culture period, water conditions were monitored and maintained in the typical ranges for pond production of *L. vannamei*. The water quality parameters were suitable for shrimp growth and health. The detailed water quality for treatments classified by treatment are summarized in Table 2 and 3. A summary of the production data for the four treatments is displayed in Table 4. The AQ1 acoustic feeder ponds outperformed or were significantly different than all other treatments for all parameters that were analyzed. The timer feed ponds also outperformed or were significantly different than the two hand fed ponds for all parameters. The two hand feeding treatments, SFP and SFP+15, were not significantly different for any parameters.

The economic data is summarized in Table 5 and also shows a significant advantage to the AQ1 treatment for value and partial income. Partial return was determined by subtracting the calculated feed cost (using US $0.96/kg of feed) from the calculated production receipts. While the feed cost was higher in the AQ1 treatment, the overall yield and the larger size of the shrimp increased the value and production receipts enough to offset the cost. The performance of the timer feeding and the AQ1 feeding system show promise for farmers who are looking to decrease the labor involved in feeding pond raised shrimp. A more complete economic evaluation is being worked on at this time but not included here, that will include a full economic analysis that does include the initial cost of equipment and setting up feeders which includes locally available equipment and labor. These costs could dictate what level of technology the farmers can afford to convert to and to what degree they will automate. Basic timer feeders (6x per day) clearly increased the growth of shrimp fed an equivalent ration and will improve the overall performance of the shrimp. As the initial investment is lower they are better for smaller farms that may not have the capital for full AQ1 implementation. Small solar feeders, appropriate for small-medium sized ponds, can be purchased and installed fairly inexpensively and would be a cost effective alternative to those with limited capital to invest. The AQ1 system requires more capital but provides automation for water quality as well as feed management. It is expected that the increased revenue will offset the cost of the equipment but the farmer will have to have considerably more capital to move to the fully automated systems for all ponds on a commercial sized farm.

Table 1 Ingredient and proximate composition of diet manufactured by Zeigler Bros. Inc. (Gardners, PA, USA).

Ingredient	%
Soybean meal	50.00
Wheat	23.10
Poultry by-product meal	8.00
Corn Gluten meal	8.00
Dicalcium phosphate	3.13
Fish Oil Top dress	3.00
Fish Oil Mixer	2.00
Bentonite	1.50
Lecithin	1.00
Vitamin premix	0.12
Mineral premix	0.12
Tiger C	0.02
Copper sulfate	0.01
Protein	37.22
Lipid	7.01
Fiber	2.56
Moisture	10.18
Ash	8.55
Phosphorus	1.20

Table 2. Average (and range) for water quality parameters among different feed management treatments for Pacific white shrimp from 0 to 16 weeks measured on three times daily (before sunrise, midday, and at sunset) using a YSI ProPlus meter.

Parameter	SFP	SFP + 15%	Timer	Acoustic
Morning Salinity (ppt)	11.93	11.71	12.03	11.83
	(6.49-16.39)	(3.13-15.74)	(7.14-15.90)	(9.96-16.6)
Afternoon Salinity (ppt)	11.92	11.70	12.05	11.72
	(8.4-17.58)	(4.90-14.84)	(8.15-16.09)	(0.26-21.13)
Night Salinity (ppt)	11.92	11.70	12.03	11.81
	(9.39-16.33)	(9.91-14.73)	(8.75-15.84)	(9.95-15.09)
Morning Dissolved Oxygen (mg/L)	4.50	4.59	4.60	4.39
	(0.58-8.94)	(1.52-7.13)	(1.92-6.67)	(1.08-13.21)
Afternoon Dissolved Oxygen (mg/L)	9.86	9.07	9.25	9.14
	(3.65-19.41)	(3.34-17.21)	(2.08-16.23)	(3.12-17.33)
Night Dissolved Oxygen (mg/L)	8.81	8.38	8.02	8.00
	(2.75-16.66)	(2.61-15.29)	(1.16-17.07)	(2.09-16.62)
Morning pH	8.02	8.04	7.95	7.98
	(7.35-9.33)	(7.35-9.11)	(7.32-9.18)	(7.38-9.16)
Afternoon pH	9.10	8.97	8.99	8.89
	(7.74-10.17)	(7.70-10.17)	(7.64-10.06)	(7.68-9.87)
Night pH	9.00	8.90	8.84	8.79
	(7.63-10.11)	(7.64-10.15)	(7.73-10.13)	(7.55-10.09)
Morning Temperature (°C)	29.9	30.0	29.9	30.1
	(26.2-32.9)	(26.2-32.7)	(26.3-32.4)	(26.3-32.8)
Afternoon Temperature (°C)	32.2	32.0	32.1	32.1
	(26.6-36.6)	(26.8-36.1)	(26.8-34.8)	(26.8-35.1)
Night Temperature (°C)	32.1	32.1	32.1	32.3
	(26.8-36.1)	(26.9-35.6)	(26.9-34.8)	(27.0-35.3)

Table 3. Average (and range) for water quality parameters among different feed management treatments for Pacific white shrimp from 0 to 16 weeks.

Parameter	SFP	SFP+15%	Timer	Acoustic
Turbidity (NTU)	9.98	7.43	8.92	9.38
	(2.4-29.2)	(1.8-13.8)	(2.8-47.1)	(2.2-46.7)
Salinity (ppt)	10.24	9.88	10.23	9.92
	(7.9-13.5)	(8.2-12.2)	(8.2-13)	(8.3-12.5)
Conductivity (mS/cm)	18.05	17.54	18.11	17.67
	(13.79-23.38)	(14.14-23.41)	(14.39-23.9)	(14.36-24.75)
Chlorophyll *a* (µg/L)	325.76	292.88	267.09	315.08
	(9.68-916.4)	(15.59-942.5)	(14.95-994.7)	(4.35-1748.7)
Total Ammonia Nitrogen (mg/L)	0.298	0.151	0.479	0.634
	(0-3.872)	(0-0.890)	(0-3.660)	(0-3.970)
Nitrite-Nitrogen (mg/L)	0.048	0.007	0.032	0.063
	(0-0.802)	(0-0.082)	(0-0.274)	(0-0.753)
Nitrate-Nitrogen (mg/L)	0.004	0.010	0.012	0.010
	(0-0.130)	(0-0.190)	(0-0.233)	(0-0.215)
Total Nitrogen (mg/L)	4.066	4.562	3.594	4.039
	(0-7.351)	(0-5.461)	(0-6.353)	(0.167-8.671)
Soluble Reactive Phosphorus (mg/L)	0.146	0.255	0.315	0.261
	(0-1.178)	(0-1.342)	(0-2.108)	(0-1.431)
Total Phosphorus (mg/L)	0.666	0.611	0.720	0.824
	(0.192-1.258)	(0.112-1.477)	(0.120-2.108)	(0.105-1.859)
Total Suspended Solids (mg/L)	0.103	0.085	0.084	0.084
	(0.02-0.295)	(0.024-0.242)	(0.027-0.295)	(0.015-0.161)
Total Volatile Suspended Solids (mg/L)	0.075	0.064	0.056	0.060
	(0-0.182)	(0-0.112)	(0-0.200)	(0-0.125)
Biological Oxygen Demand (mg/L)	12.43	10.91	10.31	10.84
	(2.4-26.84)	(1.44-20.92)	(2.64-22.28)	(1.84-29.36)

Table 4. Growth performance data of Pacific white shrimp cultured in lined earthen ponds for 16 weeks fed using varying feeding strategies, stocked at 17 shrimp/m^2 with a mean initial weight 0.07g.

Treatment	Yield	Final Wt. (g)	% Survival	FCR	Weight Gain (g)	Weight Gain (g/week)	Biomass (kg)	Feed Input (kg)	%Body Wt. Fed	Final Population	Shrimp/m^2
SFP[1]	3,068.5^{a}	23.55^{a}	75.8	0.94	23.5^{a}	1.47^{a}	303.27^{a}	285.63^{a}	5.95	13,031	13.0
SFP+15%	3,032.5^{a}	24.65^{a}	72.2	1.04	24.6^{a}	1.54^{a}	301.81^{a}	312.86^{a}	6.51	12,341	12.3
Timer	3,294.3^{a}	28.66^{b}	66.9	0.98	28.6^{b}	1.79^{b}	325.91^{a}	318.78^{a}	6.15	11,502	11.5
Acoustic	4,568.8^{b}	35.91^{c}	73.9	1.14	35.8^{c}	2.24^{c}	452.48^{b}	518.78^{b}	7.19	12,679	12.7
P-Value	0.0016	<.0001	0.3112	0.0598	<.0001	<.0001	0.0016	<.0001	0.0557	0.3067	0.3067
PSE[2]	226.60	1.1703	2.9779	0.0468	1.1702	0.0731	22.389	19.843	0.2887	514.25	0.5143

Values represent means (n=4)

[1]Standard Feeding Protocol

[2]Pooled Standard Error

*Values in the same column with different superscripts are significantly different ($P < 0.05$) based on analysis of variance followed by Student Newman-Keuls multiple range test

Table 5. Economic data for a 16 week production period of Pacific white shrimp grown in lined earthen ponds and fed a commercial shrimp diet.

Treatment	Feed Cost (USD)	Feed Cost (USD kg/shrimp)	Value (USD)	Partial Income (USD)
SFP[1]	284.06[a]	0.94	1,181.00[a]	906.80[a]
SFP+15%	310.20[a]	1.03	1,177.60[a]	877.30[a]
Timer	315.89[a]	0.97	1,344.60[a]	1,038.60[a]
Acoustic	507.88[b]	1.12	1,989.80[b]	1,491.80[b]
P-Value	<.0001	0.0841	0.0005	0.0023
PSE[2]	19.049	0.0460	104.81	92.837

Values represent means (n=4)

[1]Standard Feeding Protocol

[2]Pooled Standard Error

*Values in the same column with different superscripts are significantly different ($P < 0.05$) based on analysis of variance followed by Student Newman-Keuls multiple range test

Did this project meet the intended Key Performance Indicators (KPIs)?.

1) The project was successfully completed.
2) The data will be used as part of a Master of Science Thesis and we will also develop both industry based publications and scientific reviewed publications describing the results.
3) The results of the project will be incorporated into training materials used for the Shrimp RAPCO
4) We have developed and published a YouTube video describing feed management and the results using automatic feeders.
    a. https://youtu.be/sWXR3Nq-vsY

Expected Outputs/Deliverables - List each deliverable identified in the project, indicate whether or not it was supplied and if not supplied, please provide an explanation as to why.

1) The project was successfully completed
2) Publications are being develop and are expected to be published in the future.
3) We have developed and published a YouTube video describing feed management and the results using automatic feeders.
    a. https://youtu.be/sWXR3Nq-vsY
4) Presentations at scientific meetings – due to the short duration of this cycle the data could not be presented at any meetings but will be presented at the WAS LACQUA 2016

meeting in Lima, Peru Nov. 29 – Dec.1, 2016 as well as WAS Aquaculture America in San Antonio TX Feb. 19-22, 2017.

What, if any, follow-up steps are required to capture benefits for all US soybean farmers? Describe in a few sentences how the results of this project will be or should be used.

Despite the fact that the feed represents the primary variable cost and a major factor in production performance, feed management is one of the least studied areas in shrimp production. The development of science based feed management practices is critical to the continued success of the industry. Based on these results it is clear that development of feed management techniques and demonstration of technologies can significantly improve performance of the shrimp.

Results to date, demonstrated improved efficiency of feed used, increased growth rates resulting in increased feed use and final biomass production. These all drive for a more efficient shrimp farming system which in turn increase the use of shrimp feeds and subsequently soy products.

Given the limited information on feed management, we would like to continue the line of research to look at the efficacy of the AQ1 system under different condition and evaluate feeding responses of the animals. There is a huge amount of information that can be learned from this automated system and clear performance improvement if such systems are demonstrated, promoted and adopted by the industry.