EFFECTS OF WATER RECIRCULATION ON WATER QUALITY AND BOTTOM SOIL IN AQUACULTURE PONDS

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Oscar Zelaya, Claude E. Boyd, David R. Teichert-Coddington, and Bartholomew W. Green
Department of Fisheries and Allied Aquacultures
Auburn University, Alabama, USA

ABSTRACT

There is considerable interest in reducing negative environmental impacts of shrimp and fish farming. One of the most promising methods for reducing the environmental effects of pond aquaculture is to use water-recirculating systems to minimize effluents. However, few studies have been performed to evaluate the effect of recirculation upon soil and water quality in ponds. This study evaluates changes in physical and chemical characteristics of pond water and soils in response to varying density of production and in the presence or absence of water recirculation. Ponds were stocked with *Litopenaeus vannamei* and arranged in three treatments: 1) high-density stocking (50 post-larvae m^{-2}) (HDR) with water recirculation into another pond of equal volume without shrimp (R); 2) high-density stocking (50 post-larvae m^{-2}) without recirculation (HD); and 3) low-density stocking (25 post-larvae m^{-2}) without water recirculation (LD). Water quality variables determined weekly included soluble reactive phosphorus, total phosphorus, total nitrogen, nitrites, nitrates, and total suspended solids. Every two weeks determinations were done for 5-d biochemical oxygen demand and chlorophyll *a*. Soil variables determined at the beginning and end of the study included total nitrogen, soil respiration, pH, carbon, and sulfur. Analysis of variance techniques were used to determine if significant differences existed among treatments with respect to soil and water quality variables.

INTRODUCTION

Eutrophication of surrounding coastal areas can result from nutrients discharged in shrimp pond effluents. This is especially true for semi-intensive and intensive culture systems with rates of feeding and fertilization such that water exchange rates require frequent discharge of pond effluents.

Shrimp pond effluents are often high in suspended and dissolved organic matter (Boyd, 1992). The high biological oxygen demand of the pond effluents can cause oxygen depletion in receiving waters—especially in estuaries already receiving organic wastes from nearby urban and agricultural areas. In addition to nutrients and organic matter discharged from shrimp culture ponds, sediments removed from pond bottoms are often discharged into receiving waters (Boyd, 1990). These sediments can increase turbidity in receiving waters.

Large amounts of uneaten feed, feces, and metabolic wastes accumulate in pond waters and pond soils. These wastes are degraded through microbial processes to produce ammonia, nitrite, nitrate, and phosphate. These nutrients stimulate algal growth and may lead to dense blooms in the pond. In addition, some of these degradation products are toxic to shrimp at high concentrations. Collapse of algal populations can also cause shrimp stress and mortality through oxygen depletion. A conventional solution to this problem has been increased water exchange. Excess metabolites and algae are thus removed from the pond and replaced with better quality water. The water exchange, however, may have detrimental effects in the receiving waters. Water recirculation with digestion lagoons has been proposed as an alternative to high rates of water exchange and flushing. The purpose is to provide a system to degrade organic matter and fix nutrients before effluent discharge to receiving waters or to improve water quality in production ponds. The efficiency of this system has not been evaluated. This study evaluates the changes in physical and chemical characteristics of pond water and soils that occur in response to water recirculation with digestion ponds.

METHODS AND MATERIALS

The experiment was conducted in ponds at the Alabama Department of Conservation, Claude Peteet Mariculture Center (CPMC) at Gulf Shores, Alabama. Ponds were 0.1 ha in area and averaged 1 m in depth. Ponds were lined with high-density polyethylene to prevent seepage and were filled with 25 cm of soil. Pond water was pumped from the intercoastal waterway.

The experimental design consisted of three treatments, each replicated three times:

1) High-density stocking (50 post-larvae m^{-2}) with water recirculation (HDR);
2) High-density stocking (50 post-larvae m^{-2}) without water recirculation (HD); and
3) Low-density stocking (25 post-larvae^{-2}) without water recirculation (LD).

Each recirculation replicate was stocked with shrimp, and water was recirculated with an adjacent pond of equal size and volume that was not stocked with shrimp (R). The recirculation rate was one pond volume per week.

Ponds without water circulation were filled, and water was added only to replace evaporation. In recirculation ponds, water was pumped from culture pond to treatment pond and then pumped back to the culture pond. Water retention time in treatment ponds was one week, and culture and treatment ponds had equal volume.

The production cycle was 21 weeks (May 17 to September 29, 1999). All ponds had automatic aeration systems with a capacity of 24 HP ha^{-1} using propeller aspirator aerators. The feeding rate administered to all ponds was adjusted according to shrimp growth but was not higher than 150 kg ha^{-1} at the peak. Shrimp were fed using a 35% protein pelleted feed purchased from Burris Feed Mill, Slidell, Louisiana. The feeding rates were increased according to a standard feeding table as shrimp biomass increased. Feeding trays were used to prevent overfeeding.

Water analyses were done weekly. Samples of water representing the surface 80-cm stratum were removed with a water column sampler. Analysis included soluble reactive phosphorus (SRP) by the ascorbic acid method according to APHA et al. (1975), total phosphorus (TP) and total nitrogen (TN) by digestion and persulfate oxidation (Eaton et al., 1995), total ammonia nitrogen (TAN) by the indophenol method (Boyd and Tucker, 1992), nitrites (NO_2-N) by formation of colored azo compounds (Boyd and Tucker, 1992), nitrates (NO_3-N) by NAS reagent method (Gross and Boyd, 1998), and total suspended solids (TSS). At least twice a month fresh samples were collected for 5-d biochemical oxygen demand (BOD_5) (Eaton et al., 1995) and chlorophyll *a* analysis.

Soil samples were collected before stocking the ponds and just before harvesting. Soil samples represented three consecutive levels: the first 2.5 cm, the second 2.5 cm, and the last 5 cm. Samples were dried immediately after collection. Parameters for the soil analyses included: pH measured in a 1:1 water-soil slurry (Boyd, 1992); carbon measured with a LECO EC12 induction furnace analyzer; and total nitrogen and total sulfur determined by incinerating the soil samples in a LECO induction furnace HP10 and titrating the liberated sulfur with standard KIO_3 using a LECO sulfur titrator. Soil respiration analyses were run for the samples taken from the first 2.5-cm layer according to the method described by Boyd (1995).

Analysis of variance techniques were used to determine if there were significant differences among treatments in water quality variables.

RESULTS

Mean shrimp yields for LD, HD, and HDR were 1,706 kg ha^{-1}, 4,648 kg ha^{-1}, and 3,687 kg ha^{-1} (1,843 kg ha^{-1} total water area), respectively. There was no significant difference ($P < 0.05$) in yields between HD and HDR or between LD and HDR treatments based on total water area. Mean harvest weights of shrimp ranged from 22 to 25 g and were not significantly different between treatments. Significant reductions in concentrations of TN, TAN, and NO_2-N were found in HDR ponds compared with HD ponds (Table 1). When concentrations of variables in HDR and treatment (R) ponds were summed (HDR + R), the mean total for TAN was still significantly less than in HD ponds. However, mean totals for all other variables, except NO_3-N and NO_2-N, were significantly greater than in HD ponds. No differences were noted in water quality between HDR and LD ponds. No significant treatment differences were discovered for soil carbon, nitrogen, or phosphorus. In conclusion, recirculation of water from a production pond through a digestion lagoon of equal volume had no effect on shrimp yields. Nitrogen concentrations in the production pond were reduced by dilution, but only TAN was effectively reduced by digestion in the recirculation system.

Soil samples are currently being analyzed and submitted to statistical analysis.

ANTICIPATED BENEFITS

The findings will allow a discussion of the feasibility of using water recirculation to minimize the discharge of pond effluents and the environmental implications of aquaculture with or without recirculation in Honduras.

This research has contributed to a better understanding of pond dynamics. It has also provided an environment for a Honduran graduate student to learn research techniques, sampling methods, water and soil analysis methods, and analytical protocols that are very useful to fill the need for research and improvement of sustainable aquaculture in Honduras.

Table 1. Water quality means and relevant comparison among treatments, Significance (S) and No Significance (NS) differences are indicated within each column ($P < 0.05$).

Treatment	TSS (mg l^{-1})	SRP (mg l^{-1})	TP (mg l^{-1})	TN (mg l^{-1})	TAN (mg l^{-1})	NO_3-N (mg l^{-1})	NO_2-N (mg l^{-1})	BOD_5 (mg l^{-1})	Chlorophyll *a* (mg m^{-3})
LD	91.3	0.28	0.92	4.95	0.928	0.06	0.02	18.53	181.73
HD	98.8	0.18	0.88	5.18	1.76	0.11	0.04	20.37	209.27
HDR	93.7	0.43	1.04	4.72	0.65	0.08	0.02	18.46	188.84
R	78.9	0.51	0.92	3.70	0.498	0.05	0.02	14.04	88.05
HDR + R	172.6	0.93	1.96	8.42	1.51	0.13	0.04	32.50	276.9
COMPARISON									
HDR vs HD	NS	S	NS	S	S	NS	S	NS	NS
HDR vs LD	NS	NS	NS	NS	NS	NS	NS	NS	NS
HDR vs R	S	NS	NS	S	NS	NS	NS	S	S
(HDR + R) vs HD	S	S	S	S	S	NS	NS	S	S

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