Use of aspirator-type and paddlewheel aerators in membrane-lined shrimp ponds operated under limited discharge

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Targeting higher shrimp biomass in intensive shrimp ponds requires supplemental aeration to maintain adequate dissolved oxygen (DO) levels and to strip out carbon dioxide (Peterson and Pearson 2000). The aeration technologies can be adopted to increase DO levels in the pond water and help reduce water quality problems that can result in poor shrimp performance. To increase biosecurity, minimize the risk of losing crops due to disease outbreaks and to reduce potential negative environmental impacts from effluent water on receiving streams, producers and researchers are developing shrimp culture technologies for limited discharge or closed recirculating systems (Hopkins *et al.* 1995, 1996; Samocha *et al.* 2002, 2004). In ponds operated with limited discharge, aeration and mixing devices have been used to suspend particulate matter and enhance the development of bacterial flocs in the water column (Rogers 1989, Avnimelech and Ritvo 2001). These bacterial flocs help in the nitrogen cycling process and provide a supplemental food source for the cultured animals in the ponds (Avnimelech *et al.* 1992). Aeration devices being used in shrimp culture operations include pump sprayers, propeller aspirator-pumps, paddlewheels and diffused air systems.

Paddlewheel aerators are the most common devices used by shrimp farmers all over the world and there is abundant literature on the aeration efficiency of these devices. On the other hand, the use of propeller aspirator-type aerators are not very common in shrimp farming and the literature concerning the aeration efficiency of those devices is limited. Stationary paddlewheel aerators are normally placed in ponds parallel to the dikes, which create an elliptical or radial water flow resulting in rapid flow conditions at the periphery and causing stagnant conditions in the center (Avnimelech 1995, Peterson and Muir 1999, Peterson 2000). In a recent study, Delgado *et al.* (2003) found that the oxygen levels at the inner bottom regions of the ponds were <2.0 mg/L during the peak culture period. This observation suggests horizontal oxygen stratification with a well-mixed outer region because of the higher water speed compared to the poorly mixed inner bottom center region due to low water speed.

In case of shrimp culture ponds, both the vertical and the horizontal stratification have been observed. Shrimp tend to avoid the inner pond zones especially during the night. To break the oxygen stratification in the inner center zone in a pond, the present study used aspirator-type aerators along with the paddlewheel aerators.

The primary parts of an aspirator-type aerator are a motor, a hollow shaft with an orifice at the end and an impeller that is attached to the rotating shaft. Usually, aerators are mounted on PVC floats with the motor above the water surface, though some aspirator-type aerators may have a submerged motor. In operation, the impeller accelerates the water to a velocity high enough to cause a drop in pressure within the hollow shaft. Air is forced down the shaft by atmospheric pressure and fine bubbles enter the turbulent water around the impeller through the orifice. The propeller motion helps spread the oxygen-rich water in the pond. On the other hand, the paddlewheel aerator is a mechanical device which splashes water into the air. This splashing increases the DO content of this water by putting large volumes of water in direct contact with the atmosphere. The continued motion of the paddlewheel helps disperse this oxygen-enriched water in the pond.

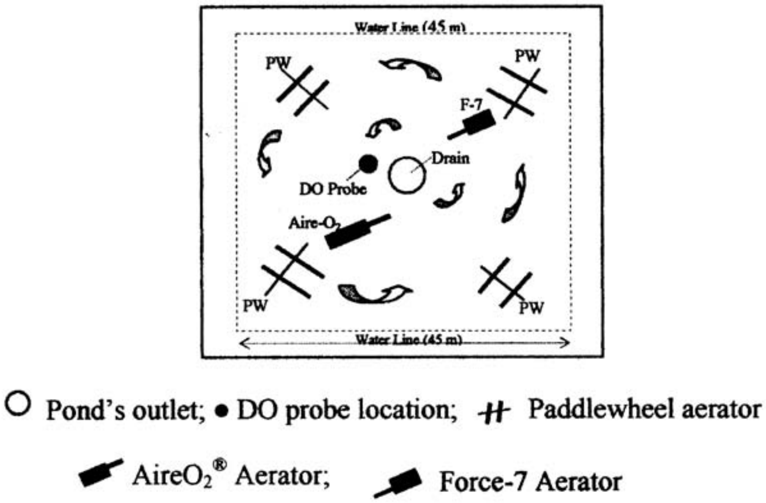
Objective of the Study

The present study was designed to compare the performance of paddlewheel aerators and two types of aspirator-type aeration devices; namely, the Aire-O_2®[2] and Force-7[3] in membrane-lined shrimp ponds stocked with the Pacific white shrimp, *Litopenaeus vannamei*, and operated with limited discharge.

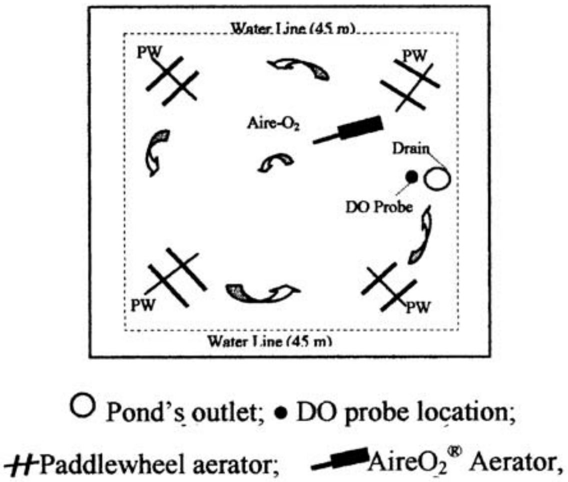
Testing

Three outdoor HDPE-lined ponds (2,050 m^3 volume and 2,000 m^2 water surface area) at the Texas Agriculture Experiment Station, Shrimp Mariculture Research Facility, Corpus Christi, Texas USA were used for the study. All ponds were stocked with juvenile shrimp (average weight 0.8 g). Two ponds were stocked at a density of 90 shrimp/m^3 (92/m^2) while the third was stocked at 47 shrimp/m^3 (48 shrimp/m^2). Feed was distributed manually four times a day, seven days a week. Feed rations were adjusted weekly based on predicted growth and survival assuming an FCR of 1:1.5. Except for emergency releases due to heavy rains, no water was discharged from the ponds. Municipal freshwater was added when needed to offset evaporation losses and to maintain salinity. The pond stocked at the low-density was harvested 129 days after stocking while the other two ponds were harvested 138 days after stocking. Four paddlewheel aerators along with one Aire-O$_2$® and one Force-7 aspirator-type aerators were installed in each of the high-density ponds while the low-density pond was equipped with four paddlewheel aerators and one Aire-O$_2$®. The paddlewheel aerators were positioned across the corners in both ponds at a distance of about 6 m from the levee to create water current parallel to the levees and a circular gyre in the pond. The Aire-O$_2$® and Force-7 were positioned at a distance of approximately 15-17 m from the pond levees close to the center drain to enhance circular flow and suspension of the particulate matter in each pond (Drawing 1). The Aire-O$_2$® unit in the low-density pond was positioned to direct flow towards the center of the pond (Drawing 2). Each of the paddlewheel and the AireO$_2$® aeration devices used in the study had equal power requirements of 2 hp while the Force 7 aeration unit had a nominal power requirement of 1.5 hp. The aeration performances of the three aeration devices were evaluated late in the study period when shrimp biomass and organic load in the system were high enough to demonstrate the effects of each aeration component.

Drawings 1 and 2 show the aerator configuration, pond outlet location and the positioning of the dissolved oxygen probe in the high-density and the low-density ponds, respectively. Preliminary monitoring of DO levels in different locations in each pond showed similar patterns. The DO data reported here are from readings made near the drain outlet in each pond. The DO monitoring probe (DataSonde® 4[4]) was positioned close to the pond outlet at the center in high-density ponds (Drawing 1) while in the low-density pond it was positioned near the outlet located about 4 m from the levee (Drawing 2). The DO probe was positioned 25-30 cm above the pond bottom. The instrument was programmed to record the DO every 30 min starting at 1600 until 0830 the following morning. Table 1 summarizes



Drawing 1. Diagram showing the location of the aeration devices and the dissolve oxygen probe in the high-density ponds.



Drawing 2. Diagram showing the location of the aeration devices and the dissolve oxygen probe in the low-density pond.

the combinations of paddlewheels, AireO$_2$® and Force-7 aspirator-type aerators evaluated in this study.

Study Results

The DO concentrations were plotted to show changes over time. The discussion and conclusions are based upon the DO patterns generated by the different aeration devices positioned in the same pond under similar environmental conditions. Furthermore, only readings from consecutive nights were included in the analyses. Some of the salient features of the study are summarized below.

Comparison of aerator combinations on equal power basis

Comparing the DO levels using different aerators at the same energy input, the results show that DO levels were higher in case of a combination which included two paddlewheels and one AireO$_2$® (total power input = 6 hp) versus tree paddlewheels without the AireO$_2$® (Figures 1, 2 and 3).

Similar results were also observed when a combination of three paddlewheels and one AireO$_2$® (total 8 hp) were compared to four paddlewheels (total power input of 8 hp) as shown in Figures 4 and 5. The paddlewheels in combination with Force-7 also show higher DO compared to paddlewheels alone under the same number of aeration units (Figures 4 and 6).

Dissolved oxygen fluctuations

The DO levels showed a greater degree of fluctuation in the case of a combination of paddlewheels alone compared to a combination of paddlewheels with any of the aspirator-type aerators (Figures 1-5). The DO fluctuations were to the extent of nearly ±1 mg/L. This trend was observed when three or four paddlewheel combinations were used without aspirator-type aerators (Figures 1 and 4). The changes in DO levels over a 24 h period were gradual when paddlewheel aerators were used in combination with the AireO$_2$® or Force-7 aerators (Figures 3 and 4).

Comparison between AirO$_2$® and Force-7 aerators

The data suggest that the AireO$_2$® aerator in combination with paddlewheels outperformed the Force-7 when operated with paddlewheels (Figure 6). Nevertheless, one should make note that the Force-7 unit had a lower power input. Furthermore, operating paddlewheels together with AireO$_2$® and Force-7 showed better DO levels under equal number of aeration devices (Figure 6) compared to other combinations.

The paddlewheel undoubtedly helps to increase the dissolved oxygen levels in the pond periphery, or outer region, but the propulsive water jet from the aspirator-type aerators shoot the water in an angle, thereby helping mix the water to a greater extent in the inner zone. These preliminary results suggest that under the conditions of this study, the use of paddlewheel aerators in combination with aspirator-type aerators resulted in increased DO levels in the ponds and required less energy than the use of paddlewheels alone. In addition, the use of paddlewheel and as-

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Table 1. The aerator combinations evaluated for their performance in lined shrimp ponds operated with limited discharge.

Aerator Combinations	Aerator Combinations	Aerator Combinations
3 PW[a] (6 hp)	2 PW + 1 AireO$_2$® (6 hp	
4 PW (8 hp)	3 PW + 1 AireO$_2$® (8 hp)	
2 PW + 1 AireO$_2$® (6 hp)	2 PW + 1 Force-7 (6 hp)	1 PW + AireO$_2$®, + 1 Force-7 (6 hp)

[a]PW = paddlewheel aerator

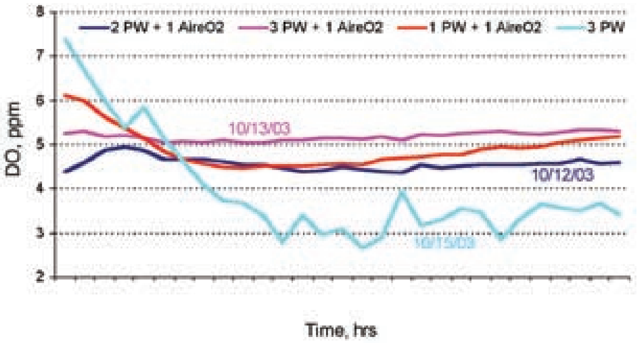

Fig. 1. Dissolved oxygen patterns of different aerator combinations.

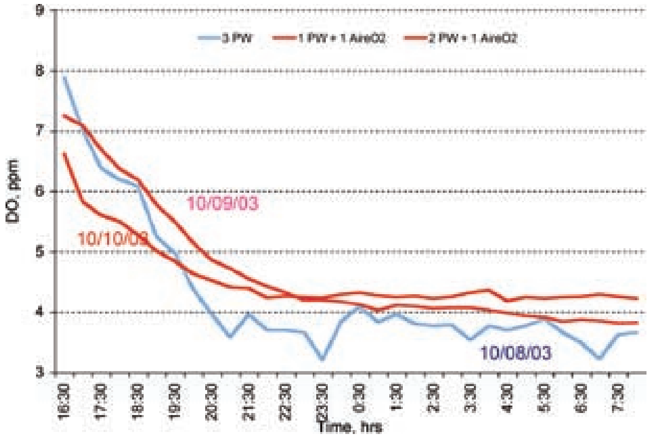

Fig. 2. Dissolved oxygen patterns of different aerator combinations.

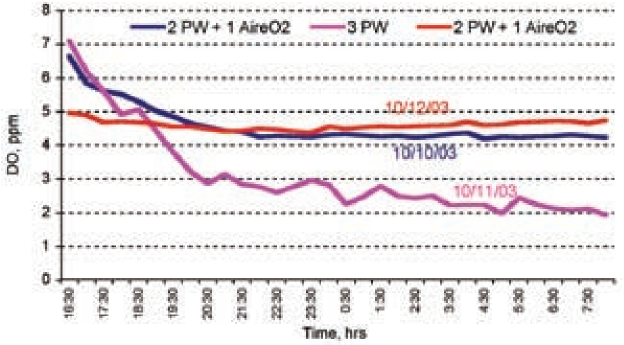

Fig. 3. Dissolved oxygen patterns of different aerator combinations.

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pirator-type aerators significantly reduced DO fluctuations in the ponds compared to paddlewheel aerators alone.

Conclusions/Recommendations

The DO data were collected during the most critical period of the shrimp culture cycle, fourth quarter. Monitoring was conducted at night when DO levels play a crucial role in shrimp performance. The data collected suggest that the use of paddlewheel aerators alone may not be the optimal solution to maintain adequate DO in ponds during the critical hours of the night. Use of the paddlewheel together with aspirator-type aerators can provide higher DO levels at reduced energy input/cost in ponds operated under limited discharge. Any combination of paddlewheels with AireO$_2$® or Force-7 aerators produced higher DO levels than a combination of paddlewheels without aspirator-type aerators under similar energy inputs. Paddlewheel combinations with any of the aspirator-type aerators provided a stable DO pattern over a period of time whereas the paddlewheels without aspirator-type devices showed a greater degree of fluctuation in DO levels (±1 mg/L over half an hour period). Paddlewheels combined with a AireO$_2$® showed higher DO levels than when combined with a Force-7 aerator. However, since the nominal power requirement of the Force-7 unit used in this study was only 1.5 hp, another study is needed on an equal power basis to determine differences between the two devices.

Notes

[1] Texas Agricultural Experiment Station, Shrimp Mariculture Research Facility, 4301 Waldron Rd. Corpus Christi Texas, 78418 USA.

[2] Aire-O$_2$ Series II aerator 3 phase, 230/460 V - 60 Hz, 2 hp with TEFC 1.15 s.f. motor made by Aeration Industries International, Inc., Chaska, Minnesota USA.

[3] Model 7.1T, 3 phase, 220 V - 60 Hz, 1.5 hp, made by AquaEco®, Cadelbosco Sopra, Italy.

[4] Hydrolab Corporation, Austin, Texas USA.

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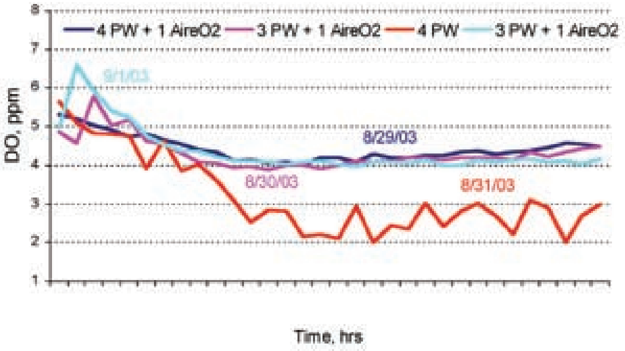

Fig. 4. Dissolved oxygen patterns of different aerator combinations.

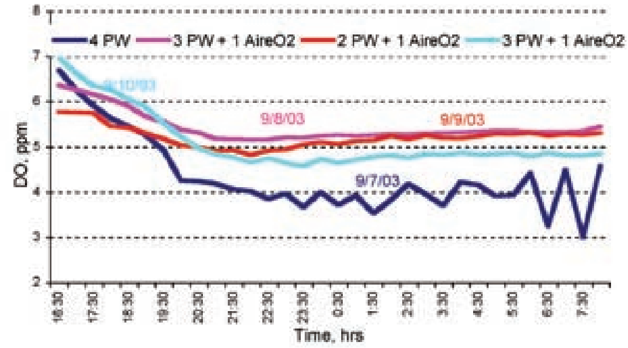

Fig. 5. Dissolved oxygen patterns of different aerator combinations.

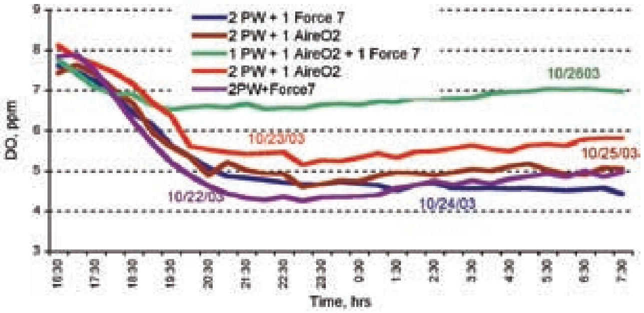

Fig. 6. Dissolved oxygen patterns of different aerator combinations.