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# INFLUENCE OF DAILY WATER EXCHANGE VOLUME ON WATER QUALITY AND SHRIMP PRODUCTION

*Eighth Work Plan, Honduras Research 3 (HR3)*
*Final Report*

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## ABSTRACT

Daily water exchange is a common practice in semi-intensive shrimp culture in Central America. Rationales for water exchange are to improve pond dissolved oxygen concentrations and to flush out nutrients before they reach toxic levels. However, the benefit of water exchange in semi-intensive shrimp culture has been poorly demonstrated. Two experiments were conducted in Honduras to determine the effects of daily water exchange and emergency water exchange on shrimp production, and to develop nitrogen and phosphorus chemical budgets. Ten 0.93-ha ponds located on a commercial shrimp farm were used for this completely randomized design study to test two water exchange regimes: water exchanged at 10% of pond volume per day, six days per week; and water exchanged only in response to early morning dissolved oxygen concentrations ≤ 2.0 mg $l^{-1}$. Ponds were stocked with hatchery-spawned post-larval (PL) *Peneaus vannamei* at 15 PL $m^{-2}$. A survival rate of 50% was assumed because of Taura Syndrome effects on hatchery-produced larvae. The experiment was conducted during the rainy season (109-day duration) and during the dry season (96-day duration). Gross yield of *P. vannamei* was not affected significantly by the different water exchange regimes during either the rainy season or dry season experiment. Gross yield averaged 1,060 and 997 kg $ha^{-1}$ during the rainy season, and 637 and 689 kg $ha^{-1}$ during the dry season for the daily and emergency exchange treatments, respectively. Feed conversion ratios averaged 1.45 and 1.2 during the rainy and dry season experiments, respectively. Pond water quality variables during each study were affected significantly by water exchange regime; water quality tended to be better in ponds with daily water exchange. Exchange water and feed were the two largest sources of nutrients to ponds during both seasons. Shrimp harvest accounted for 23 to 24% and 40 to 45% of total nitrogen inputs in the daily and emergency exchange treatments, respectively, while exchange discharge accounted for 56 to 69% and 16 to 22% of total nitrogen inputs, respectively. Phosphorus harvested as shrimp accounted for 13% and 18 to 24% of total phosphorus inputs in the daily and emergency exchange treatments, respectively, and water exchange accounted for 45 to 62% and 12% of total phosphorus inputs, respectively.

## INTRODUCTION

Shrimp culture in Honduras and other parts of Central America is practiced at the semi-intensive level, where final stocking rates vary from 5 to 11 shrimp $m^{-2}$, and daily water exchange rates average 10% of pond volume. In semi-intensive culture, water is exchanged primarily to correct low early morning oxygen concentrations. It is also thought to discharge metabolites which hinder shrimp growth. The benefit of water exchange has been poorly demonstrated. Some studies cast doubt on the need for water exchange in shrimp farming when aeration is used (Hopkins et al., 1993; Hopkins et al., 1994). However, semi-intensive shrimp farming in Central America uses no aeration and is firmly based on water exchange, usually on a daily basis (Teichert-Coddington, 1995). On the other hand, preliminary evidence from past experiments indicates that water exchange could be reduced without impact on shrimp production. Excessive water exchange wastes fuel, contributes to deterioration of pumps and sedimentation of water supply canals and ponds, and may increase total nutrient discharge from ponds.

The objectives of these experiments were to determine the effects of daily water exchange and emergency water exchange on shrimp production, and to develop nitrogen and phosphorus chemical budgets.

## METHODS AND MATERIALS

Ten 0.93-ha (± 0.04 ha SD) ponds located on a commercial shrimp farm on a riverine estuary of the Gulf of Fonseca, Honduras, were used for this completely randomized design study to test two water exchange regimes. Water was exchanged at 10% of pond volume per day, six days per week, or only in response to early morning dissolved oxygen concentrations ≤ 2.0 mg $l^{-1}$. In a dissolved oxygen emergency (when early morning DO was ≤ 2.0 mg $l^{-1}$), up to 25% of the pond volume was exchanged. No water exchange occurred during the first three weeks of culture. In all water exchanges, water first was discharged and then added to refill ponds. Data for all water exchange events were recorded. Total material exchange per pond during weekly water exchange was calculated by subtracting mass discharge from mass intake. The experiment was conducted during the rainy season and repeated during the dry season.

Ponds for the rainy season experiment were stocked with hatchery spawned post-larval (PL) *Penaeus vannamei* at 150,000 PL $ha^{-1}$ (15 PL $m^{-2}$) on 25 to 26 May 1997; five randomly selected ponds were stocked the first day, and the remaining five the following day. Stocking of ponds for the dry season experiment also took place over two days (15 to 16 January 1998). A survival rate of 50% was assumed because of Taura Syndrome effects on hatchery-produced larvae. Most of the mortality was assumed to occur during the first month following stocking. Shrimp in the rainy season experiment were harvested 109 days after stocking (12 to 13 September 1997) by completely draining ponds. Dry season experiment ponds were harvested by draining on 21 to 22 April 1998 (96 days after stocking). Total weight of shrimp was obtained for each pond. Mean individual weight was determined by weighing a sample of 300 shrimp per pond.

Shrimp were fed a 20% or 39% protein commercially formulated ration during each experiment at the discretion of the farm manager (Table 1). The 39% protein feed was offered when shrimp growth based on weekly sampling appeared to have stagnated. Shrimp were fed six days per week beginning on 18 June 1997 for the rainy season experiment and on 10 February 1998 for the dry season experiment. Feed rate for all ponds was based on the theoretical feeding curve for *P. vannamei*:

$$\mathrm{Log}_{10}Y = -0.899 - 0.56\mathrm{Log}_{10}X$$

where

Y = the feed rate as a percent of biomass and
X = the mean shrimp weight in grams.

Daily feed rate was calculated for individual ponds, and then averaged so that all ponds received the same quantity of feed on a daily basis. Feed was offered once daily. Shrimp growth was monitored weekly by cast net samples of each pond's population. Feed rate was adjusted weekly based on shrimp samples. Feed conversion ratio (FCR) was calculated as the weight of feed offered divided by gross yield of whole shrimp.

Water quality variables in each pond were measured weekly in pond and intake water. Intake water was sampled from supply canals, while pond water was sampled by pooling a minimum of six column samples collected at random within the pond. Pond water and replacement water samples were obtained with a column sampler. Water samples were analyzed for pH measured potentiometrically, nitrate-nitrogen by cadmium reduction (Parsons et al., 1992), total ammonia-nitrogen (Parsons et al., 1992), soluble reactive phosphorus (SRP) (Grasshoff et al., 1983), chlorophyll *a* (Parsons et al., 1992), total alkalinity by titration to pH 4.5 endpoint, salinity, and 2-d biochemical oxygen demand ($BOD_2$) at 20°C. Total nitrogen and total phosphorus were determined by nitrate and phosphate analysis, respectively, after simultaneous persulfate oxidation (Grasshoff et al., 1983). Pond chemical budgets were developed for phosphorus and nitrogen. Dissolved oxygen (DO) concentration and temperature were measured in ponds twice daily (0400 and 1600 h) at 25 cm below the water surface. Pond soils were sampled (2.5 cm-deep cores, five sub-samples per pond pooled for analysis) were analyzed for phosphorus, nitrogen, organic matter, and pH before and after the rainy season experiment following methodology given by Munsiri et al. (1995). Analyses were conducted at the Auburn University Soil Testing Laboratory.

Data were computer analyzed by unpaired t-test using the Statview 5 software package (SAS, 1998). Percent data were arcsin transformed prior to analysis. Differences were declared significant at alpha level 0.05.

## RESULTS

Pond water temperatures normally show significant seasonal variation, with lower temperatures occurring from December

Table 1. Nutrient composition and calculated protein content of formulated shrimp rations used during the rainy and dry season shrimp (*Penaeus vannamei*) production experiments in Honduras.

| Variable | Rainy Season | | Dry Season | |
|---|---|---|---|---|
| | *20% Protein* | *39% Protein* | *20% Protein* | *39% Protein* |
| Dry Matter (%) | 89.29 | 89.52 | 90.88 | 89.94 |
| Nitrogen (% of dry matter) | 3.35 | 6.29 | 3.31 | 6.40 |
| Phosphorus (% of dry matter) | 1.24 | 1.16 | 0.93 | 0.92 |
| Protein (%N x 6.25) | 20.9 | 39.3 | 20.7 | 40.0 |

Table 2. Mean (± SD) gross yield of shrimp, final weight, survival, and food conversion ratio (FCR) during the rainy and dry seasons for *Penaeus vannamei* reared in 1-ha earthen ponds with daily water exchange (10% of pond volume) or emergency water exchange (to maintain dissolved oxygen concentrations ≥ 2.0 mg $l^{-1}$) (n = 5).

| Variable | Rainy Season | | Dry Season | |
|---|---|---|---|---|
| | *Daily* | *Emergency* | *Daily* | *Emergency* |
| Gross Yield (kg $ha^{-1}$) | 1,060 ± 83.2 | 997 ± 141.5[a] | 637 ± 68.5 | 689 ± 76.6[a] |
| Individual Weight (g $shrimp^{-1}$) | 12.3 ± 1.86 | 10.7 ± 1.44[a] | 8.7 ± 0.97 | 8.4 ± 1.04[a] |
| Survival (%) | 52 ± 0.7 | 59 ± 0.4[a] | 46 ± 0.7 | 51 ± 0.9[a] |
| Feed Conversion Ratio | 1.4 ± 0.09 | 1.5 ± 0.19[a] | 1.2 ± 0.15 | 1.2 ± 0.16[a] |

[a] No significant difference between treatment means within season (*P* > 0.05).

through February (Teichert-Coddington et al., 1994). However, the El Niño effect was developed fully in Honduras during 1997 and resulted in little seasonal variation in pond water temperatures. Mean early morning water temperatures were 30.0 and 29.2°C during the rainy and dry season experiments, respectively (Figure 1). There was one storm event per season that caused a significant reduction in pond temperatures during a three- to five-day period.

Gross yield of *P. vannamei* was not affected significantly by water exchange regime during either the rainy season or dry season experiment (Table 2). Shrimp survival also did not differ significantly between treatments in either experiment and averaged 52% across both experiments (Table 2). Shrimp growth and final weight were similar for both water exchange regimes during both experiments (Table 2; Figure 2). Feed conversion ratios averaged 1.45 and 1.2 during the rainy and dry season experiments, respectively (Table 2).

Pond water quality variables during each study were affected significantly by water exchange regime (Table 3). Where differences were significant, water quality tended to be better in ponds with daily water exchange. Mean total salinity was significantly lower in ponds with daily water exchange during both seasons (Table 3). As would be expected, pond salinities were greater during the dry season (Table 3). Significantly higher concentrations of total nitrogen were measured in ponds subjected to emergency water exchange during both seasons (Table 3). During the rainy season experiment total nitrogen concentrations in ponds were similar until week 11 when concentrations increased in the emergency water exchange treatment ponds (Figure 3). Total nitrogen concentration was greater in emergency water exchange ponds throughout most of the dry season experiment (Figure 3). Significant treatment differences in total phosphorus concentrations were detected only during the rainy season experiment (Table 3). Total phosphorus began to accumulate in emergency water exchange treatment ponds beginning about week 9 of the rainy season experiment (Figure 4). No significant differences in total phosphorus were detected between treatments during the dry season, although concentrations in emergency water exchange treatment ponds were higher (Table 3; Figure 4). Mean chlorophyll *a* concentration began to increase in emergency water exchange treatment ponds beginning week 10 of the rainy season experiment, and resulted in significantly greater chlorophyll *a* concentration (Table 3, Figure 5). Dry season experiment chlorophyll *a* concentrations were more variable and did not differ significantly between treatments (Table 3; Figure 5). Mean $BOD_2$ was significantly greater in the emergency water exchange treatment during the rainy season experiment, but no significant differences were detected during the dry season experiment (Table 3). Weekly variation in mean treatment $BOD_2$ was similar to that observed for chlorophyll *a* treatment means (Figure 6). Treatment affected mean early morning DO significantly during the rainy season experiment (Table 3). Mean early morning pond DO concentrations tended to be lower in the emergency exchange treatment, especially in the latter part of each culture cycle (Figure 7).

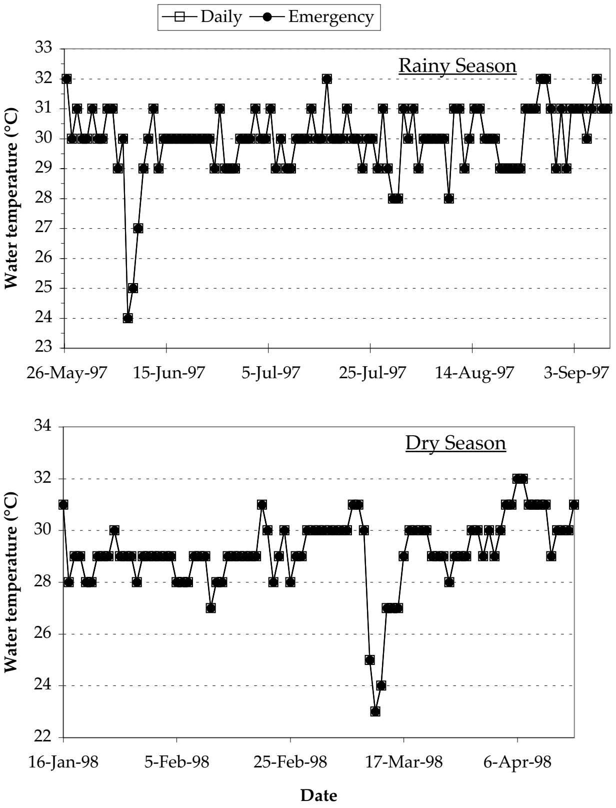

Figure 1. Mean early morning water temperature in 1-ha earthen shrimp production ponds managed with daily water exchange (10% pond volume) or emergency water exchange (to maintain dissolved oxygen concentrations ≥ 2.0 mg $l^{-1}$).

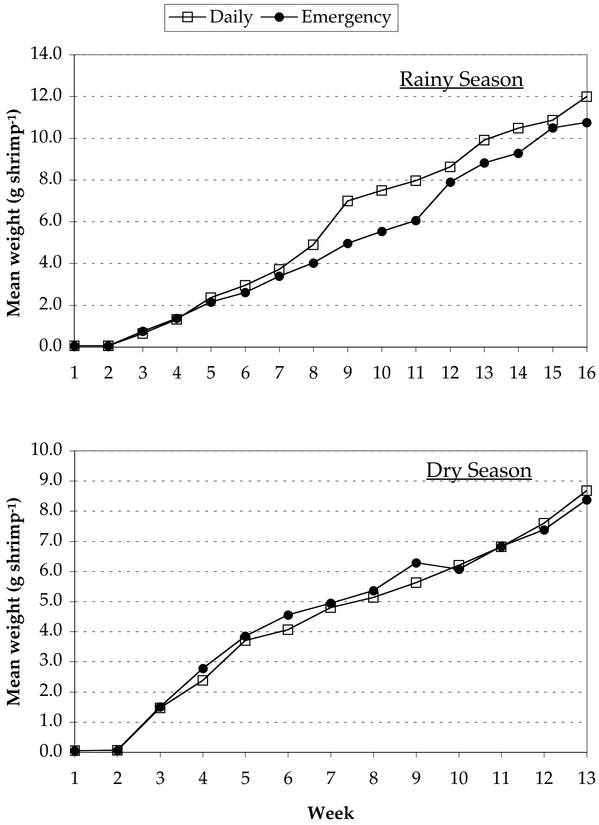

Figure 2. Growth of shrimp in 1-ha earthen ponds during rainy and dry season experiments in Honduras to test the effects of daily or emergency water exchange.

Table 3. Means (± SD) of water quality variables by treatment during rainy and dry season experiments to test effects of water exchange rates (daily or emergency) on *Penaeus vannamei* production in earthen ponds in Honduras (n = 5).

| **Variable** | **Rainy Season** | | **Dry Season** | |
|---|---|---|---|---|
| | *Daily* | *Emergency* | *Daily* | *Emergency* |
| pH | 8.6 ± 9.34 | 8.6 ± 9.22[a] | 8.5 ± 9.76 | 8.5 ± 9.43[a] |
| Salinity (g l$^{-1}$) | 19.7 ± 0.73 | 22.5 ± 0.63[c] | 34.4 ± 0.16 | 36.9 ± 0.78[c] |
| Total Nitrogen (mg l$^{-1}$) | 1.0 ± 0.02 | 1.5 ± 0.011[c] | 1.1 ± 0.11 | 1.6 ± 0.31[c] |
| Total Ammonia-Nitrogen (mg l$^{-1}$) | 0.016 ± 0.001 | 0.020 ± 0.002[b] | 0.028 ± 0.004 | 0.036 ± 0.005[b] |
| Nitrate-Nitrite-Nitrogen (mg l$^{-1}$) | .001 ± 0.0004 | 0.002 ± 0.0004[a] | 0.000 ± 0.0000 | 0.002 ± 0.004[a] |
| Total Phosphorus (mg l$^{-1}$) | 0.19 ± 0.005 | 0.27 ± 0.013[c] | 0.20 ± 0.025 | 0.26 ± 0.059[a] |
| Soluble Reactive Phosphorus (mg l$^{-1}$) | 0.09 ± 0.008 | 0.12 ± 0.009[c] | 0.08 ± 0.021 | 0.11 ± 0.040[a] |
| Total Alkalinity (mg l$^{-1}$ as $CaCO_3$) | 109.5 ± 18.47 | 129.8 ± 5.42[b] | 174.0 ± 2.59 | 191.59 ± 6.16[c] |
| Chlorophyll *a* (mg m$^{-3}$) | 19.0 ± 1.13 | 45.0 ± 11.08[c] | 14.9 ± 5.26 | 21.1 ± 7.9[a] |
| $BOD_2$ (mg $O_2$ l$^{-1}$) | 2.5 ± 0.14 | 3.8 ± 0.38[c] | 2.6 ± 0.49 | 3.4 ± 0.82[a] |
| Early Morning DO (mg l$^{-1}$) | 4.7 ± 0.07 | 4.3 ± 0.26[c] | 4.8 ± 0.39 | 4.3 ± 0.39[a] |

[a] No significant difference between treatment means within season ($P > 0.05$).
[b] Significant difference between treatment means within season ($P < 0.05$).
[c] Highly significant difference between treatment means within season ($P < 0.01$).

Nitrogen and carbon concentrations in pond sediments were higher in the final samples compared to the initial samples (Table 4). Changes in pond sediment phosphorus concentrations and pH were variable between initial and final samples (Table 4).

Exchange water and feed were the two largest sources of nutrients to ponds during both seasons (Table 5). In ponds receiving daily water exchange, exchange water provided 46 to 54% of total nitrogen input and 32 to 48% of total phosphorus input. Exchange water provided 10 to 13% of total nitrogen

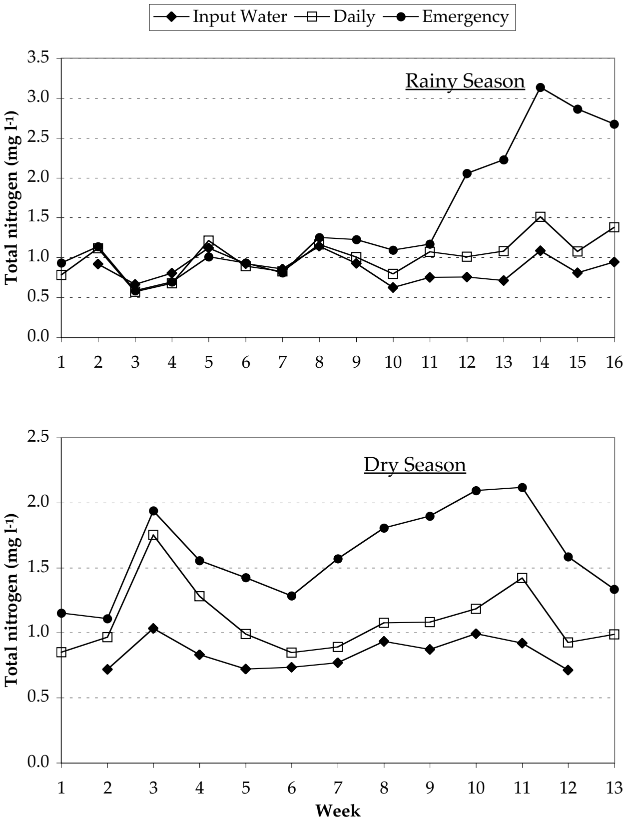

Figure 3. Mean total nitrogen concentrations in ponds [managed during rainy and dry season experiments with daily water exchange (10% pond volume) or emergency water exchange (to maintain dissolved oxygen concentrations ≥ 2.0 mg l$^{-1}$)] and in inlet water.

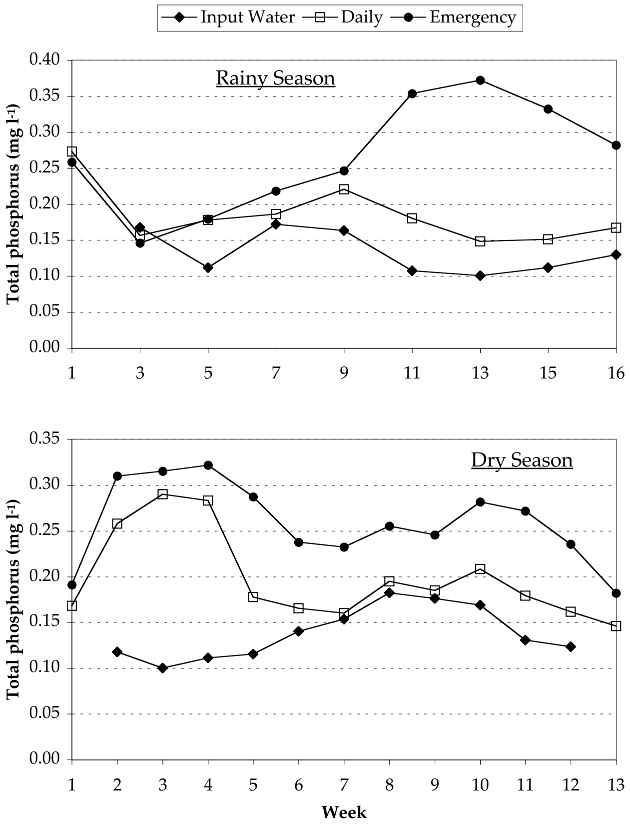

Figure 4. Mean total phosphorus concentrations in ponds [managed during rainy and dry season experiments with daily water exchange (10% pond volume) or emergency water exchange (to maintain dissolved oxygen concentrations ≥ 2.0 mg l$^{-1}$)] and in inlet water.

input and 5 to 11% of total phosphorus input in ponds in the emergency exchange treatment. Nitrogen and phosphorus inputs as feed were 36 to 48% and 42 to 59% of total inputs, respectively, in the daily exchange treatment, and 66 to 79% and 72 to 83% of total inputs, respectively, in the emergency exchange treatment. Total nutrient inputs were greater in the daily exchange treatment. Shrimp harvest accounted for 23 to 24% and 40 to 45% of total nitrogen inputs in the daily and emergency exchange treatments, respectively, while exchange discharge accounted for 56 to 69% and 16 to 22% of total nitrogen inputs, respectively. Phosphorus harvested as shrimp accounted for 13% and 18 to 24% of total phosphorus inputs in the daily and emergency exchange treatments, respectively, and water exchange accounted for 45 to 62% and 12% of total phosphorus inputs, respectively. Unrecovered nitrogen was 11% and 9 to 17% of total nitrogen inputs in the daily and emergency exchange treatments, respectively. Unrecovered phosphorus was 37 to 58% and 47 to 58% of total phosphorus

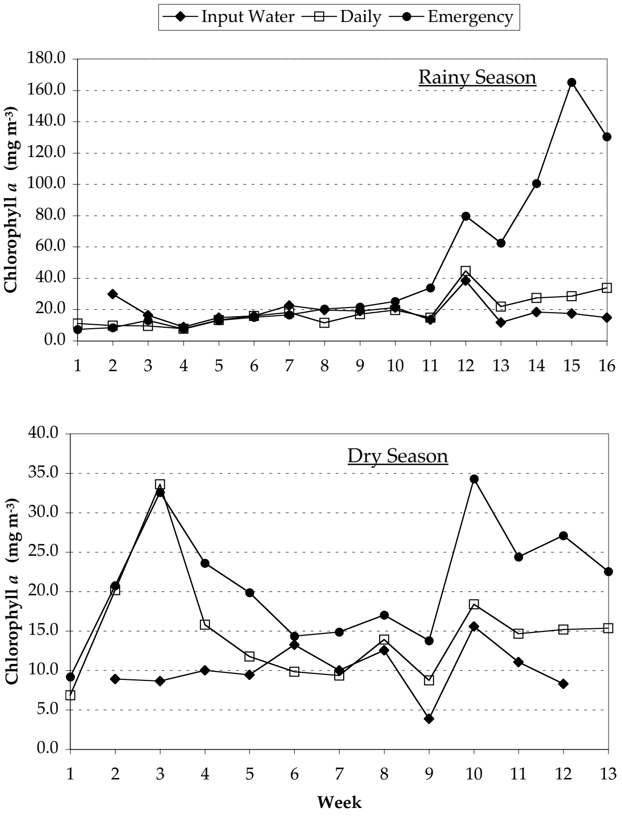

Figure 5. Mean chlorophyll *a* concentrations in ponds [managed during rainy and dry season experiments with daily water exchange (10% pond volume) or emergency water exchange (to maintain dissolved oxygen concentrations ≥ 2.0 mg l$^{-1}$)] and in inlet water.

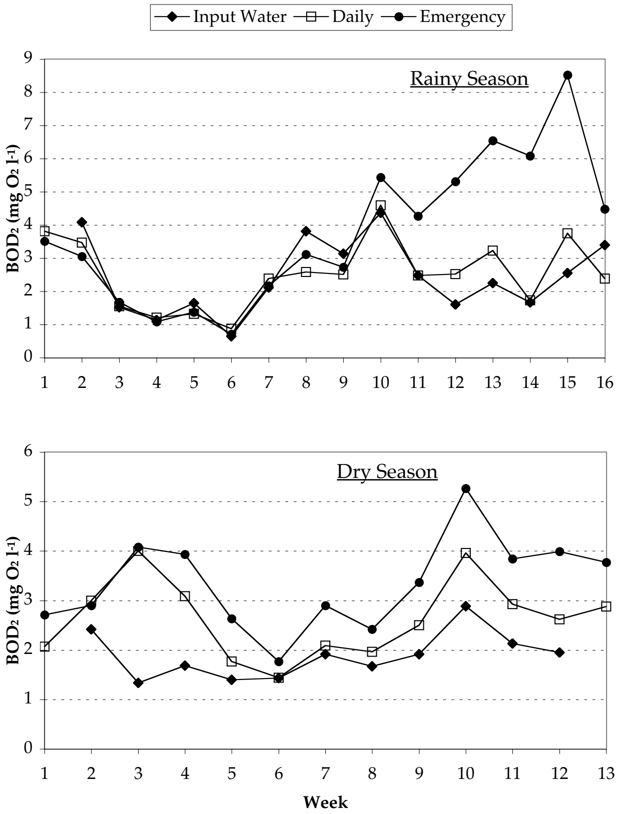

Figure 6. Mean two-day biochemical oxygen demand (BOD$_2$) in ponds [managed during rainy and dry season experiments with daily water exchange (10% pond volume) or emergency water exchange (to maintain dissolved oxygen concentrations ≥ 2.0 mg l$^{-1}$)] and in inlet water.

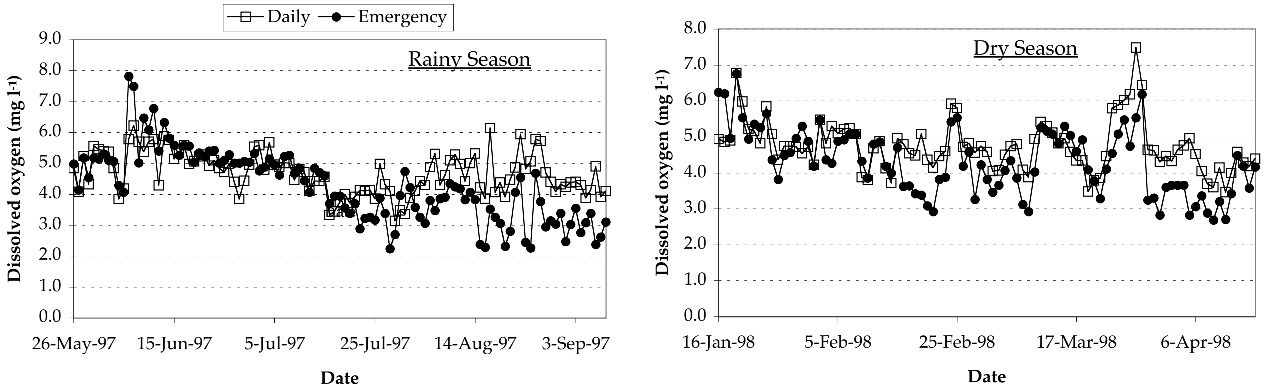

Figure 7. Mean early morning dissolved oxygen concentrations in 1-ha earthen shrimp production ponds managed with daily water exchange (10% pond volume) or emergency water exchange (to maintain dissolved oxygen concentrations ≥ 2.0 mg l$^{-1}$).

inputs in the daily and emergency exchange treatments, respectively. Nitrogen and phosphorus harvested in shrimp increased when feed was calculated as the only exogenous nutrient input into the pond. Harvested shrimp accounted for 50 to 64% and 51 to 67% of feed nitrogen, and 22 to 32% and 22 to 34% of feed phosphorus in the daily and emergency exchange treatments, respectively.

## DISCUSSION

Dry season shrimp yields were lower than rainy season yields in spite of a < 1°C difference in mean early morning water temperature. Pond salinity during the dry season experiment averaged 35 g $l^{-1}$, approximating full-strength sea water. During the final month of the dry season experiment, pond salinities were sometimes hypersaline, but never exceeded 45 g $l^{-1}$. Dry season shrimp yields in Honduras always are lower than yields obtained during the rainy season (Teichert-Coddington et al., 1994). Teichert-Coddington et al. (1994) reported that temperature and salinity affect shrimp production, but that mean monthly temperature is the most important variable affecting shrimp yields.

Shrimp gross yield, growth, survival, and feed conversion ratio were not affected significantly by water exchange regime. The principal reasons given by producers for water exchange are to correct episodes of low DO and to flush ponds of metabolites that may impede shrimp growth. Significant differences in mean water quality variables were observed during the rainy season experiment, but not during the dry season experiment. In spite of many water quality treatment means having similar magnitudes during both studies, there was greater variability in the data from the dry season, which precluded detection of significant differences. Daily water exchange during the rainy season resulted in significantly lower mean water quality variables, but gross yield did not differ significantly, although the daily exchange gross yield was about 6% higher. Mean early morning DO did differ significantly between treatments during

Table 4. Results of initial and final pond sediment analyses for the rainy season experiment. Samples of the top 2.5 cm of pond sediment were collected for analysis.

| Pond | Nitrogen (%) | | Phosphorus (mg kg$^{-1}$) | | Carbon (%) | | pH | |
|---|---|---|---|---|---|---|---|---|
| | *Initial* | *Final* | *Initial* | *Final* | *Initial* | *Final* | *Initial* | *Final* |
| VRE01 | 0.07 | 0.12 | 106.46 | 50.35 | 0.71 | 1.06 | 7.55 | 7.34 |
| VRE02 | 0.06 | 0.19 | 103.30 | 88.43 | 0.76 | 1.44 | 7.55 | 7.27 |
| VRE03 | 0.09 | 0.17 | 67.26 | 85.46 | 0.99 | 1.26 | 7.46 | 7.14 |
| VRE04 | 0.05 | 0.13 | 105.16 | 102.18 | 0.64 | 1.05 | 7.03 | 7.35 |
| VRE05 | 0.05 | 0.10 | 113.14 | 82.12 | 0.63 | 1.06 | 7.56 | 7.24 |
| VRE06 | 0.13 | 0.19 | 77.84 | 63.54 | 1.15 | 1.39 | 7.35 | 7.22 |
| VRE07 | 0.14 | 0.18 | 49.61 | 60.20 | 1.22 | 1.41 | 7.17 | 7.35 |
| VRE08 | 0.12 | 0.20 | 57.78 | 82.30 | 1.05 | 1.40 | 7.20 | 7.02 |
| VRE09 | 0.10 | 0.19 | 68.93 | 63.54 | 1.05 | 1.36 | 7.19 | 7.29 |
| VRE10 | 0.16 | 0.20 | 55.18 | 63.17 | 1.37 | 1.61 | 7.08 | 7.38 |

Table 5. Mean gains, losses, and unrecovered quantities (in kg) of nitrogen and phosphorus in 1-ha earthen shrimp (*Penaeus vannamei*) production ponds managed with daily water exchange (10% pond volume) or emergency water exchange (to maintain dissolved oxygen concentrations ≥ 2.0 mg $l^{-1}$) (n = 5).

| Variable | Rainy Season | | | | Dry Season | | | |
|---|---|---|---|---|---|---|---|---|
| | *Daily* | | *Emergency* | | *Daily* | | *Emergency* | |
| | Nitrogen | Phosphorus | Nitrogen | Phosphorus | Nitrogen | Phosphorus | Nitrogen | Phosphorus |
| GAINS | | | | | | | | |
| Shrimp Stock | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Canal Water | | | | | | | | |
| Initial Flooding | 8.36 | 2.34 | 7.89 | 2.20 | 7.73 | 1.54 | 9.27 | 1.54 |
| Exchange Inflow | 61.52 | 9.01 | 7.85 | 1.00 | 45.13 | 7.65 | 6.20 | 1.01 |
| Feed | 63.32 | 16.52 | 59.54 | 15.53 | 29.95 | 6.51 | 30.54 | 6.64 |
| LOSSES | | | | | | | | |
| Shrimp Harvest | 31.89 | 3.70 | 30.22 | 3.44 | 19.01 | 2.10 | 20.51 | 2.24 |
| Pond Water | | | | | | | | |
| Exchange Discharge | 74.56 | 12.55 | 16.47 | 2.17 | 56.76 | 9.74 | 7.14 | 1.08 |
| Draining | 11.75 | 1.42 | 21.94 | 2.35 | 9.28 | 1.43 | 10.75 | 1.55 |
| UNRECOVERED | 15.00 | 10.20 | 6.65 | 10.78 | -2.23 | 2.44 | 7.61 | 4.32 |

the rainy season and was lower in the emergency exchange treatment during the later part of the production cycle that corresponded to an accumulation of nutrients in ponds. Fewer water quality treatment differences during the dry season experiment may be related to the lower quantity of feed used and to the nutrient load in exchange water. The absence of significant differences in shrimp production and the presence of significant treatment differences in water quality variables do not demonstrate conclusively that daily water exchange is not beneficial. Certainly as practiced, beginning several weeks after pond stocking, water exchange is not being employed optimally. Water exchange did have a significant impact on water quality variables during the last four to six weeks of the rainy season culture period. Relying strictly on emergency water exchange will be perceived by producers as too risky, especially since water quality deterioration occurs in the latter part of the production cycle when producers have the greatest investment in their crop. A compromise solution would be to delay initiation of daily water exchange until week 10 of the production cycle.

Feed and exchange-water nitrogen and phosphorus inputs as a percent of total inputs in daily water exchange treatment ponds were similar to results reported previously (Teichert-Coddington et al., 1996; Green et al., 1997). Inputs of feed and exchange-water nitrogen as a percent of total inputs in emergency exchange treatment ponds were similar to data reported for ponds with no water exchange (Boyd, 1985; Daniels and Boyd, 1989). Total nitrogen and phosphorus inputs in emergency exchange ponds were 40 to 45% and 30 to 40% lower, respectively, than in daily exchange ponds because of the reduced nutrient load in the exchange water. Greater quantities of nutrients are added to and discharged from ponds when water exchange occurs on a daily rather than emergency basis.

## ANTICIPATED BENEFITS

Results of these experiments demonstrate that water exchange regime does not significantly affect shrimp production, but can result in significant reduction in some water quality variable concentrations. These data support reduced water exchange frequency for semi-intensive shrimp culture in Honduras, which will reduce nutrients added to and discharged from ponds and will reduce pumping costs.

## ACKNOWLEDGMENTS

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