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Low-salinity, inland shrimp culture in Brazil and Ecuador

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By Alberto J.P. Nunes, Ph.D. and Colón Velásquez López, M.Sc.

Economic, disease issues move farms away from coasts



Some aquaculture farms in Latin America are being converted from tilapia production to Penaeid shrimp production. The shrimp's ability to adapt to a range of salinity allows these inland locations to work.

Penaeid shrimp inhabit many aquatic habitats, from marine through estuarine to fully freshwater environments, and their inherent ability to tolerate a broad range of salinity variations is key to their survival. Many shrimp producers are now taking advantage of this distinctive characteristic to rear some species in oligohaline or low-salinity waters with less than 1 ppt (parts per thousand) salt.

In Latin America, former tilapia farms 50 km from the closest seawater source are now in full production of Pacific white shrimp. Such inland shrimp farming close to saline river effluents is becoming more feasible due to the increased land competition, high investment costs, the spread of disease, and environmental restraints associated with coastal shrimp aquaculture development.



P. vannamei from low-salinity production.

Salinity tolerance

While some *Penaeus* species are considered stenohaline, having the ability to live within only a narrow range of salinity below that of seawater, several species are euryhaline and able to withstand sudden salinity fluctuations as great as 10 ppt. Euryhaline species include the Pacific white shrimp (*Penaeus vannamei*) and the black tiger shrimp (*P. monodon*), both recognized as strong osmoregulators.

In some Brazilian grow-out farms, white shrimp may be exposed to hyperoceanic salinity levels of around 50 ppt. In southern Ecuador, where shrimp production first started, many farms operate with salinity concentrations as low as 1 ppt.

Acclimation procedures

A major requirement for the success of low-salinity culture is the acclimation process, which shrimp must undergo before pond stocking. *P. vannamei* can achieve osmotic balance and fully acclimate to salinity environments below 1 ppt through gradual drops in environmental salinity during its postlarval stages.

Although acclimation protocols differ greatly between hatcheries and grow-out farms, shrimp survival during acclimation commonly exceeds 90 percent. In hatcheries, both the chronological and morphological age of postlarvae (PL) are used to determine their readiness to acclimation. PL must be at least eight days old to adequately withstand a reduction in salinity. PL as young as six days may also be used, although acclimation is longer, riskier and more stressful.

Gill development and osmoregulation



Oligohaline shrimp culture is practiced in ponds like this one.

Shrimp osmoregulatory capacity is related to the branched development of their gills. Gill filaments only appear in penaeids during their later mysis substages. During the early postlarval period, gills are in a rudimentary stage and only reach full development in the late postlarval phases.

In Brazil, most hatcheries operate with large rearing tanks and stocking densities of 100 to 200 PL per liter. Therefore, salinity reduction is only feasible when PL orders are high enough to compensate for the labor and time invested during the acclimation procedure. PL may be sold conditioned from 15-ppt to less than 1-ppt salinity.

In Ecuador, hatcheries acclimate PL to 5 ppt, with further acclimation completed at the farm. During the two-day acclimation procedure, tanks are drained to half their volume and seawater is diluted by gradually adding freshwater. A protocol used in Brazilian hatcheries for salinity reduction is presented in Table 1.

Nunes, Low-salinity acclimation protocol for *Penaeus vannamei*, Table 1

Salinity Range	PL ₈ or Older	Younger Than PL ₈
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35 ppt to 20 ppt	Reduce 2 ppt every 20 min	Reduce 2 ppt every 20 min
25 ppt to 15 ppt	Reduce 2 ppt every 30 min	Reduce 2 ppt every 30 min
15 ppt to 10 ppt	Reduce 1 ppt every 30 min	Reduce 2 ppt every 30 min
10 ppt to 5 ppt	Reduce 1 ppt every 30 min	Reduce 2 ppt every 2 hours
5 ppt to less than 1 ppt	Reduce 1 ppt every 1 hour	Reduce 2 ppt every 5 hours

Table 1. Low-salinity acclimation protocol for *Penaeus vannamei* in Brazilian hatcheries.

When full acclimation of PL is not possible in the hatchery, salinity acclimation takes place at the farm in round, 60,000-liter intensive nursery tanks or small 1,000-liter tanks. With both tank sizes, conservative acclimation procedures are used (Table 2), as PL osmoregulatory ability seems to decrease after PL15. Acclimation starts 24 hours after PL arrival, and may last five to nine days.

Nunes, Low-salinity acclimation protocol for *Penaeus vannamei*, Table 2

Conditioning Period	35 ppt to 1 ppt	20 ppt to 1 ppt	10 ppt to 1 ppt
Day 1	Reduce 8 ppt	Reduce 4 ppt	Reduce 2 ppt
Day 2	Reduce 8 ppt	Reduce 4 ppt	Reduce 2 ppt
Day 3	Reduce 8 ppt	Reduce 4 ppt	Reduce 2 ppt
Day 4	Reduce 4 ppt	Reduce 2 ppt	Reduce 2 ppt
Day 5	Reduce 2 ppt	Reduce 2 ppt	Reduce 2 ppt
Day 6	Reduce 2 ppt	Reduce 2 ppt	–
Day 7	Reduce 2 ppt	Reduce 2 ppt	–
Day 8	Reduce 2 ppt	–	–
Day 9	Reduce 1 ppt	–	–

Table 2. Low-salinity acclimation protocol for *Penaeus vannamei* in Brazilian growout farms. Acclimation period depends on water-salinity concentration of shipped postlarvae.

Water quality requirements

Scientists at the Harbor Branch Oceanographic Institution of Florida, USA, have conducted extensive work on the water quality requirements of *P. vannamei* grown under low-salinity conditions. Their recommended ranges agree with measurements made at an inland farm in Ecuador (Table 3).

Nunes, Recommended water quality levels for *Penaeus vannamei*, Table 3

Water Quality Variable	Recommended	Observed
pH	7.0-8.3	8.9 ± 0.4 (8.1-9.8)
Total Hardness (as CaCO ₃)	≥ 150 ppm	630 ± 139 (300-900) ppm
Calcium Hardness (as CaCO ₃)	≥ 100 ppm	128 ± 20 (100-180) ppm
Total Alkalinity (as CaCO ₃)	≥ 100 ppm	110 ± 14 (74-133) ppm
Salinity	> 0.5 ppt	1.8 ± 1.0 (0.5-5.9) ppt
Chloride	≥ 300 ppm	930 ± 540 (300-3,250) ppm

Observed values indicate mean ± standard deviation of 30 measurements in three growout ponds. Numbers in parentheses refer to minimum and maximum values.

Table 3. Recommended water quality levels for *Penaeus vannamei* culture under low-salinity conditions (Van Wyk et al., 1999), and observed values over a rearing cycle at an inland shrimp farm in Ecuador.

In addition to dissolved oxygen and temperature, hardness, alkalinity, sodium, and chloride levels are critical. Under low-salinity conditions, these variables may be restrictive because they directly interfere with crustacean osmoregulation, exoskeleton formation, and water equilibrium.

Salinity

Water can be classified according to its salinity ranges as follows: limnic, below 0.5 ppt; oligohaline, 0.5 to 0.6 ppt; mesohaline, 0.6 to 18 ppt; polyhaline, 18 to 30 ppt; and, oceanic, 30 to 40 ppt. Adult *P. vannamei* can tolerate limnic conditions for several weeks, but 0.5-ppt salinity appears to be the minimum acceptable level for their normal growth and survival. Hand refractometers do not provide an accurate reading of low-salinity waters, so farmers often mistakenly think they are rearing shrimp under full freshwater conditions when salt is present at these low concentrations.

Salinity is a measure of the total amount of inorganic salts in water, mainly chloride, sodium, sulfate, magnesium, calcium, and potassium. Chloride is the most important ion present in seawater, and thus can be used to indicate if salinity is within acceptable limits. In 35-ppt seawater, chloride concentrations can reach 19,344 ppm (parts per million). In comparison, water with 300-ppm chloride can have a salinity reading around 0.5 ppt.

Hardness and alkalinity

Hardness is a measure of the amount of calcium and magnesium in water, while alkalinity indicates the buffering capacity of the water against pH variations. In oligohaline waters, unlike seawater, calcium and magnesium can be limiting. This may result in animals with soft exoskeletons or stunted growth as a result of molting difficulties.

With alkalinity greater than 100 ppm, saltwater is also more buffered than freshwater. In semi-arid regions, however, ion concentration in water due to excessive evaporation can lead to high alkalinity in freshwater. Boyd (1990) noted that clay or loam soils often contain high amounts of calcium carbonate in contrast to sandy soils, resulting in ponds with high alkalinity levels.

In pond culture for freshwater crustaceans, 50-ppm hardness and 20-ppm alkalinity are considered the lowest acceptable limits. Water with reduced hardness and alkalinity can be adjusted by liming the soil or water.

Seasonal changes in rainfall and river runoff can cause significant water quality variations in ponds. In Ecuador, the strong influence of the El Niño phenomenon causes salinity to drop from 15 ppt to less than 2 ppt, significantly reducing alkalinity and total hardness. Although Ecuadorian farmers say this is the most productive time for shrimp farming, under continuous oligohaline conditions, rainfall must be closely monitored to keep water from reaching its lower limits.

Performance results

During low-salinity conditions in Ecuador, *P. vannamei* perform better and achieve commercial weight more rapidly than in dry periods. This appears to be associated with increased microalgae abundance and diversity, and a lower incidence of disease outbreaks. The rainy season also brings higher water temperatures as a result of the El Niño event.

From May to July 1998, in ponds located in the El Oro province, 15-g shrimp were harvested after three months of grow-out, with a mean productivity of 1.5 metric tons (MT) per hectare per crop. Although higher river discharge and rainfall increased the amount of suspended solids in pond water, the shrimp did not appear to be affected by gregarines and other parasites. *Vibrio* bacteria counts were below 100 colony-forming units per milliliter, and shrimp survival exceeded 50 percent.

In Brazil, *P. vannamei* grown under continuous oligohaline waters performed as well as under oceanic water conditions (Table 4). Despite a longer production cycle and lower survival for shrimp reared with riverine water, FCR, productivity, and final body weight were not statistically different.

Nunes, *Penaes vannamei* performance, Table 4

Culture Parameter	Oligohaline Water	Oceanic Water
Area (ha)	3.0 ± 1.7 (1.3-7.0) ^a	5.3 ± 1.9 (1.5-9.0) ^b
Stocking Density (shrimp/m ²)	30 ± 4 (22-38) ^a	26 ± 4 (20-42) ^b
Culture Period (days)	122 ± 8 (113-144) ^a	89 ± 6 (77-100) ^b
Shrimp Final Body Weight (g)	11.7 ± 1.0 (10.5-13.5) ^a	12.5 ± 1.4 (10.6-15.6) ^a
Yield (kg/ha/crop)	2,155 ± 428 (1,621-3,044) ^a	2,093 ± 541 (1,096-3,051) ^a
Shrimp Survival (%)	62 ± 12 (41-86) ^a	81 ± 9 (60-98) ^b
FCR	1.3 ± 0.1 (1.2-1.6) ^a	1.3 ± 0.1 (1.2-1.5) ^a

Ponds had no mechanical aeration. Results in parentheses refer to minimum and maximum values.

Common letters in each line denote no significant difference at the $\alpha = 0.05$ level.

Table 4. *Penaes vannamei* performance (mean ± standard deviation) in continuous oligohaline (13 ponds, < 1 ppt) versus oceanic water (14 ponds, 30 to 40 ppt) during two growout cycles in northeastern Brazil.

The energy cost of osmoregulation in penaeids appears to be very small. Even under extreme salinity conditions over 50 ppt, *P. vannamei* perform well, exhibiting only a minor detriment in food conversion efficiency.

Before stocking, shrimp are acclimated to appropriate levels of salinity in tanks.

Conclusion

Low-salinity shrimp culture is a viable and profitable alternative for areas with low water salinity or saline soil features unsuitable for agriculture or other purposes. In northeastern Brazil, there are currently 240 ha of farmed area, consisting mostly of small producers. An additional 300 ha should be in operation by the end of this year. Development of inland shrimp farms is also proceeding rapidly in Ecuador. With competition and land values intensifying in coastal areas, interest in low-salinity farming will likely continue to increase.

Note: Cited references are available from the authors.

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Authors



ALBERTO J.P. NUNES, PH.D.

Agribands do Brasil Ltda.
Paulínia, SP, Brazil



COLÓN VELÁSQUEZ LÓPEZ, M.SC.

Universidad Técnica de Machala
El Oro, Machala, Ecuador

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