

Influence of Nursery Period on the Growth and Survival of *Litopenaeus vannamei* Under Pond Production Conditions

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Abstract

Techniques for head starting or nursing postlarvae (PL) has received considerable attention with regards to nursery protocols, yet there is little data pertaining to the effects of nursery period on the final growout of shrimp to marketable size. This study was performed to investigate the influence of nursery duration on survival and growth of *Litopenaeus vannamei* during subsequent pond culture. For this research, a single population of high health PL were received from a commercial hatchery and held in a tank for acclimation, quantification, and distribution to nursery tanks or ponds. Treatments included direct stocking of 10-d-old postlarvae (PL₁₀) into production ponds as well as the nursing of PL in a covered greenhouse nursery system for an additional 10 or 20 d. After nursing, the PL were harvested, quantified, and transferred to growout ponds. All ponds were stocked at a density of 35 PL/m² and maintained under standardized conditions. Shrimp were fed with a 35% protein shrimp feed, twice daily during the 112-d growth trial. Ponds were aerated as needed using a maximum of 19 hp/ha to maintain adequate dissolved oxygen (DO > 3.0). No statistical differences ($P > 0.05$) were found in survival, yield, or growth between treatments. At harvest, survivals during growout were generally higher in ponds with nursed shrimp (77% for PL₂₀ and 79% for PL₃₀) than in ponds receiving PL₁₀ shrimp (67%). Yields were similar between treatments, ranging from 3,525 for direct stocked shrimp to 3,747 kg/ha for those that were nursed for 10 d. Although growth rates of PL under pond conditions will be faster than that of a nursery system, results suggest that a nursery period of at least 10 d helps improve survival during pond production and promotes better size uniformity. Shrimp nursed for 20 d showed little improvement in survival over shrimp nursed for 10 d but did result in a more uniform size of shrimp at harvest.

Among the challenges faced by shrimp pond managers is the need to have constant and predictable production. Consistent production is often based on an accurate estimation of shrimp densities in culture ponds. Density during the growout cycle is often predicted based on the initial stocking density, assumed survival, and sampling. Improper stocking and poor estimates of density can affect growth rates, feed inputs, final yields, and ultimately profitability. The first few weeks after stocking are thought to be the most critical in terms of survival of postlarvae (PL). Consequently, methods to allow more accurate stocking and improve survival during the early stages of production period could significantly im-

prove overall production and facilitate a more predictable harvest.

Marketable shrimp can be produced either by direct stocking of PL into growout ponds resulting in a single phase growout system, or by stocking the PL into transitional systems for a short period, followed by transfer to growout ponds. A culture system that incorporates only one transfer of shrimp from the nursery to the growout pond is referred to as a two-phase growout system (Lawrence 1985; New and Rabanal 1985; Lawrence and Huner 1987). Advantages given for the use of nurseries include: improved control of counts when stocking growout ponds; more size uniformity at pond harvest; better utilization of farm infrastructure; improved risk management, particularly for biosecurity; stronger PL; and decreased feed waste (Hirono 1983;

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Pretto 1983; Aquacop 1985; Seidman and Issar 1988; Fast 1991; Sturmer et al. 1992). The major disadvantage attributed to nursery systems is the additional stress caused by harvesting and transferring from the nursery to growout ponds. The increased investment in culture systems and the increased management skills needed to run these systems could also be considered disadvantages.

The use of nurseries is more common with semi-intensive and intensive farming systems (Samocha and Lawrence 1992). In tropical and subtropical regions the nursery system is not critical hence, their use depends on the preference of the producer. Nurseries may be more critical in temperate climates and low salinity environment areas, as well as those with potential disease problems. In temperate climates nurseries can serve to extend the culture period at the front end as pond waters are warming through the spring, so they are often built within "greenhouse-like" structures. In areas of low salinity, the acclimation of young PL to the low salinity water is also a critical component of production (McGraw et al. 2002), which can be performed in conjunction with the nursery system. Furthermore, in areas where diseases are problematic, the nursery is an excellent way to extend biosecurity through early development.

Although techniques for nursing shrimp have been well studied (Samocha et al. 2002), there is little data pertaining to the effects of nurseries on the final growout of shrimp to marketable size. Consequently, this study was designed to evaluate the effect of nursery durations on survival and growth during subsequent pond culture.

Materials and Methods

The study was conducted at the Alabama Department of Conservation and Natural Resources Marine Resource Division's Claude Petet Mariculture Center in Gulf Shores, Alabama, USA. Six 4.3-m³ fiberglass tanks and eleven 0.105-ha rectangular

ponds were utilized. Ponds were lined with high density, black polyethylene plastic and the bottoms covered with native soil. Each pond had an internal concrete catch basin with an internal screened stand pipe to control the water level to an average depth of 1 m. Ponds were filled with pre-filtered water from the Intracoastal Canal between Mobile and Perdido Bay, Alabama. After filling, the ponds were fertilized at a rate of 18 L/ha with 38-8-0 liquid fertilizer 7 d before the experiment started. Twelve to 24 h before stocking, a 1:15 motor oil and diesel fuel mixture was applied evenly over each pond's surface at a rate of 9 L/ha to reduce the air breathing insect population.

Ten-d-old postlarvae (PL₁₀) of *L. vannamei* were received from a commercial hatchery (Harlingen Shrimp Farms LTD, Los Fresnos, Texas, USA). Upon arrival the salinity, temperature, and dissolved oxygen (DO) of the shipping water was recorded and the acclimation process to transfer the PL into ponds or the nursery system was begun. Acclimation consisted of increasing the temperature and decreasing the salinity of the water at a rate of 2 C/h and 2 ppm/h, respectively. After acclimation, a volumetric count was performed to determine the number of PL.

Three treatments were assigned randomly to 11 ponds and included: direct stocking of PL₁₀ (DS), 10-d nursed shrimp (N10), and 20-d nursed shrimp (N20). One treatment (DS) had five replicates and the other two treatments (N10 and N20) had three replicates each. Aspirator-pump aerators (0.75 kW, 2 hp Aire-O₂, Minneapolis, Minnesota, USA) were installed in all ponds for an aeration capacity of 19 hp/ha. Aeration was used as needed to maintain adequate dissolved oxygen (DO > 3 mg/L at dawn).

The nursery system consisted of six 4.3-m³ semi-rectangular fiberglass tanks. Nursery tanks were equipped with airstones for aeration, and bottled oxygen was kept in reserve to oxygenate tanks in case the electric blower failed. During the first 4 d of nursing, PL were fed with *Artemia* (2/mL).

Beginning on the fifth day, PL were fed at 50%, 30%, and 25% of their estimated body weight with crumbled shrimp feed for weeks 1, 2 and 3, respectively. Postlarvae were stocked into the nursery system at a density of 28 PL/L. The system's make up water was exchanged with unfiltered low salinity water from a reservoir pond. The system was initially run as a static system and then the water exchange was slowly increased up to 100%/d by the second week of culture. At the conclusion of the nursery period, the appropriate nursery tanks were drain harvested, then shrimp numbers and average weights were determined gravimetrically. A portion of the shrimp from each harvested nursery tank was distributed to the assigned ponds.

All ponds were stocked at a density of 35-PL shrimp/m². Direct stocked shrimp were fed at a rate of 10 kg/ha per d for the first 10 d and at a rate of 20 kg/ha per d for the next 10 d. After 20 d, feeding was based on estimated biomass. After 10 d of nursing, the second group of shrimp (N10) were stocked into ponds and feed was offered at a rate of 20 kg/ha per d for the first 10 d, after which they were fed based on estimated biomass. After 20 d in the nursery, the third group of shrimp (N20) were stocked into ponds and fed based on their estimated biomass. At least 30 shrimp were taken weekly from each pond to monitor growth and to adjust feeding rates. A commercial 35% protein shrimp feed was given twice a day on a 7 d/wk basis. The feeding calculations were based on a fixed Food Conversion Ratio (FCR) of 1.6, and a forecast growth based on the average growth of the last 2 wk for each pond. For example: if the average shrimp growth was 1 g/wk during the previous 2 wk and the estimated population of a pond was 19,687 shrimp, the calculated feed input would be the forecasted growth, multiplied by the number of shrimp in the pond, multiplied by the FCR, divided by the number of days per week ($1 \times 19,687 \times 1.6/7$) resulting in a feed input of 4.5 kg/d (45 kg/ha per d).

The assumed survival rate (over the course of the pond culture period) used in feed calculations was 70% for the DS and 85% for the N10 and N20 treatments.

Dissolved oxygen levels were monitored twice a day, at sunrise (0500–0600 h) and at night (2200–2400 h). Weekly water samples were obtained from each pond in the late afternoon (1700 h) and analyzed for total ammonia-nitrogen (TAN) and pH. Salinity and Secchi disk readings were taken once a week.

After 112 d of culture, the shrimp ponds were drain harvested over a 5-d period, 1 d prior to the initiation of harvesting. Throughout the harvest period the shrimp were not fed and temperatures were minimal for growth. Harvest was accomplished by draining two-thirds of the water from each pond during the night. The following morning, the rest of the water was pumped out through a hydraulic fish pump with a 25-cm suction (Aqualife-Life pump, Magic Valley Heli-Arc Mfg, Twin Falls, Idaho, USA). The pump was placed in a concrete catch basin, and the shrimp were pumped and dewatered as they were moved to the harvest truck. Shrimp were then washed and weighed to determine gross yield. One-hundred individual shrimp were randomly collected from each pond and weighed to the nearest 0.1 g to obtain mean individual weights. Individual weight data was used to determine mean weights, standard deviation, and coefficients of variation for final shrimp weights which were determined for each pond. Feed conversion ratios were calculated for each pond based on feed inputs and final yields of shrimp. The resulting data was analyzed by one-way ANOVA to determine significant differences among treatments ($P \leq 0.05$). To evaluate potential effects of nursery duration on size variation at the conclusion of the growth trial, the coefficient of variation for the individual weights of shrimp sampled from each pond was determined and regressed against the number of days in the nursery. Statistics were conducted using the SPSS software

TABLE 1. Survival of *L. vannamei* postlarvae (PL) as well as minimum and maximum water temperatures for nursery tanks stocked as PL₂₀ and nursed for 10 and 20 d at a density of 28 PL/L.

Tank	Survival	Temperature (C)		
		Mean	Maximum	Minimum
T1	64%	29.1	33	25
T2	67%	28.8	33	26
T3	64%	28.7	33	26
T4	89%	28.3	31	25
T5 ^{ab}	77%	28.4	31	25
T6 ^a	87%	28.4	32	26
Average	75%	28.6	32.2	25.5

^a Shrimp nursed for 20 d.

^b Tank harvested twice.

(SPSS 10.0 for Windows, Chicago, Illinois, USA).

Results and Discussion

Nursery Stage

Overall survival in the nursery system was 75% (Table 1). This survival is consistent with typical survival at this facility as well as the 70–80% reported in a survey of nursery systems in Latin America (Stern and Letellier 1992; CICTUS 1983). The observed survival was less than the 90% reported by Samocha (1999) and the 85–95% by Sturmer et al. (1992).

Survival within the individual nursery tanks was variable and appears to be related to the differences in water temperatures and handling during the nursery periods. The three tanks with the lowest survivals (64–67%), received the most solar radiation and had the highest temperature (33 C), which was observed over a 5-d period. One nursery tank was harvested twice during the experiment and experienced a slightly lower survival (77%), which may be explained by the stress caused during the harvest compared to the two tanks that had the better survivals (87% and 89%). None of the three tanks with the highest survival received direct sunlight during the experiment. Based on these observations, stressful temperatures and excessive handling should be

minimized as they may contribute to increased mortality.

After 10 and 20 d in the nursery, the shrimp had an average weight of 0.018 g and 0.038 g, respectively. At the time of stocking the N20 treatment, shrimp were considerably smaller (0.038 g) than the shrimp that had been stocked directly into the ponds (0.707 g), which were sampled on the same day. Furthermore at this point in time, shrimp that were nursed for 10 d and then stocked into the ponds for 10 d had an intermediate weight of 0.290 g.

Nursery sizes for the N20 were higher than the ones reported by CICTUS (1983), who reported weights of 0.01–0.02 g after a 22-d nursery period in raceways at a stocking rate of 20 PL/L and 80% survivals. After 20 d in ponds, DS were similar in size to those of Villalon (1991), who reported weights between 0.5 and 1.0 g after 4 wk in nursery ponds. Hence, the observed nursery results were typical of those reported in other studies.

Growout Stage

Results at pond harvest (112 d of culture) for DS, N10, and N20 treatments were: 15.01, 13.90, and 12.77 g/shrimp mean weight; 67, 77, and 79% survival; and 3,525, 3,747, and 3,533 kg/ha mean yields, respectively (Table 2). Mean growth per week was 0.94, 0.87, and 0.80 g/wk and mean FCRs were 1.97, 2.03, and 2.12, respectively. There were no statistical differences found in survivals, average weights, yields, growth per week, or FCR, among the treatments. However, there appeared to be clear trends in the data as individual weights were lowest in the N20 treatment and highest in the DS treatment. This appears to be due to differences in the initial weight after the nursery period. The relative weight differences observed among treatments after the first 20 d in culture were maintained during the entire growing cycle (Fig. 1).

Observed mean survivals during the growout were greater when juveniles were

TABLE 2. Average production at harvest for *L. vannamei* directly stocked (DS) as PL_{10} nursed for 10 d (N10) and stocked as PL_{20} or nursed for 20 d (N20) and stocked as PL_{20} . Ponds were stocked at a density of 35 PL/m^2 with a total culture period of 112 d. There were no significant differences between treatments ($P > 0.05$).

Treatment	DS	N10	N20	P
Yield (kg/ha)	3,525	3,747	3,533	0.757
Mean weight (g)	15.0	13.9	12.8	0.268
CV of individual weights (%) ^a	21.2	18.7	17.5	0.246
Growth/wk (g)	0.94	0.87	0.80	0.268
FCR ^b	1.97	2.03	2.12	0.795
Survival in ponds (%)	67	77	79	0.146
Total survival (%) (nursery & ponds)	67	58	59	0.234
N ^c	2	5	3	

^a Coefficient of variation = standard deviation/mean \times 100.

^b Feed Conversion Ratio (FCR) = feed input/final yield.

^c N represents the number of replicate ponds analyzed. One pond in the DS treatment was excluded from the analyses due to a *Microcystis* bloom which resulted in high mortality and poor growth of the shrimp.

nursed for 10 or 20 d (77% and 79%) than those that were stocked directly into ponds after acclimation (67%). Observed survivals were very similar between shrimp that had been nursed for 10 and 20 d. When total survivals, which included the nursery

and the growout periods, were considered, the order among treatments was reversed. The DS had a total survival of 67% compared to a total survival of 58% and 59% for, N10 and N20 (Table 2). Unlike most nurseries, this site has traditionally had low

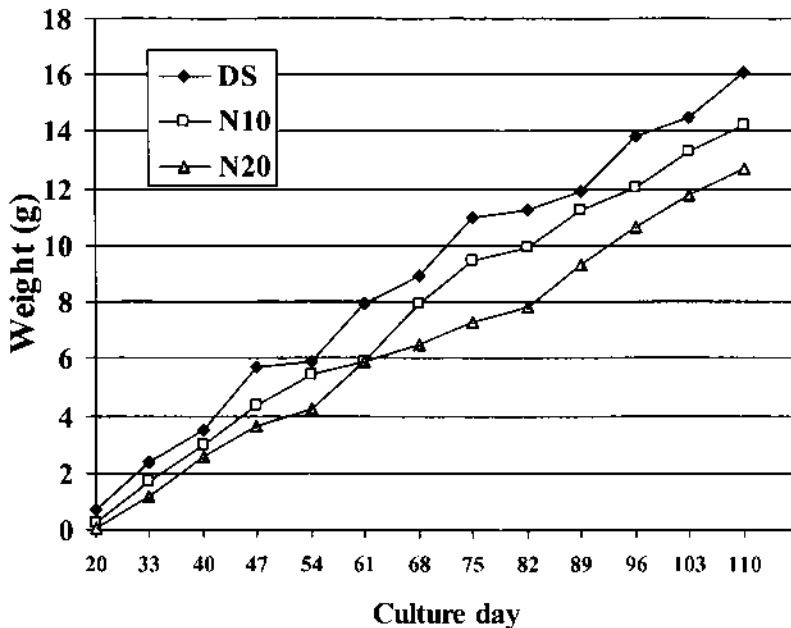


FIGURE 1. Mean weights for *L. vannamei* stocked at 35 PL/m^2 in outdoor production ponds and sampled on a weekly basis with a total culture period of 112 d. A single population of postlarvae was received and assigned to the following treatments: directly stocked (DS) as PL_{10} ; nursed for ten days (N10) and stocked as PL_{20} ; or nursed for 20 d (N20) and stocked as PL_{20} .

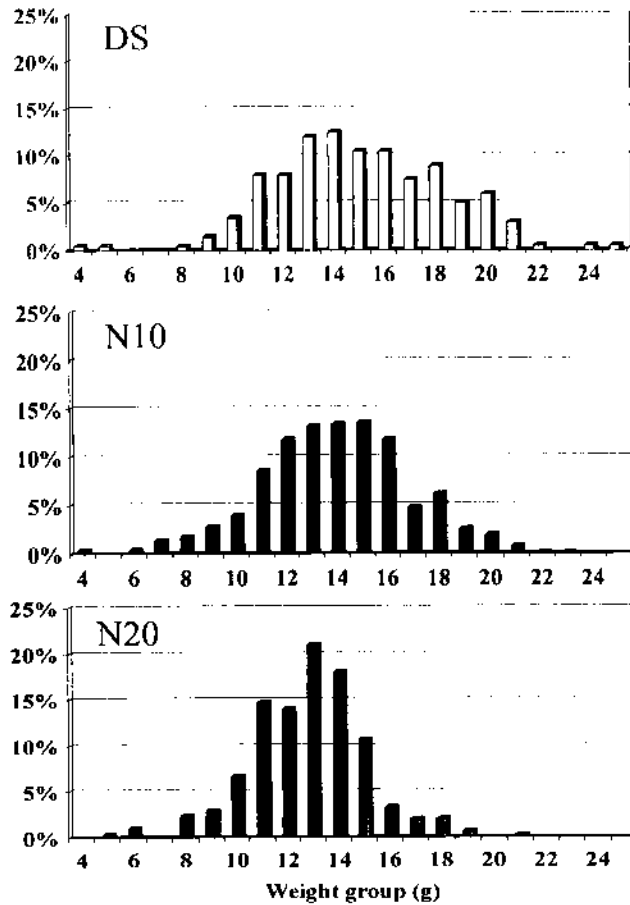


FIGURE 2. Population size distribution at harvest for *L. vannamei* directly stocked (DS) as PL_{10} , nursed for 10 d (N10) and stocked as PL_{20} , or nursed for 20 d (N20) and stocked as PL_{10} . Ponds were stocked at a density of 35 PL/m^2 with a total culture period of 112 d.

nursery survival. Hence, if the survival in the nursery could be improved, the overall survival would be enhanced. In general, the more predictable and higher survival in ponds of nursed shrimp would be more desirable to most producers. Postlarvae are relatively cheap compared to investments of feed and time once the shrimp are stocked in growout ponds; survival determines final biomass and predicting survival influences feed input.

Another trend observed at harvest was differences in size distribution of the shrimp. The longer the nursery period, the more uniform the shrimp weight (Fig. 2). This general observation is supported by re-

gression analyses which indicated that the length of the nursery period reduced the coefficient of variation ($P = 0.09$, R -Square 0.31). Stern and Letellier (1992) also observed these same improvements in uniformity, which is important to shrimp farmers when marketing their product.

Water Quality

Salinity during the experimental period ranged from 15 to 24.5 ppt. The pH fluctuated between 6.93 and 9.16 with an average between 7 and 8 for each pond. Total ammonia-nitrogen (TAN) was consistently below 0.01 mg/L. The highest TAN value registered was 5.8 mg/L which occurred

TABLE 3. Principal water parameters for *L. vannamei* directly stocked (DS) as PL_{10} nursed for 10 d (N10) and stocked as PL_{20} or nursed for 20 d (N20) and stocked as PL_{30} . Ponds were stocked at a density of 35 PL/m^2 with a total culture period of 112 d. There were no differences between treatments ($P > 0.05$).

	Max	Min	Average
Salinity (g/L)	24.5	15	18
pH	9.2	6.9	7.5
TAN ^a (mg/L)	5.8	0.01	0.01
Temperature (C)	33	21	27.5
Visibility (cm)	78	10	20

^aTAN = Total ammonia-nitrogen.

during a phytoplankton die-off. Aeration made possible the maintenance of DO above 3 mg/L during the production cycle. Temperature ranged between 33 and 21 C. It was high in the middle of the summer, and lowest during the harvest week. The average during the whole cycle period was between 26 and 29 C. Water clarity was measured with a Secchi disk. The highest reading was 78 cm, and the lowest was 10 cm. The average range during the growing cycle was between 15 and 25 cm (Table 3).

Salinity and pH from all treatments were within recommended ranges for *L. vannamei* (Boyd 1989). Average TAN levels were acceptable; however TAN spiked in the pond which experienced a phytoplankton die-off. Because the pH was 7.48 and the temperature was 28 C at the time of the die-off, the un-ionized ammonia levels were still within acceptable ranges that have been observed in other studies such as those summarized by Somacha et al. (2002). Dissolved oxygen levels at dawn reached 3 mg/L at times, but generally levels were above 5 mg/L, which are considered to be good conditions for growth. Secchi readings were a little lower than the recommended 40–60 cm reading by Boyd (1989). These readings were due to heavy phytoplankton blooms and low water exchange. The heavy blooms resulted in large BOD's during die-offs, but heavy aeration maintained acceptable DO levels. One pond experienced a *Microcystis*

bloom, which resulted in high mortality of the shrimp; hence, this pond data was excluded from the study.

At times during the culture period, temperature may have exceeded desirable levels. Wyban et al. (1995) reported that reduced growth and feeding could be expected when pond temperature is 30 C or higher. Shrimp growth and survival in the study may have been affected by the high temperatures present during the culture period, especially in the nursery when shrimp are most fragile. We considered high temperatures a major factor for the lower survivals in three of the nursery tanks that had high temperatures of 33 C during several days. During growout, water temperatures of the ponds were between 30 and 33 C during 3 wk of the study. These high temperatures may have negatively affected shrimp growth and survival. Average growth per week was below the standard 1.0 g/wk during this period (Holtzman 1998).

Conclusion

Even though no statistical differences in survival, yield, or growth were observed between nursed and non-nursed shrimp, the trends suggest nurseries may have benefits that merit their use. As one would expect, if pond conditions are suitable, PL will initially grow faster under low density pond conditions as compared to high density nursery conditions. However, the use of a nursery allows the facilities to be more efficiently used, as higher densities are used per unit area. They also reduce the amount of time the shrimp need to be in growout ponds, which is especially important when shrimp are raised in temperate climates or in areas with problematic diseases. Trends suggest that nurseries improve survival during growout and increase size uniformity at harvest. Size uniformity after an extended nursery period could offer processing and marketing benefits. Furthermore, as it is generally easier to quantify larger shrimp, nurseries allow for an improved estimation of shrimp stocked into the growout ponds,

which aids in pond management. The positive trends indicated in this study suggest that nursing shrimp does have a positive impact on production primarily in terms of size uniformity and that work should be performed linking nursery system protocols with the growout cycle.

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