



## **Pond-to-pond variability in post-larval shrimp, *Litopenaeus vannamei*, survival and growth in inland low-salinity waters of west Alabama**

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### **Abstract**

Despite the recent success of Alabama shrimp farmers in culturing the Pacific white shrimp, *Litopenaeus vannamei*, in inland low-salinity waters there is large variability in growth and survival among ponds. Farmers suspect that high mortality occurs during the first weeks of culture following stocking of post-larvae (PL). In order to determine the effect of pond ionic composition on PL growth and survival, three trials were carried out at a shrimp farm. Trials 1 and 2 evaluated PL growth and survival over 21- and 28-day periods, respectively, using static water from different production ponds. Trial 3 evaluated growth and survival over 7, 14, 21 and 28 days using water from one production pond. Results suggest that initial mortality (8–10%) is attributed to the acclimation process and occurs immediately following stocking. Pond-to-pond variations in ionic profiles could be a contributing factor but are not likely the major reason for variable 'survival'. Mortalities after stocking appear to occur quickly as there were no differences in survival from 7 to 28 days post stock. Variable survival is likely due to a combination of reasons including environmental factors, but is largely due to poor handling of PL and stocking errors that produce perceived reductions in survival.

**Keywords:** *Litopenaeus vannamei*, postlarvae, low salinity, pond variability, survival

### **Introduction**

Shrimp culture using inland low-salinity well waters (LSWW) in west Alabama has faced several challenges, including rearing shrimp in waters containing

less than ideal ionic profiles. Saoud, Davis and Rouse (2003) reported large differences in salinity and ionic profile among LSWW sources in the west Alabama region. Low levels of aqueous potassium ( $K^+$ ) and magnesium ( $Mg^{2+}$ ) have resulted in less than ideal growth and survival of Pacific white shrimp, *Litopenaeus vannamei*, reared in LSWW (Davis, Saoud, Boyd & Rouse 2005; Roy, Davis & Saoud 2006; Roy, Davis, Saoud & Henry 2007). Farmers typically counteract deficiencies of  $K^+$  and  $Mg^{2+}$  in the water column by supplementing fertilizers (K-Mag<sup>®</sup> muriate of potash) rich in these minerals directly to the water before stocking postlarvae (PL) (McNevin, Boyd, Silapajarn & Silapajarn 2004). These remediation strategies have greatly increased the growth, survival and overall production of shrimp, thus increasing profits for local farmers.

Despite these apparent successes, farmers continue to report variable shrimp survivals following the harvest of production ponds, with the highest mortality suspected during the beginning and end of the production cycle (Alabama Inland Shrimp Producers Association, pers. comm.). These differences are not only found between the different shrimp farms, but also among ponds from the same farm. In May of each year, PLs are transported from coastal suppliers (usually Florida or Texas) to west Alabama shrimp farms and acclimated to low-salinity waters for 7–30 days, depending on the farmer. Following the acclimation period, PLs are stocked into low-salinity production ponds ranging in salinity from 2.0 to 9.0 ppt. Poor survival and growth have been attributed to osmoregulatory stress caused by this unique low-salinity rearing environment (Roy *et al.* 2007). While farmers increase  $K^+$  and  $Mg^{2+}$  levels by applying fertilizers to ponds before stocking,

inevitably ponds will still have variable ionic compositions (differences in salinity,  $K^+$  levels and  $Mg^{2+}$  levels) due to a number of environmental factors (Boyd, Boyd & Rouse 2007).

The primary objective of this research was to investigate the possibility that suboptimal ionic profiles of pond water could be leading to poor survival. In order to determine the effect of pond ionic composition on post-larval growth and survival of *L. vannamei*, several trials were carried out in tanks at a low-salinity shrimp farm in west Alabama in Spring 2006 and 2007. These growth trials were designed to compare PL survival among different pond water sources containing different ionic profiles. Additionally, we tracked weekly growth and survival over a 28-day period in order to determine at what point mortality is occurring following the stocking of PLs into low-salinity production ponds.

## Materials and methods

### Trial 1 (2006)

All trials in this study were conducted on-site at a low-salinity shrimp farm (Greene Prairie Aquafarm, Boligee, AL, USA) in west Alabama. Four ponds (N2, N6, N7 and S1) from Greene Prairie Aquafarm were randomly selected as water sources for the study. In addition, pond water was obtained from another low-salinity shrimp farm (LJ) that has had historically poor survival and growth during the last several production years. Pond water was pumped from production ponds into a hauling unit and transported to a static tank system consisting of fifteen 600 L tanks. This trial and subsequent trials were carried out in tanks because it is not feasible to track PL survival in production ponds due to their small size and because the ponds would have to be completely drained in order to truly quantify survival. Each tank was equipped with two airstones supplied with aeration from a 1 hp regenerative blower. Water from each pond (N2, N6, N7, S1 and LJ) was then pumped into three replicate tanks 7 days before the commencement of the trial. Air-breathing insects were terminated by placing a coat of vegetable oil over the tank to prevent surfacing.

Postlarvae were obtained from Harlingen (Los Fresnos, Texas) and transported by the farmer in hauling units to the farm before stocking. Postlarvae were acclimated over a 7-day period to low-salinity pond water in an outdoor nursery system that pumped pond water through the system. The nursery

system was equipped with aeration via a regenerative blower. Shrimp (0.005 g mean weight) were obtained from the farmer for the experiment. Fifty postlarvae were hand counted and stocked into each tank and fed PL-ready *ad libitum* twice daily for 21 days. The PLs were stocked on the same day the farmer stocked his production ponds. At the end of the growth trial, tanks were harvested and PLs were counted and group weighed. Water quality parameters were monitored daily and are reported as the mean  $\pm$  standard deviation. Dissolved oxygen ( $7.8 \pm 0.89 \text{ mg L}^{-1}$ ), temperature ( $25.6 \pm 2.5 \text{ }^\circ\text{C}$ ) and pH ( $8.3 \pm 0.28$ ) were monitored daily. Total ammonia nitrogen ( $0.32 \pm 0.42 \text{ mg L}^{-1}$ ) and nitrite nitrogen ( $<0.001 \text{ mg L}^{-1}$ ) were measured once a week according to Solorzano (1969) and Parsons, Maita and Lalli (1985) respectively. A water sample was taken at the beginning of the experiment and analysed for ions (sodium, potassium, calcium, magnesium, boron and phosphorous) using ICAP (Clesceri, Greenberg & Eaton 1998).

### Trial 2 (2007)

For this trial, five ponds were randomly selected as water sources for the study. Pond water was pumped from production ponds into a hauling unit and transported to a static tank system consisting of twenty 600 L tanks. Each tank was equipped with two airstones supplied with aeration from a 1 hp regenerative blower. Water from each pond was then pumped into four replicate tanks 7 days before the commencement of the trial. Air-breathing insects were terminated by placing a coat of vegetable oil over the tank to prevent surfacing.

Postlarvae were obtained from Shrimp Improvement Systems (Florida Keys, Florida) and transported by the farmer in hauling units to the farm before stocking. Postlarvae were acclimated over a 7-day period to low-salinity pond water in an indoor greenhouse nursery system that pumped pond water through the system. The nursery system was equipped with aeration via a regenerative blower. Shrimp (0.0098 g mean weight) were obtained from the farmer for the experiment. Fifty postlarvae were stocked into each tank and fed PL-ready *ad libitum* twice daily for 28 days. At the end of the growth trial tanks were harvested and PLs were counted and group weighed. Throughout the experiment, dissolved oxygen ( $8.1 \pm 0.59 \text{ mg L}^{-1}$ ), temperature ( $25.5 \pm 3.5 \text{ }^\circ\text{C}$ ) and pH ( $8.7 \pm 0.2$ ) were monitored daily. Total ammonia nitrogen and nitrite nitrogen were measured once a

week according to Nessler’s method (APHA 1989) and Parsons *et al.* (1985) respectively.

**Trial 3 (2007)**

For this trial, one pond was selected as the water source for the study. Pond water was pumped from the production pond into a static tank system consisting of sixteen 600 L tanks. Each tank was equipped with two airstones supplied with aeration from a 1 hp regenerative blower. Water was pumped from the pond to the tanks 7 days before the commencement of the trial. Air-breathing insects were terminated by placing a coat of vegetable oil over the tank to prevent surfacing.

This experiment was stocked on the same day as Trial 2 using the same cohort of PLs (0.0098 g). Fifty postlarvae were stocked into each tank. After stocking, four tanks were randomly selected and harvested every 7 days for 4 weeks (7, 14, 21 and 28 days). At harvest, PLs were counted and group weighed. Trial 3 was conducted concurrently with Trial 2 and both trials thus, share the same water quality parameters. All values were within acceptable ranges for the culture of *L. vannamei*.

**Statistical analyses**

Statistical analyses were performed using SAS (V8.2, SAS Institute, Cary, NC, USA). Data for the three trials were analysed using one-way analysis of variance and the Student–Newman–Keuls multiple range test to determine whether significant differences ( $P \leq 0.05$ ) existed among treatment means (Steel & Torrie 1980). Correlation analysis was utilized to determine possible effects of selected ions on survival of post-larval shrimp.

**Results**

**Trial 1**

After 21 days of culture, there were no significant differences in shrimp final weight, survival or weight gain among ponds from the same farm (N7, N6, N2 and S1) (Table 1). The final weight, survival and weight gain in shrimp reared in water from these four ponds ranged from 0.37 to 0.45 g, 62 to 78.7% and 7401 to 8984% respectively. However, when compared with shrimp reared in the pond water from the farm (LJ) with historically poor survival and growth

**Table 1** Final weight (g), survival (%) and weight gain (%) for Trial 1 for *Litopenaeus vannamei* (0.005 g mean initial weight) reared in five different pond water sources for 21 days

Pond	Final weight (g)	Survival (%)	Weight gain (%)
N7	0.37 ± 0.06 <sup>a</sup>	62.0 ± 19.1 <sup>a</sup>	7401 ± 1263 <sup>a</sup>
N6	0.39 ± 0.10 <sup>a</sup>	78.7 ± 5.8 <sup>a</sup>	7847 ± 1926 <sup>a</sup>
N2	0.45 ± 0.12 <sup>a</sup>	72.6 ± 1.2 <sup>a</sup>	8984 ± 2542 <sup>a</sup>
S1	0.38 ± 0.02 <sup>a</sup>	75.3 ± 4.2 <sup>a</sup>	7658 ± 343 <sup>a</sup>
LJ	0.13 ± 0.07 <sup>b</sup>	34.0 ± 14.1 <sup>b</sup>	2494 ± 1526 <sup>b</sup>
<i>P</i> -value	0.0237	0.0098	0.0236
PSE	0.05	6.48	1031

PSE, pooled standard error. Values with different letters are significantly different ( $P < 0.05$ ).

**Table 2** Ionic profile (mg L<sup>-1</sup>) of pond waters utilized for culturing post-larval *Litopenaeus vannamei* for Trial 1 (2006) and Trial 2 (2007)

Ions (Trial 1)	Instant					
	ocean	S1	N2	N6	N7	LJ
Salinity (ppt)	4.0	3.7	3.3	2.6	2.4	9.1
Ca	42.4	85.4	103.3	67.0	71.5	994.9
K	47.32	41.2	36.9	34.4	40.3	47.6
Mg	132.26	65.1	62.7	49.2	44.7	178.6
B	0.73	0	3.8	0	0	0.5
Na	1316.3	981.4	891.2	666.3	704.4	2066.5
P	0.33	0	0.3	0.2	0.2	0
Na:K	27.8:1	23.8:1	24.1:1	19.4:1	17.5:1	43.4:1

Ions (Trial 2)	Instant					
	ocean	S1	S4	N2	N6	N7
Salinity (ppt)	4.0	4.9	4.4	5.3	4.1	4.0
Ca	42.4	99.05	56.85	66.55	73.15	87.5
K	47.32	90.7	91.8	70.05	86.65	94.15
Mg	132.26	46.45	39.85	42.5	35.65	40.45
B	0.73	2.3	2.05	2.1	1.65	1.55
Na	1316.3	2492.5	2294.5	2650.5	1996.5	1921.5
P	0.33	2.1	1.05	0	2.85	0.45
Na:K	27.8:1	27.5:1	25.0:1	37.8:1	23.0:1	20.4:1

Water samples were taken at the beginning of each trial.

there were significant differences. The final weight (0.13 ± 0.07 g), survival (34.0 ± 14.1) and weight gain (2494 ± 1526%) were significantly lower in shrimp reared in water from farm LJ after 21 days.

The ionic profiles of the different pond waters were quite different (Table 2). The four ponds from the same farm had salinities ranging from 2.4 to 3.7 ppt. The levels of calcium, magnesium and sodium also varied considerably among ponds, ranging from 42.4 to 103.3 mg L<sup>-1</sup>, 44.7 to 65.1 mg L<sup>-1</sup> and 666.3

to 981.4 mg L<sup>-1</sup> respectively. The pond water obtained from farm (LJ) had a completely different ionic profile, with a much higher salinity (9.1 ppt), as well as higher calcium (994.9 mg L<sup>-1</sup>), magnesium (178.6 mg L<sup>-1</sup>) and sodium (2066.5 mg L<sup>-1</sup>). These differences are further accentuated in Pearson's correlation analysis (Table 4). Correlation analysis of calcium, magnesium and sodium yielded a significant correlation to growth, survival and per cent weight gain of shrimp (Table 4).

**Trial 2**

No significant differences were observed in shrimp final weight or weight gain among the five ponds (N7, N6, N2, S1 and S4) examined in Trial 2 (Table 3). After 28 days of culture, the final weights ranged from 0.96 to 1.12 g with pond N2 yielding the largest shrimp and the greatest weight gain (11 968%). There were, however, significant differences in survival among ponds. Pond N2 (91.5%) had significantly lower survival than pond S1 (98.5%). Survivals in the other three ponds ranged from 93% to 93.5%.

The ionic profile of the five pond waters examined in Trial 2 was similar among ponds, with the exception of calcium (Table 2). Calcium levels ranged from 56.85 to 99.05 mg L<sup>-1</sup>. Salinities ranged from 4.0 to 5.3 ppt, while potassium, magnesium and sodium levels ranged from 70.05 to 94.15 mg L<sup>-1</sup>, 35.65 to 46.45 mg L<sup>-1</sup> and 1921.5 to 2650.5 mg L<sup>-1</sup> respectively. Pearson's correlation analysis revealed that calcium was correlated to survival ( $P < 0.05$ ), but not weight gain or the final weight of shrimp. Sodium, magnesium, potassium, phosphorous and boron were not correlated to survival, weight gain or final weight of shrimp ( $P > 0.05$ ).

**Table 3** Final weight (g), survival (%) and weight gain (%) for juvenile shrimp (0.00928 mean initial weight) in Trial 2 reared in five different pond water sources for 28 days (four replicate tanks for each pond water source)

Pond	Final weight (g)	Survival (%)	Weight gain (%)
N7	1.09 ± 0.22 <sup>a</sup>	93.0 ± 3.8 <sup>ab</sup>	11 690 ± 2394 <sup>a</sup>
N6	0.96 ± 0.09 <sup>a</sup>	93.5 ± 1.9 <sup>ab</sup>	10 210 ± 1018 <sup>a</sup>
N2	1.12 ± 0.06 <sup>a</sup>	91.5 ± 3.4 <sup>b</sup>	11 968 ± 647 <sup>a</sup>
S4	1.05 ± 0.06 <sup>a</sup>	93.0 ± 2.0 <sup>ab</sup>	11 202 ± 685 <sup>a</sup>
S1	1.05 ± 0.13 <sup>a</sup>	98.5 ± 3.0 <sup>a</sup>	11 252 ± 1403 <sup>a</sup>
<i>P</i> -value	0.471	0.0383	0.472
PSE	0.064	1.47	697

PSE, pooled standard error. Values with different letters are significantly different ( $P < 0.05$ ).

**Table 4** Pearson's correlation coefficients of select ions between postlarvae survival, weight gain (%) and final weight (g) for Trial 1 and Trial 2

	Survival		Weight gain (%)		Final weight	
	Pearson's	<i>P</i> > <i>R</i>	Pearson's	<i>P</i> > <i>R</i>	Pearson's	<i>P</i> > <i>R</i>
Trial 1 (2006)						
Ca	-0.753	0.002	-0.760	0.002	-0.758	0.002
K	-0.396	0.161	-0.532	0.050	-0.530	0.051
Mg	-0.685	0.007	-0.741	0.002	-0.740	0.003
B	0.307	0.286	0.081	0.784	0.079	0.790
Na	-0.688	0.007	-0.734	0.003	-0.732	0.003
P	0.221	0.448	0.467	0.092	0.422	0.088
Trial 2 (2007)						
Ca	0.522	0.018	0.021	0.928	0.022	0.926
K	0.312	0.181	-0.152	0.521	-0.152	0.523
Mg	0.403	0.074	-0.273	0.244	0.274	0.243
B	0.331	0.154	0.127	0.595	0.126	0.595
Na	0.105	0.660	0.215	0.363	0.215	0.364
P	0.391	0.088	-0.412	0.071	-0.412	0.071

**Table 5** Survival (%) and growth (g) of post-larval *Litopenaeus vannamei* reared in low-salinity water at 7, 14, 21 and 28 days in Trial 3

Day	Survival (%)	Growth (g)
7	90.7 ± 5.0	0.029 ± 0.001
14	92.5 ± 3.0	0.102 ± 0.010
21	88.0 ± 0.0	0.334 ± 0.010
28	93.0 ± 2.0	1.049 ± 0.064

No significant differences were observed ( $P > 0.05$ ).

**Trial 3**

There were no significant differences in survival in post-larval shrimp reared in low-salinity water for 7, 14, 21 and 28 days (Table 5). Survivals ranged from 88% to 93% across all treatments. After 28 days of culture, the final weights of shrimp averaged slightly over 1 g (Table 5).

**Discussion**

Inland low-salinity shrimp farming is a relatively new industry in west Alabama. The availability of LSWW as well as the existing infrastructure from the traditional channel catfish industry are promising advantages to this industry. While LSWW in west Alabama is deficient in key ions necessary for

effective shrimp osmotic and ionic regulation, supplementation of fertilizers rich in  $K^+$  and  $Mg^{2+}$  to pond waters has dramatically increased the survival, growth and production of *L. vannamei* (McNevin *et al.* 2004; Davis *et al.* 2005; Roy *et al.* 2007). Despite these successes, farmers are still facing a number of challenges. There is a large variability in survival and growth in shrimp among ponds. In west Alabama, variations in shrimp survival and growth are typically higher than those reported for marine-pond studies conducted in Alabama coastal ponds with access to near full-strength seawater (Amaya, Davis & Rouse 2007; Venero, Davis & Rouse 2007; Zelaya, Rouse & Davis 2007). In low-salinity waters of west Alabama, farmers have reported shrimp survivals ranging from 30% to 80% depending on the pond and year (Alabama Inland Shrimp Producers Association, pers. comm.). These differences are not only observed between different farms, which have different practices and production strategies, but also in ponds from the same farm. At harvest, it is not uncommon for dramatic differences in growth and survival among ponds to be observed. Farmers suspect that much of the mortality in their ponds is occurring early or late in the production cycle. As a result, farmers are interested in tracking survival of PLs during the first several weeks following the stocking of production ponds.

The acclimation of post-larval shrimp to low salinity is one of the most critical steps in the production cycle of *L. vannamei* in low-salinity waters. Salinity is known to influence the growth and survival of Penaeid shrimp (Zein-Eldin 1963; Laramore, Laramore & Scarpa 2001; McGraw, Davis, Teichert-Coddington & Rouse 2002). In addition, PL age and the ionic composition of the acclimation water also play an important role in the process (McGraw *et al.* 2002; McGraw & Scarpa 2003, 2004; Atwood, Young, Tomasso & Browdy 2003; Saoud *et al.* 2003; Davis *et al.* 2005; Sowers, Tomasso, Browdy & Atwood 2006; Sowers, Young, Grosell, Browdy & Tomasso 2006; Roy *et al.* 2007). Techniques for acclimating PLs usually vary considerably among farms and for this reason it is difficult to determine whether the low survival and growth observed between farms are a result of ionic profiles of pond waters, farm-specific stocking and acclimation techniques, poor-quality PL obtained from the hatchery or other factors that influence production.

Inland saline waters in west Alabama utilized for shrimp culture vary considerably in ionic composition (Saoud *et al.* 2003). In fact, salinities and ionic

composition can vary from year to year in the same pond. For instance, pond N7 had markedly different salinities in 2006 (2.4 ppt) compared with 2007 (4.0 ppt). These changes are also reflected in the ionic composition of the pond water. This is due to several reasons, including adsorption of ions to pond bottom soils (Boyd *et al.* 2007), drain harvesting methods, yearly applications of fertilizers containing  $K^+$  and  $Mg^{2+}$  (McNevin *et al.* 2004) and the weather. Because of this, each production season, farmers find it difficult to predict the potential success of individual ponds as it relates to shrimp survival and growth.

The ionic composition of the pond water can have a direct effect on the survival and growth of post-larval and juvenile *L. vannamei*. Saoud *et al.* (2003) reported differences in the survival of 10-, 15- and 20-day-old PLs during short-term bioassays using LSWW from different sources and attributed these differences to differences in  $K^+$  and  $Mg^{2+}$  levels of the culture waters. Davis *et al.* (2005) reported that the survival and growth of post-larval *L. vannamei* was positively impacted by  $K^+$  and  $Mg^{2+}$  supplementation. McGraw and Scarpa (2003) reported a minimum environmental  $K^+$  requirement for survival of *L. vannamei* in low-salinity water. Our results indicate that better survival and growth were achieved in shrimp reared in pond waters from the farm (Ponds S1, N2, N6 and N7) that received supplementation of  $K^+$  and  $Mg^{2+}$  before stocking when compared with shrimp reared in pond water from farm LJ, which did not receive  $K^+$  and  $Mg^{2+}$  supplementation. Water from pond LJ had a higher Na:K ratio (43.4:1) than the other four ponds (17.5:1–24.1:1) that received  $K^+$  supplementation (Table 2). In Trial 1 (Table 4), survival, weight gain and final weight were negatively correlated to calcium, magnesium and sodium ( $P < 0.05$ ). This is consistent with other studies that have evaluated the influence of Na:K ratios on shrimp survival and growth at low salinity (Saoud *et al.* 2003). Roy *et al.* (2007) reported differences in the survival and mean final weight of post-larval *L. vannamei* stocked in 4 ppt waters containing different  $K^+$  levels (and thus different Na:K ratios). As the level of aqueous  $K^+$  increased (and the Na:K ratio decreased), survival and growth of post-larval *L. vannamei* improved (Roy *et al.* 2007). Zhu, Dong, Wang and Huang (2004) reported differences in the growth, feed intake and energy allocation when Na:K ratios were altered in juvenile *L. vannamei* reared at 30 ppt. It is worth noting that in the study by Zhu *et al.* (2004), shrimp reared in 30 ppt water with Na:K ratios ranging from 43 to 40:1 achieved adequate

growth. In previous studies by our laboratory, we have also obtained similar results culturing shrimp in water with Na:K ratios around 40:1 at lower test salinities (Roy *et al.* 2006, 2007). In Trial 1, however, shrimp reared in water from pond LJ (Na:K of 43.4:1 at a salinity of 9.1 ppt) had significantly lower survival, final weight and weight gain when compared with shrimp reared in waters containing a lower Na:K ratio (17.5:1–24.1:1) and salinity (2.4–3.7 ppt). Based on these results, it is likely that low-salinity water from pond LJ is potentially lacking in another ion or ions. Sowers, Gatlin, Young, Isely, Browdy and Tomasso (2005) evaluated shrimp growth and survival when cultured in low-salinity water (2 ppt) prepared from sea salt compared with prepared mixed-salts containing similar and different levels/ratios of Na<sup>+</sup>, K<sup>+</sup>, Ca<sup>2+</sup> and Mg<sup>2+</sup>. Overall, survival was better in shrimp reared in the low-salinity water prepared from sea salt even when the Na:K ratios were the same or lower in the prepared mixed salt environments. The results from their study suggest that the differences observed in survival may be attributed to the presence of an ion or ions found in sea salt that was not used for preparation of the water for the mixed-salt environments. Because of the high variability in the ionic profiles of west Alabama shrimp farms, it is probable that modification of Na:K ratios to mirror seawater might not always solve problems related to poor survival and growth. In some cases, it is likely that additional ions might also be deficient and may contribute to poor survival of shrimp (Sowers *et al.* 2006).

In Trial 2, differences in survival were observed among shrimp reared in five different pond waters. Correlation analysis, however, did not fully explain these differences in survival. Although a significant correlation was observed between calcium and shrimp survival (Table 4), other osmoregulatory ions such as magnesium, sodium or potassium were not correlated to shrimp survival ( $P > 0.05$ ). Because pond waters utilized in Trial 2 all received supplementation of potassium and magnesium fertilizers before the experiment, it is probable that ionic deficiencies were accounted for before commencement of the experimental trials. Thus, it appears that current strategies to remediate ionic deficiencies in low-salinity waters of west Alabama by supplementing K-Mag<sup>®</sup> and muriate of potash are adequate for successful culture of *L. vannamei* in this unique rearing environment. This is further supported by the lack of significant differences in shrimp survival in Trial 3, where shrimp were harvested at 7, 14, 21 and 28 days

(Table 5). The 8–12% mortality observed following 28 days of culture appears to be occurring in the first week following the stocking of PLs.

Based on the results of these studies, pond-to-pond differences in ionic profiles could be contributing factors to poor survival but do not appear to be the primary factor. The apparent variability in survival observed by farmers is most likely due to initial errors in stocking as well as mortality due to improper transfer of the postlarvae from holding tanks to production ponds. Hence, farmers are encouraged to improve stocking protocols.

### Acknowledgments

The authors would like to extend their gratitude to the Alabama Agricultural Experiment Station and National Oceanic and Atmospheric Administration (NAO60AR4170191) for providing funds for this research. Thanks are also due to Travis Brown and Nelson Sansing for technical assistance with this study. The mention of trademarks or proprietary products does not constitute an endorsement of the product by Auburn University and does not imply its approval to the exclusion of other products that may also be suitable.

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