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Can Sediment Removal During Shrimp Production in the Wet Season Improve Pond Conditions of the Improved Extensive Shrimp System in the Mekong Delta, Vietnam?

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Abstract

Removing accumulated shrimp pond sediment is one of the most common management practices in shrimp aquaculture. In the Mekong Delta of Vietnam, the improved extensive shrimp farmers remove pond sediment when they observe abnormalities in their ponds (e.g. shrimp mortality, excessive algal development, foul smell, or too much turbidity). This on-farm study examines whether removing pond sediment in the wet season during shrimp production improves pond conditions. Sampling took place twice during shrimp production in six experimental ponds (bottom sediment was manually removed after the first sampling) and three control ponds (bottom sediment remained undisturbed). Results showed that sediment removal did not improve pond water conditions. The organic loadings of the pond bottom remained unchanged while macrozoobenthos density, species richness, diversity and evenness of the aquatic community were not affected. Only a small increase in redox potential of the pond sediment ($p<0.01$) was recorded. It is strongly recommended that farmers do not remove pond sediment in the improved extensive shrimp system under the defined conditions.

Introduction

Soils and the accumulated sediment are integral parts of shrimp ponds (Avnimelech and Ritvo 2003) which influence water quality, shrimp growth, and production (Boyd 1995; Avnimelech and Ritvo 2003). Accumulated sediment in shrimp ponds originates from the residues of pond inputs, e.g. uneaten feed, biological wastes, suspended solids from input water, and eroded soil (Lat 2002; Avnimelech and Ritvo 2003; Brennan et al. 2002; Preston and Clayton 2003). As a result, it contains higher amounts of organic matter, total nitrogen, and phosphorus as compared to normal soils (Lat 2002). Accumulated sediment is undesirable in intensive shrimp systems (Funge-Smith

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and Briggs 1998) while effects in extensive and improved extensive shrimp systems have not been reported.

In Southeast Asia, there are three major approaches to pond sediment management, being “remain”, “remove”, and “resuspend” (Lat 2002). Shrimp farmers in Thailand believe that removing accumulated pond sediment leads to better shrimp yields as sediment is a source of pathogenic agents to shrimps (Yuvanatemiya et al. 2011). In Thailand, pond management practices include drying of pond bottom between crops, liming, tilling and periodic sediment removal (Wudtisin and Boyd 2006). Some farmers in Southern Thailand also treat their pond sediment by dewatering through sun drying or sand bedding. Some shrimp farmers in Thailand and eastern Indonesia leave some accumulated sediment in the ponds after harvest to improve water condition for the next crop (Lat 2002). In Chantaburi province (Thailand), 97% of commercial shrimp farmers use water jets to dislodge sediment from their ponds (Yuvanatemiya et al. 2011). Partial removal of pond sediment is preferred while complete removal is not commonly practised (Lat 2002). In the Mekong Delta of Vietnam, the improved extensive shrimp farmers remove pond sediment employing either partial or complete removal methods. Many remove pond sediment during the dry season while some (18%) take the action during the wet season. About 20% of farmers carry out this farming practice irrespective of the season. The reasons for sediment removal are many, such as shallow pond water, too much turbidity, excessive algal growth, or shrimp death (Tho 2012). Sediment removal is a labour intensive process (Brennan et al. 2002) and constitutes the main cost of shrimp pond preparation in the Mekong Delta of Vietnam (Brennan et al. 2000; Preston and Clayton 2003). In 2008, the labour cost for manual sediment removal in the improved extensive shrimp ponds in the area ranged between $USD18.6-31 ha^{-1}$ (Tho 2012).

There is little literature on the effects of sediment removal on shrimp pond conditions. It is generally accepted that sediment removal is essential to reduce the risk of shrimp diseases (MPEDA/NACA 2003). Removing pond sediment increases pond depth and makes harvest operations easier. Removed sediments are used to repair the pond dikes (Boyd 1995). Catfish and freshwater prawn ponds in Thailand from which sediment was occasionally removed tend to have better soil quality compared to carp ponds from which sediment was not removed (Wudtisin 2005). This practice improves the physical and chemical characteristics of shrimp pond bottom (Yuvanatemiya and Boyd 2006) but did not reduce Vibrios, sulfate-reducing bacteria, or heterotrophic bacteria in shrimp ponds (Smith 1998). In the Mekong Delta of Vietnam, effects of sediment removal to pond conditions have remained unknown. This paper documents the effects of partial removal of pond sediment in the improved extensive shrimp system in the wet season during shrimp production on pond conditions in the coastal Cai Nuoc district, Mekong Delta of Vietnam.

Materials and Methods

The study area and the improved extensive shrimp ponds

The coastal Cai Nuoc district (395.14 km^2) is situated in the South-west of Ca Mau province, Mekong Delta of Vietnam (Fig. 1). It is a lowland delta plain, with average elevation of 0.2 m above mean sea level. The district is connected to the South China Sea and the Gulf of Thailand by a dense network of rivers and canals. It has two distinct seasons: a wet season (May–October, average rainfall of 2,100 mm), and a dry season (November–April, average rainfall of 200 mm).

The improved extensive shrimp system in which black tiger shrimp (*Penaeus monodon* Fabricius 1798) is farmed accounted for 88% of all shrimp related areas and occupied more than 70% of the district's total land area in 2008 (DoA 2009). A typical improved extensive shrimp pond is composed of a central platform, which accounts for the majority of pond area, and a surrounding trench (2-2.5 m width, 0.6-0.8 m depth). The improved extensive shrimp system is characterized by (1) earthen monoculture ponds, (2) a stocking density of 1-7 postlarvae m^{-2}, (3) irregular sediment removal, (4) a survival rate of 3-20%, and (5) low and unstable shrimp yields (Hens et al. 2009; Tho et al. 2011). Prior to stocking, 50% of farmers apply fertilizers (NPK, urea, DAP) to promote phytoplankton development in their shrimp ponds. The amount of fertilisers applied to the ponds varies according to the phytoplankton bloom and no proper records are maintained on its application (Tho 2012). No feeding is applied to the ponds. Although the initial stocking is low, most farmers stock supplementary shrimp larvae (up to 50-100% of the original amount stocked) over the following months. The average shrimp production of this shrimp system was estimated at 390 kg ha^{-1} yr^{-1} (Tho 2012).

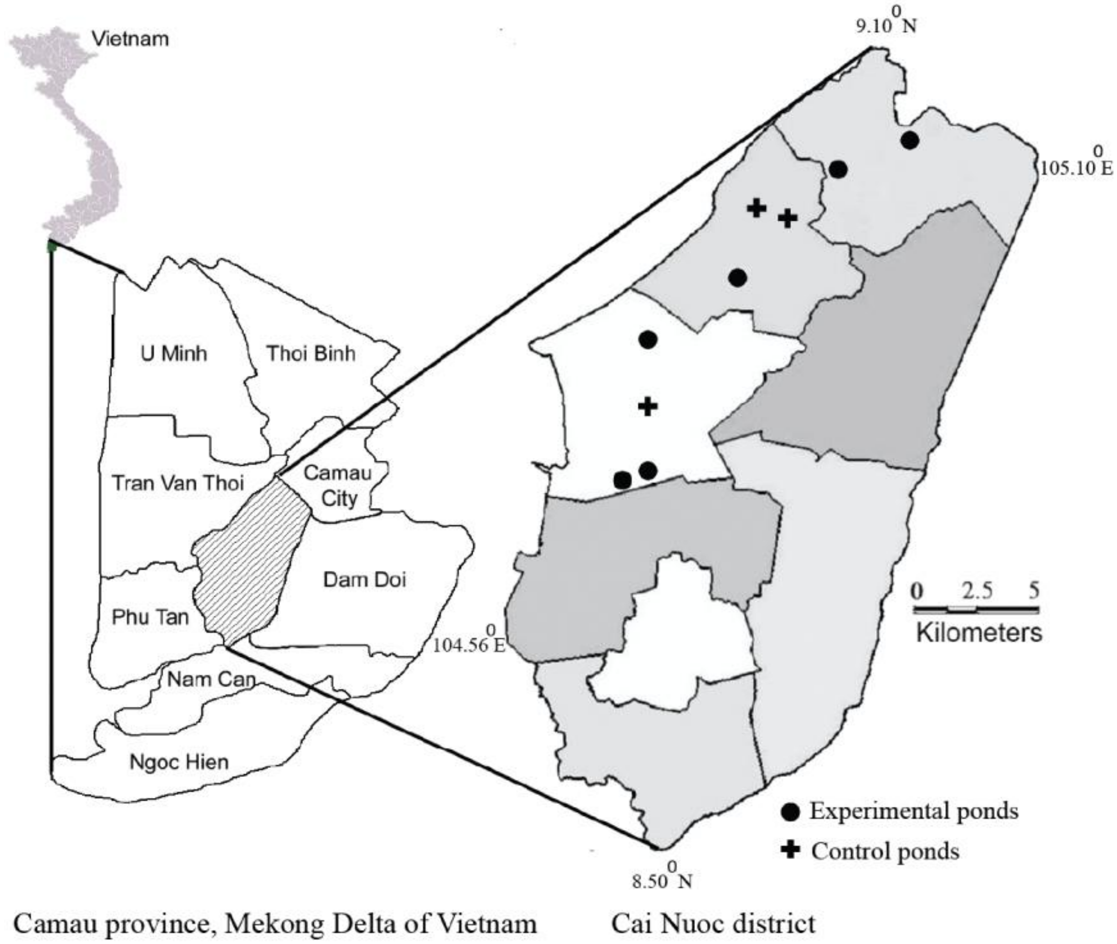

Fig. 1. The study area and the sites for the experiment.

Sampling scheme

This on-farm experiment was conducted during shrimp production in the middle of the wet season 2011 (July-August), following a preliminary survey on pond management strategy. Nine shrimp ponds of similar sizes that had not been subjected to sediment removal for about 12-14 months were selected (Fig. 1). All of these ponds were converted from the traditional rice fields about 10-11 years ago. These nine ponds were divided into two distinct pond groups: experimental ponds (six) and control ponds (three). Sampling 1 took place in all of the nine ponds. About 10 days later, the experimental ponds were subject to a manual sediment removal from the trench while the control ponds were left unaltered. The dredged sediment was deposited on the dikes. Sampling 2 was conducted in all of the nine ponds, about 2-3 weeks after sediment removal. Pond water was not exchanged during the experiment. Shrimp production of the ponds under study was not estimated.

Sampling of pond water

Pond depths were calculated as the average of five measurements in the trench. Salinity, temperature, pH, DO, and turbidity of pond water were measured *in situ* in the trench at 20 cm depth using a TOA instrument (WQC-22A, DKK-TOA Corporation, Tokyo, Japan). For the other parameters, sampling was conducted at three locations in the middle of the water column of the trench as sub-samples which were subsequently mixed to form a composite sample for analysis. Hydrogen sulfide (H_2S) was sampled near the water-sediment interface of the trench. All samples were kept in the dark at approximately 4 ^{0}C and transported to the lab the same day for analysis.

Quantitative sampling of phytoplankton was conducted by filtering through a Juday net (20 μm mesh size) a total volume of 60 L of pond water collected at six different sites (10 L each) of the pond into a final 100-mL plastic bottle. Quantitative sampling of zooplankton was conducted by the same procedure but with a different mesh size (60 μm). All samples were fixed by a formalin solution of 4%.

Sampling of pond bottom sediment

Pond sediment was sampled at three locations in the trench as sub-samples using an Ekman grab. The sub-samples were later combined into a composite sample which was kept in a plastic bag for organic matter (OM) analysis. The pH (pH_w) and redox potential (Eh) of freshly collected sediment were measured *in situ* using a combined Eh/pH meter (pH 62K, APEL Co Ltd, Saitama, Japan). The Eh was measured using an EMC 130 Meinsberg electrode (Sensortechnik Meinsberg GmbH, Ziegra-Knobelsdorf, Germany) while the pH_w was measured by a glass electrode. Quantitative sampling of macrozoobenthos was conducted using the Ekman grab with a surface area of 0.025 m^2. At each site, samples were taken at four nearby locations, resulting in a total area sampled for macrozoobenthos of 0.1 m^2. The samples were sieved through a screen of 0.5 mm, fixed by a formalin solution of 8%, and stored in 100-mL plastic bottles.

Sample analysis

Analysis of water parameters was performed using the standard procedures by APHA (1995): (1) BOD: 5-Day BOD Test; (2) TSS: Gravimetric, dried at 105 ^{0}C; (3) NH_4-N: Indophenol blue method; (4) NO_3-N: Salicylate method; (5) Total N: digested by Kjeldahl Digestion System, Indophenol blue method; (6) PO_4-P and total P: Ascorbic acid method; (7) H_2S: Methylene blue method; (8) Chl-a: extracted by acetone 95%, determined by the spectrophotometer method. OM of sediment was determined by the loss-on-ignition method (550 ^{0}C, 4 h).

Phytoplankton and zooplankton species were identified respectively by an Olympus BX41 microscope and an inverted microscope. The number of individuals of each species of plankton were later counted and converted to number of individuals per m^3. Macrozoobenthos samples were dyed by Rose Bengal for 24 h, washed through a 1-mm sieve, collected, identified, counted, and converted to number of individuals per m^2.

Calculation of biological indices

The diversity of the aquatic community was measured by (1) the Shannon-Wiener index (H') (Shannon and Weaver 1949), (2) the Hill's index N_1 (measures the number of abundant species), and (3) the Hill's index N_2 (measures the number of very abundant species) (Hill 1973). Species richness was estimated by the Hill's index N_0 (total number of all species regardless of abundance) (Hill 1973). The evenness of the community was expressed by the Pielou's evenness index (J') (Pielou 1969).

Statistical analysis

A Two-way Repeated Measures ANOVA was applied to analyse the effects of sediment removal on pond conditions. Sampling (sampling 1, sampling 2) and pond group (experimental ponds group, control ponds group) were treated respectively as within-subjects factor and categorical factor. The physico-chemical and biological parameters were treated as dependent variables. Effects of sediment removal were determined based on the interaction effects between the within-subjects factor and the categorical factor on dependent variables. All significance testing was done at the 0.05 level. All statistical analyses were performed using the Statistica package (version 7.0, Statsoft Inc., Tulsa, Oklahoma, USA).

Results and Discussions

Quality of water and sediment of the shrimp ponds under study

Physico-chemical characteristics of water and sediment of the shrimp ponds under study are shown in 4 blocks (Experimental ponds at sampling 1, control ponds at sampling 1, experimental ponds at sampling 2, and control ponds at sampling 2). Values of mean and standard deviations are displayed for each of the parameters (Table 1).

Table 1. Water and sediment quality of the shrimp ponds under study.

Parameter	**Exp-S1[1]**		**Con-S1[2]**		**Exp-S2[3]**		**Con-S2[4]**	
	Mean	Stdev.	Mean	Stdev.	Mean	Stdev.	Mean	Stdev.
Pond water								
Pond depth (cm)	68.17	10.11	85.33	21.39	63	23.14	80.67	21.13
pH	8.33	0.26	7.94	0.15	8.44	0.36	7.93	0.57
Temperature (^{0}C)	31.93	2.5	32.6	0.61	33.12	2.87	33.03	2.17
Salinity (g L^{-1})	0.92	0.26	0.66	0.2	0.78	0.22	0.51	0.13
Turbidity (NTU)	44.67	22.57	46	39	33	16.46	21	10.58
DO (mg L^{-1})	4.92	1.55	3.68	0.51	5.45	1.27	4.97	1.74
BOD (mg L^{-1})	12.67	2.16	9.67	3.06	15.83	5.38	11.67	3.79
TSS (mg L^{-1})	16.27	3.93	13.2	4.92	10.17	5.64	9	5.57
Alkalinity (mg L^{-1})	130.7	32.75	133.14	30.59	425.17	133.3	400.57	91.77
NH_4-N (mg L^{-1})	0.28	0.06	0.2	0.04	0.5	0.11	0.35	0.09
NO_3-N (mg L^{-1})	0.12	0.03	0.16	0.05	0.11	0.03	0.1	0.04
Total N (mg L^{-1})	4.07	2.7	4.96	2.43	2.84	0.37	1.81	0.71
PO_4-P (mg L^{-1})	0.03	0.02	0.01	0.01	0.14	0.13	0.1	0.15
Total P (mg L^{-1})	0.56	0.64	0.21	0.16	1.28	0.34	2.01	0.96
H_2S (mg L^{-1})	0.04	0.01	0.02	0.01	0	0	0	0
Chl-a (µg L^{-1})	0.1	0.06	0.08	0.09	0.05	0.06	0.01	0.01
Pond sediment								
pH	7.24	0.41	7.46	0.39	7.35	0.11	6.98	0.52
Eh (mV)	-370.8	23.9	-314.7	106.3	-339.7	30.3	-354.7	85.7
OM (%)	11.98	0.77	12.09	0.77	10.73	0.6	11.54	0.8

[1]Exp-S1: experimental ponds at sampling 1, [2]Con-S1: control ponds at sampling 1, [3]Exp-S2: experimental ponds at sampling 2, [4]Con-S2: control ponds at sampling 2. Stdev.: Standard deviation.

Pond depths and water parameters

Fluctuations of pond depths are recognized but not due to sediment removal as shown in the Two-way repeated measures ANOVA (Fig. 2). Significantly lower salinities in sampling 2 ($p<0.01$) were most probably ascribed to the heavy rains rather than sediment removal. Sediment removal did not affect pH, TSS and turbidity of shrimp pond water (Fig. 2).

Removing pond sediment did not significantly affect the organic loadings of the shrimp pond water (Fig. 3). H_2S was found at harmful levels (0.01-0.05 mg·L^{-1}) in both pond groups in sampling 1 but not detected in sampling 2. This was not necessarily the result of sediment removal but probably the effect of dilution under rainy conditions. In the same shrimp system of the study area, low H_2S concentrations (≤0.02 mg·L^{-1}) were reported (Tho et al. 2011).

Organic matter, redox potential, and pH of pond sediment

In shrimp ponds, OM accumulates most strongly in the upper 10-20 cm of the sediment (Munsiri et al. 1995). Both pond groups showed slightly reduced OM values in sampling 2. However, sediment removal yielded no effect on the contents of organic loadings of the pond bottom (Fig. 4). This can be explained by both the low effectiveness of manual sediment removal during shrimp production and the subsequent back-washing of freshly deposited sediment under rainy conditions. Our finding was consistent with Yuvanatemiya et al. (2011) that treatments of shrimp pond bottom (flushing, tilling, sun-drying) did not yield significant changes in organic carbon concentrations of pond soils.

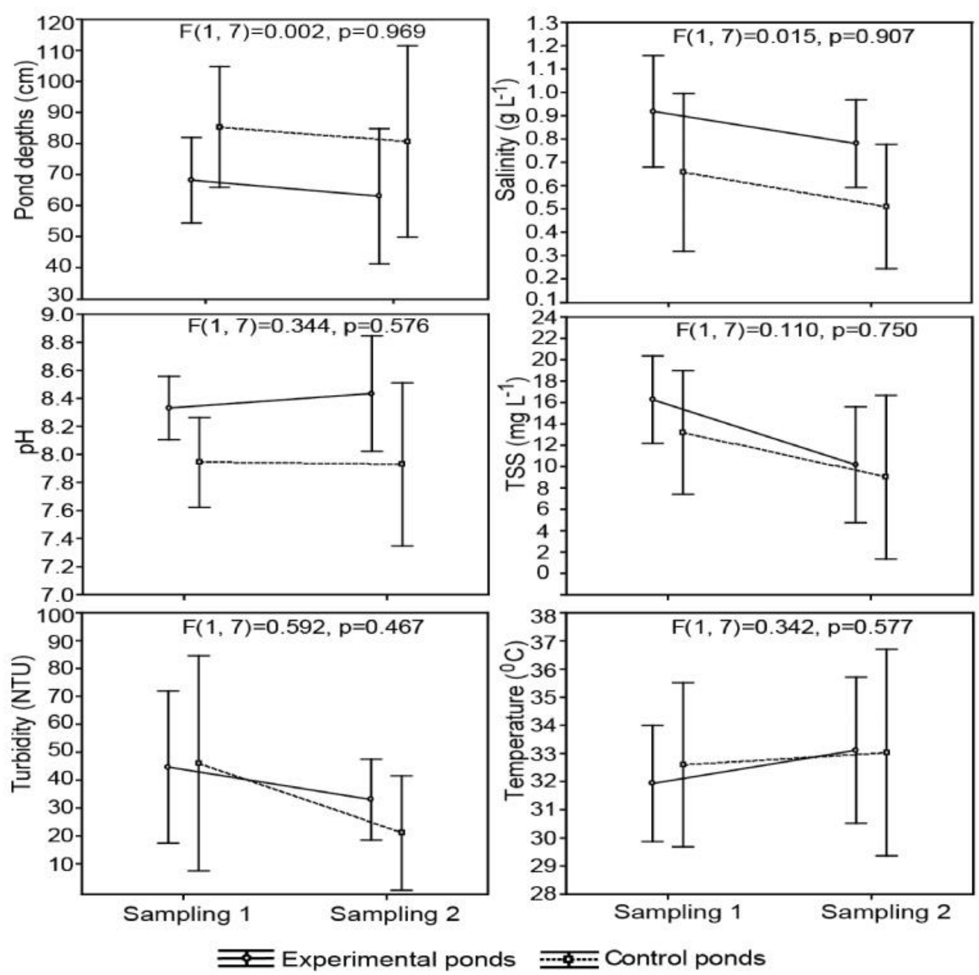

Fig. 2. Two-way repeated measures ANOVA for pond depths and basic parameters of Cai Nuoc shrimp pond water. Vertical bars denote 0.95 confidence intervals.

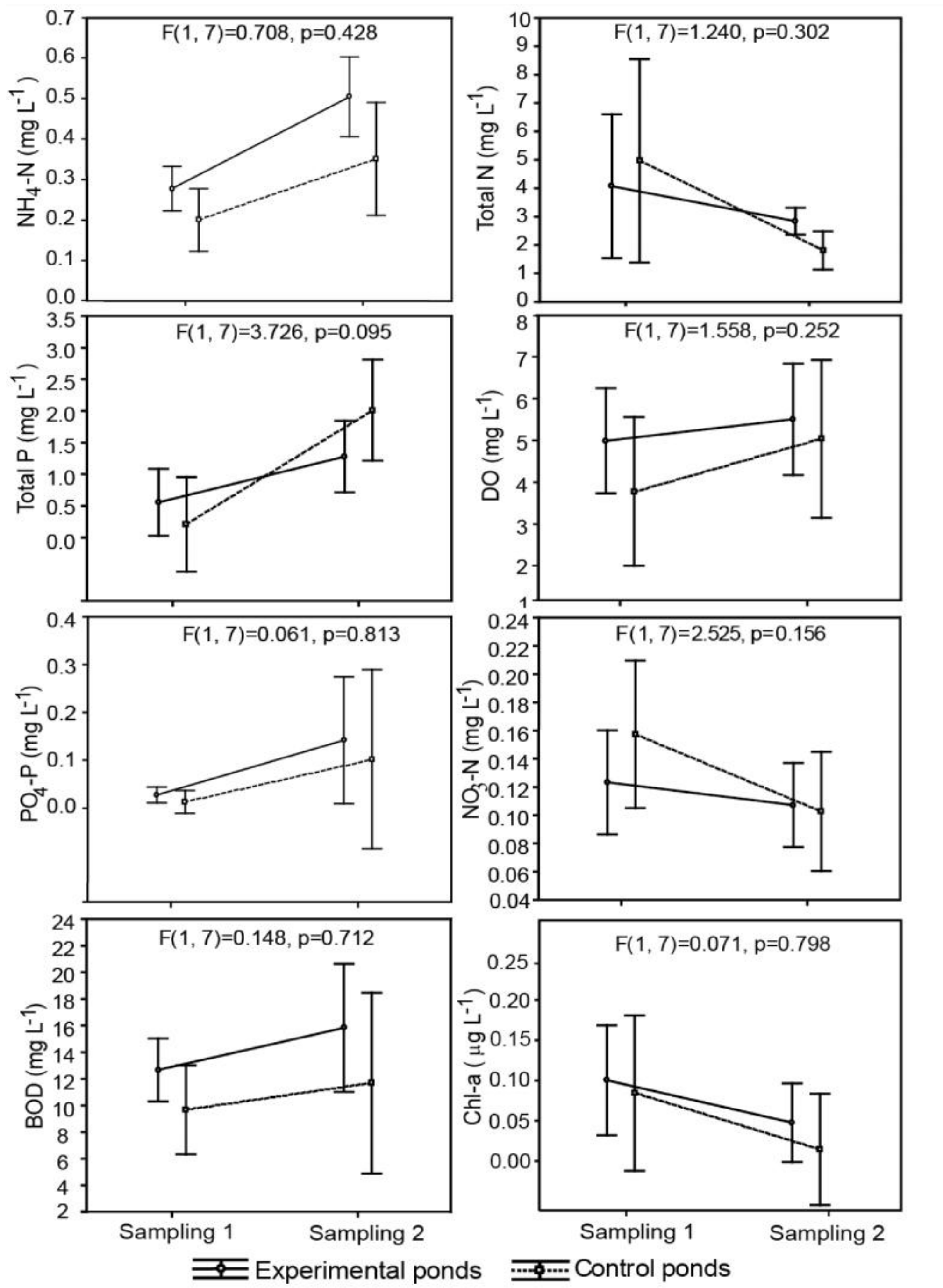

Fig. 3. Two-way repeated measures ANOVA for organic loadings of Cai Nuoc shrimp pond water. Vertical bars denote 0.95 confidence intervals.

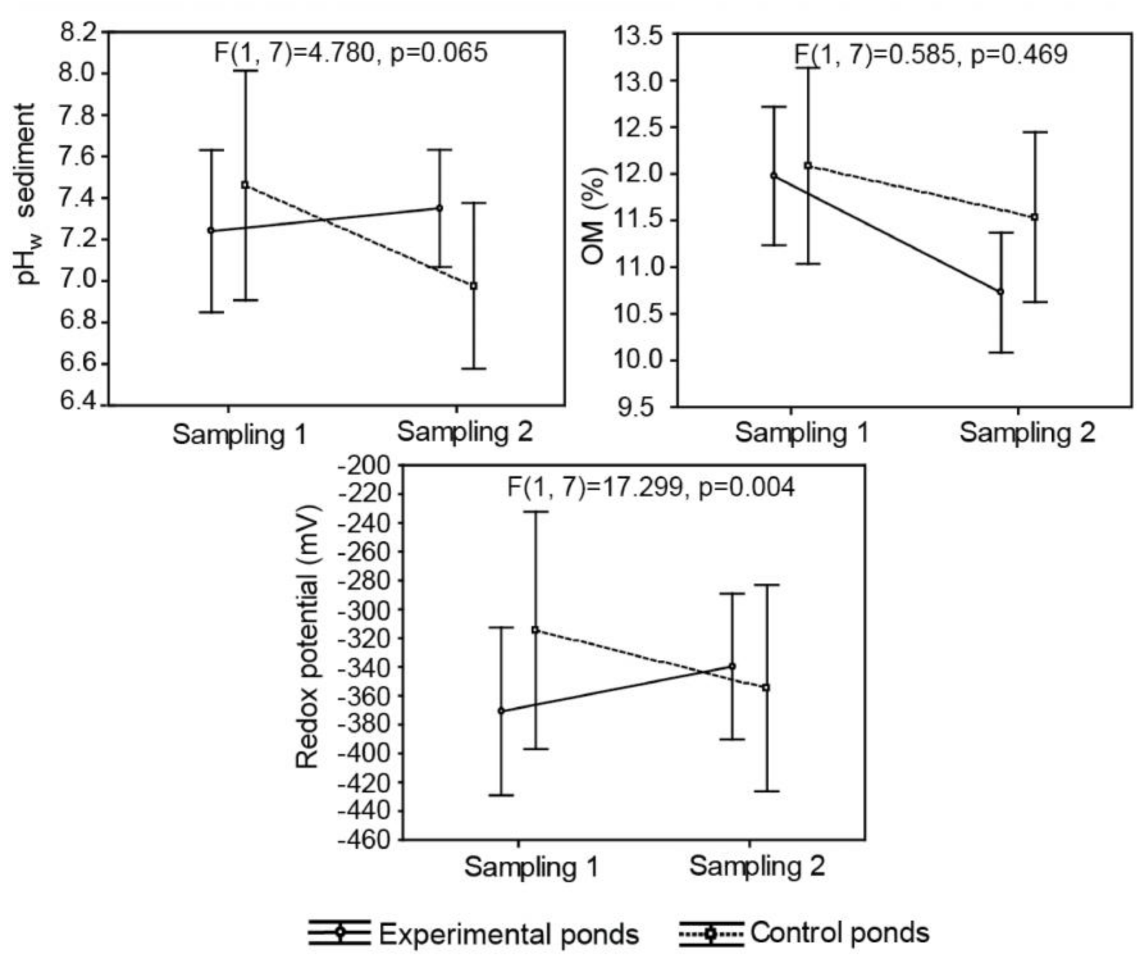

Fig. 4. Two-way repeated measures ANOVA for pH, OM, and Eh of Cai Nuoc shrimp pond sediment. Vertical bars denote 0.95 confidence intervals.

Just below the water-sediment interface of Cai Nuoc improved extensive shrimp ponds, an anaerobic condition has been developed (Tho et al. 2011; Tho et al. 2012). This is the result of a considerable consumption of pond oxygen budget for OM decomposition (Lat 2002). Redox potential (Eh) of the experimental ponds and the control ponds showed different trends between the samplings. The Two-way repeated measures ANOVA revealed a significant interaction between “pond group” and “sampling” on Eh ($F(1,7)=17.299$, $p<0.01$) (Fig. 4). It can be concluded that sediment removal produced a less anaerobic condition in the shrimp pond bottom. This originates from the partial loss of accumulated sediment through removal, which reduced oxygen demand in the sediment surface. Improvement of Eh lessens the risk of anaerobic zones at the soil–water interface in the shrimp ponds (Yuvanatemiya and Boyd 2006). In artificial mud systems, no oxygen is found at Eh<+100 mV (Hargrave 1972). Based on the classification by Ruppé and Barstad (2002), Cai Nuoc shrimp pond sediment is highly reduced (Eh<-100 mV).

The experimental ponds and the control ponds showed opposite trends of sediment pH between the samplings. Removing accumulated sediment, however, did not yield any effects on sediment pH (Fig. 4). This is consistent with the finding by Yuvanatemiya and Boyd (2006).

Biological indices

The Two-way repeated measures ANOVA shows no interactions between “pond group” and “sampling” on all of the biological indices ($p>0.05$) presented in 4 combinations (2 pond groups x 2 samplings) (Table 2). Removing pond sediment did not significantly affect the species richness, diversity, and evenness of the aquatic community in Cai Nuoc shrimp ponds.

The macrozoobenthos community of Cai Nuoc improved extensive shrimp ponds is quite poor compared to shrimp ponds elsewhere (Tho et al. 2012). In this experiment, macrozoobenthos density ranged from 10-150 ind m^{-2} (11 species) and 0-320 ind m^{-2} (10 species), respectively at sampling 1 and sampling 2. According to the classification by Whitton (1975), Cai Nuoc shrimp ponds are polluted as shown by the low Shannon-Wiener index of macrozoobenthos (0-1.24). The fact that macrozoobenthos community remained unchanged after sediment removal suggests that the action has posed negligible impacts on the biodiversity of pond bottom.

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Table 2. Interactions between "pond group" and "sampling" on the biological indices of the aquatic community in Cai Nuoc improved extensive shrimp system.

Index	**Phytoplankton**				**Zooplankton**				**Zoobenthos**			
	Exp-S1[1]	Con-S1[2]	Exp-S2[3]	Con-S2[4]	Exp-S1	Con-S1	Exp-S2	Con-S2	Exp-S1	Con-S1	Exp-S2	Con-S2
N_0	11±6.57	11.33±5.13	12.83±3.92	9.33±3.21	5.83±1.94	6.33±4.51	4.17±1.17	4.67±2.52	1.83±0.75	3.00±1.00	2.17±1.94	1.33±1.53
	F(1, 7)=.424, p=.536				**F(1, 7)=.000, p=1.000**				**F(1, 7)=3.111, p=.121**			
H'	1.20±0.63	1.21±0.51	1.10±0.49	0.80±0.28	1.14±0.17	0.97±0.92	1.19±0.29	1.27±0.55	0.50±0.40	0.89±0.19	0.50±0.52	0.48±0.67
	F(1, 7)=.435, p=.530				**F(1, 7)=.368, p=.563**				**F(1, 5)=.281, p=.619**			
N_1	4.01±3.05	3.67±1.93	3.26±1.34	2.30±0.67	3.17±0.59	3.54±3.40	3.41±1.01	3.92±1.87	1.75±0.64	2.46±0.47	1.84±1.01	1.79±1.12
	F(1, 7)=.098, p=.764				**F(1, 7)=.009, p=.925**				**F(1, 5)=.203, p=.671**			
N_2	3.28±2.54	3.05±1.77	2.56±1.13	1.79±0.64	2.36±0.62	2.70±2.48	2.93±0.83	3.44±1.42	1.73±0.61	2.20±0.21	1.70±0.91	1.67±0.94
	F(1, 7)=.094, p=.768				**F(1, 7)=.026, p=.876**				**F(1, 5)=.092, p=.773**			
J'	0.51±0.15	0.52±0.22	0.44±0.20	0.37±0.14	0.67±0.11	0.52±0.27	0.85±0.08	0.91±0.04	0.63±0.49	0.86±0.12	0.45±0.48	0.43±0.61
	F(1, 7)=.252, p=.631				**F(1, 7)=3.594, p=.100**				**F(1, 5)=0.147, p=.717**			

[1]Exp-S1: Experimental ponds at sampling 1, [2]Con-S1: control ponds at sampling 1, [3]Exp-S2: Experimental ponds at sampling 2, [4]Con-S2: control ponds at sampling 2. H': Shannon-Wiener index, N_0: Hill's index N_0, N_1: Hill's index N_1, N_2: Hill's index N_2, J': Pielou's evenness index. For each of the indices, mean±0.95 standard deviation are shown. No significant interactions between "pond group" and "sampling" on the indices were detected.

Conclusion

Manually removing pond sediment in the wet season during shrimp production did not substantially improve pond conditions of the improved extensive shrimp system. The shrimp ponds were almost physico-chemically and biologically unaffected compared to the initial conditions. It is therefore strongly recommended that farmers do not take the action under the defined conditions.

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