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Water Quality Dynamics in Brackishwater Shrimp Ponds with Artificial Aeration and Circulation*

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Abstract

Water aeration and circulation using paddlewheel aerator and motor-driven propeller blades, respectively, were maintained under four different diurnal regimes to test their effects on water quality and production of *Penaeus monodon*. Shrimp with an average weight of 0.03 gm were stocked at a density of 33 individuals/m^2 in four 0.05-ha earthen ponds. The four treatments were: (1) continuous aeration (2) nighttime aeration (3) nighttime aeration at a daytime circulation and (4) no aeration or circulation. Ammonia nitrogen (NH_3-N), dissolved oxygen, temperature and shrimp growth were monitored during a culture period of 10 weeks. Ammonia nitrogen concentration did not differ significantly under the various aeration and circulation treatments. Dissolved oxygen and temperature stratification was least evident in treatments 1 and 3. Nighttime dissolved oxygen levels were significantly lower in treatments 1 and 4. The average size of shrimp at harvest was significantly higher in treatments 1 and 3. These findings taken together indicated that there was no clear benefit from continuous aeration. Rather, a combination of nighttime aeration, when needed, and daytime circulation could result in the greatest water quality benefits with the least energy consumption.

Introduction

The effects of different combinations of continuous and intermittent artificial circulation/aeration on water quality and shrimp growth are not well documented. Many types of artificial aeration and circulation are used in intensified shrimp farming, but their respective impacts on such factors as dissolved oxygen concentrations and ammonia are not well known. For example, many shrimp farmers use paddlewheel aeration during nighttime only to prevent critically low dissolved oxygen concentration, while other farmers use continuous aeration after the shrimp reach a certain biomass.

Continuous aeration appears at first to be self-defeating as oxygen is typically supersaturated at midday. Such aeration strips oxygen from the water column during the day until equilibrium is reached at 100% saturation. The benefits of daytime aeration, if there are any, may be due to other factors as oxygen is not the only dissolved gas affected by aeration. Ammonia gas, or un-ionized ammonia, is also affected and should be removed from the water by aeration. This is particularly true during periods of elevated pH and water temperature. Even without aeration a substantial amount of ammonia is degassed from eutropic waters.

Conditions of high pH and temperature are found at midday, especially when oxygen values are greatest. Thus, the time of the day when aeration can remove the greatest amount of dissolved ammonia coincides with the time of the day when aeration can also remove the greatest amount of oxygen. The benefits of ammonia removal could outweigh the negative effect of oxygen removal. If this is the case, then continuous aeration under intensive culture conditions could be a better water quality management strategy than nighttime aeration only.

Fast et al. (1983) found that artificial circulation, without aeration, caused a redistribution of oxygen throughout the water column, but did not materially affect the exchange of oxygen between the pond water and the atmosphere. This should result in the conservation of dissolved oxygen within the pond. At the same time, it might also reduce the loss rate of ammonia, or at least result in less ammonia loss compared with aeration, or even compared with an undisturbed condition.

Because of these unknown and potentially opposing influences of artificial aeration on water quality, this experiment was designed to determine the respective effects of aeration and circulation on dissolved oxygen, temperature and ammonia concentration.

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Materials and Methods

Four 500-m^2 ponds were treated as follows: treatment 1. continuous aeration, 24 hr/day; treatment 2. nighttime aeration only from 2100-0600 hr; treatment 3. nighttime aeration from 2100-0600 hr and daytime circulation from 0600-2100 hr; treatment 4. control with no aeration or circulation.

The aerator consisted of a 0.5 hp paddlewheel similar in design to those used in Taiwan. The two paddles 0.6 m dia revolved at 138 rpm. The circulator was a 1/8 hp similar in design to the PC-11 described by Fast et al. (1983). It consisted of 40-cm fan blade which revolved at 86 rpm.

Each pond was dried before the experiment. No lime or chicken manure was added as the shrimp were given a complete artificial diet. The ponds were then filled with water to 1.0 m and stocked with *Penaeus monodon* on 25 February 1985 at 33/m^2. Their average weight was 0.03 g. Every two weeks 80% of the water was changed, the pond depth maintained at 1 m.

Oxygen and temperature were measured 5 times/week at 0400, 1000, 1400 and 1700 hr daily with a YSI model 51B oxygen meter. The pH was also measured 5 times/week with a Corning pH meter. Chlorophyll was measured twice/week by acetone extraction as described by Strickland and Parsons (1976). Ammonia was measured twice/week by the phenol hypochloride and ascorbic acid methods described by Strickland and Parsons (1976).

Shrimp were sampled and weighed every two weeks. After 63 days, on 3 March 1985, the ponds were drained and the total weight of the shrimp measured along with a subsample of individual weights.

Results and Discussion

Average whole pond temperatures for all dates were lowest at 0400 hr and highest at 1400 hr. The averages for all the ponds were 27.3 and 30.4°C, respectively (Fig. 1 and Table 1). This represents a 3.1°C temperature fluctuation per day. On the average, the control pond was slightly warmer than the treatment ponds. The reason for this is unknown, but it could be due to a high water flushing rate caused by uncontrolled leaks.

The differences in temperature between the pond surface and the bottom water is a measure of the degrees of thermal stratification. The temperature differences between treatments at 0400 hr showed no significant differences (Table 2). This reflects not only the influence of the aerators in the three treatment ponds during the night, but also the effects of diurnal cooling and mixing which occurred each night. By 1000 hr there were no significant differences between surface and bottom temperatures in treatment 1, while in all the other treatments there were significant temperature differences between the surface and the bottom (Table 2). In treatment 3 there was a significant temperature difference, although at a lower probability level ($P = 0.05$).

By 1400 and 1700 hr there was a highly significant difference in surface and bottom temperatures in treatments 2 and 4 but none in treatments 1 and 3.

These results substantiate earlier findings by Fast et al. (1983) in Hawaii where artificial circulation resulted in nearly uniform water temperatures throughout the pond, from surface to bottom, during the day in contrast with the substantial thermal stratification without circulation. Mixing raised the temperature at the pond bottom, resulting in evenness.

Average dissolved oxygen (DO) concentrations in all ponds for all dates closely paralleled the pattern for temperature. The lowest values for all ponds averaged 4.4 mg/l at 0400 hr and 9.6 mg/l at 1400 and 1700 hr (Table 3 and Fig. #2). All the ponds aerated during the night had higher DO at 0400 hr than the control. Treatment 1 with daytime aeration had lower DO than treatments 2 and 3 with nighttime aerations (8.8 vs. 9.7 mg/l). These results follow the hypothesis that daytime aeration will result in oxygen loss from those ponds that reached supersaturation during the day as artificial aeration causes oxygen concentrations to change towards 100% saturation regardless of whether the water is undersaturated or supersaturated.

Also of interest is the observation in treatment 3 which has daytime oxygen concentration similar to those of treatments 2 and 4. This confirms that daytime circulation does not materially effect oxygen exchange between the atmosphere and water, but only eliminates thermal stratification. Fast et al. (1983) also observed elevated daytime bottom oxygen and temperature during artificial circulation.

With the exception of treatment 1, the average differences in oxygen concentrations between the surface and the bottom follow exactly the same trend as did the surface/bottom temperatures (Table 4). We have no explanation for this significant difference.

The greatest significant difference between surface and bottom oxygen values occurred at 1400 and 1700 hr. There was no significant difference between surface and bottom oxygen concentrations in the aerated/circulated ponds at these times, but non-aerated/circulated ponds had significant stratification. These results also follow those reported by Fast et al. (1983) where non-mixing often resulted in strong oxygen stratification and lower oxygen concentrations at the pond bottom. The exception was when wind velocities exceeded about 20 km/hr, at which time even the ponds which were not artificially aerated/circulated had nearly uniform oxygen concentrations.

Whole pond average pH values were always lowest at 0400 hr at 8.0, and greatest at 1700 hr at 8.4. There did not appear to be much difference between treatments.

Whole pond average ammonia concentrations were lowest in the pond with continuous aeration, and next lowest in the pond with nighttime aeration and daytime circulation. These values were 0.044 and 0.055 mg/l, respectively, compared with 0.065 and 0.061 mg/l for the ponds which were not aerated/circulated during the day (Table 5). Although these values are consistent with the

hypothesis that daytime aeration/circulation will cause a greater atmospheric loss of ammonia than the non-circulated condition, the difference was not statistically significant ($P > 0.05$). These findings, while somewhat inconclusive, are difficult to assess strictly since there was a great deal of variability in our ammonia data. This variability may be due to the dynamic nature of ammonia, as well as analytical limitations at these relatively low concentrations. It can be concluded, however, that aeration/circulation under the test conditions used did not cause a significant reduction in ammonia concentrations.

Chlorophyll A values were highest in the pond with continuous aeration and lowest in the control. The values were 99.02 and 53.05 mg/l respectively (Table 6). Even with this range, analysis of variance revealed no significant difference between treatments, perhaps due to the large variation of concentration between sampling days.

Average shrimp size at harvest ranged from 2.1 g in the control to 2.8 g in treatment 1 and in treatment 2 (Table 7). There was no significant difference between treatments 2 and 3 or between the control and treatment 3. These results indicate that aeration/circulation contribute to faster growth compared to the undisturbed condition, but these are not conclusions because of lack of replication and the insignificant differences between the control and treatment 3.

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Table 1. Whole pond average water temperature (°C) for each treatment, 4x day.

Treatment	Sampling period (hr) 0400	1000	1400	1700
1	27.3	28.2	30.2	30.3
2	27.2	28.2	30.2	30.3
3	27.2	28.3	30.4	30.3
4	27.5	28.8	30.9	30.8

Table 2. Average temperature (°C) of pond surface and bottom at sampling times.

Sampling period	Treatment	F-test
0400 hr	1	n.s.
	2	n.s.
	3	n.s.
	4	n.s.
1000 hr	1	n.s.
	2	**
	3	*
	4	**
1400 hr	1	n.s.
	2	**
	3	n.s.
	4	**
1700 hr	1	n.s.
	2	**
	3	n.s.
	4	**

n.s. = not significant; ** = $P < .01$; * = $.01 < P < .05$.

Table 3. Average dissolved oxygen (ppm) for each treatment 4x day.

Treatment	Sampling period (hr) 0400	1000	1400	1700
1	4.4	7.0	9.0	8.8
2	4.5	6.9	9.7	10.0
3	4.8	7.1	9.8	10.0
4	3.7	6.1	9.5	9.6

Table 4. Average dissolved oxygen (ppm) at pond surface and bottom at sampling times.

Sampling period	Treatment	F-test
0400 hr	1	**
	2	n.s.
	3	n.s.
	4	n.s.
1000 hr	1	n.s.
	2	**
	3	*
	4	**
1400 hr	1	n.s.
	2	**
	3	n.s.
	4	*
1700 hr	1	n.s.
	2	**
	3	n.s.
	4	**

n.s. = not significant; ** = $P < .01$; * = $.01 < P < .05$.

Table 5. Average ammonia concentrations.

Treatment	mg/l
1	0.044
2	0.065
3	0.055
4	0.061

F computed = 0.6073 < F (0.05; 3.39 d.f.) = 2.89 n.s.

Table 6. Average chlorophyll A concentrations.

Treatment	mg/l
1	99.02
2	84.30
3	63.02
4	53.05

F computed = 2.083 < F (.05; 3.39 d.f.) = 2.89 n.s.

Table 7. Average weight of shrimps at harvest.

Treatment	gm	P < .05	P < .01
1	2.82	a	a
2	2.79	a	ab
3	2.36	b	abc
4	2.09	b	c

F computed = 7.026 < F (.01; 3,396) = 3.78 **

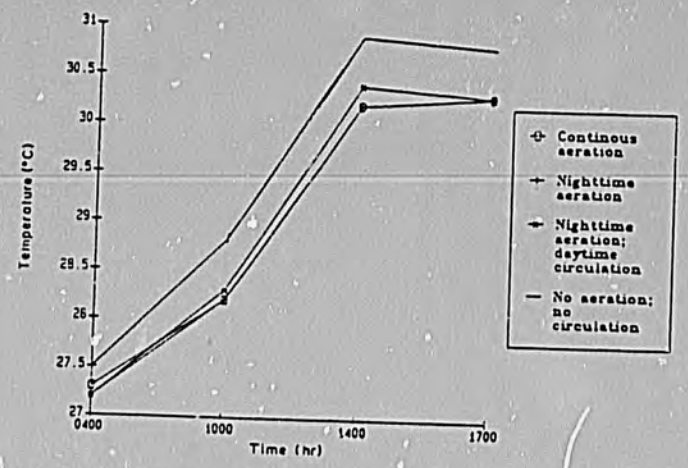

Fig. 1. Average temperature level at different sampling periods.

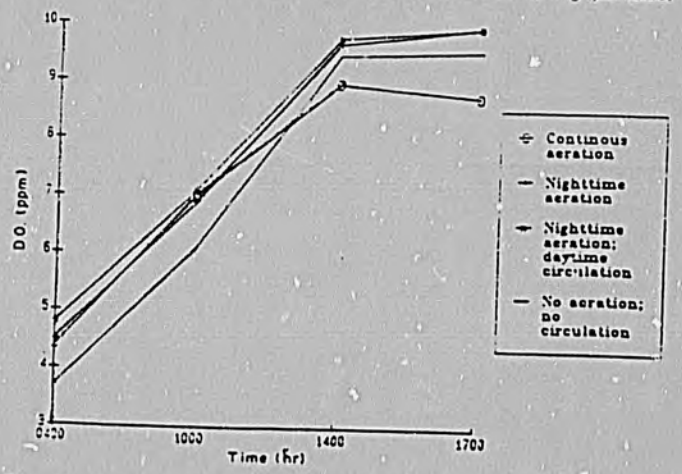

Fig. 2. Average dissolved oxygen level at different sampling periods.

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