Potential of mangrove wetlands as bio filters to treat shrimp pond effluents: A preliminary study in the North Western Sri Lanka

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ABSTRACT

Development of shrimp farming industry along the coastal belt of Sri Lanka has intensified the environmental problems in brackish water areas. The major impacts include eutrophication, silting, oxygen depletion and chemical pollution in brackish water bodies. The present study investigated the efficacy of natural wetlands in treating shrimp pond effluents in North Western Province of Sri Lanka. Three natural wetlands that directly receive shrimp pond effluents from Nalladarankattuwa, Pulichchcikulama and Sinnapaduwa were selected for the study. Wetlands were divided into three areas; water inlet, centre and outlet based on wetland structure and water drainage pattern. Water temperature, pH, DO, turbidity, conductivity, salinity and total dissolved solids were recorded in situ biweekly and water samples collected from three areas of each wetland were also analyzed for NH_3*,* PO_4^{-3}*, chlorophyll and BOD in the laboratory.*

The highest amount of total Phosphorus (1.35 mgl^{-1}*), chlorophyll (17.7* mgm^{-3}*), BOD (2.9* mgl^{-1}*), turbidity (14.78 NTU) and lowest DO (3.70* mgl^{-1}*) were recorded at the inlets and these values were significantly different from those of centers and outlets of the wetlands. The highest mean* NH_3 *concentration (0.048* mgl^{-1}*) was also recorded at the inlet of each wetland, however it did not change towards the outlet. Total dissolved solids, conductivity, salinity, pH and temperature did not vary significantly within the wetland. Wetlands reduced 36% of BOD, 39% of chlorophyll and 66% of phosphorus and 11% of turbidity. Dissolved oxygen concentrations at the outlets of wetlands were 38% - 40% greater than that of inlets. Results revealed that some of the negative effects of shrimp pond effluents could be reduced by natural mangrove wetlands. Rehabilitation and conservation of more wetlands in the shrimp farming area of the North western province may reduce the environmental impacts of shrimp pond effluents.*

INTRODUCTION

Shrimp exports have become one of the non-traditional foreign exchange earners of Sri Lanka and account for nearly 90% of the total aquaculture exports. Shrimp farming industry has been centered on the north-western coastal belt of the country and the total estimated shrimp farming area in the North Western Province alone is around 3500 ha. Dutch canal which is the main water source for shrimp farms also receives pond effluents throughout the culture period. As such, direct contamination of incoming water by effluents is unavoidable. This causes "Self –

pollution" that is defined as the pumping of water into aquaculture ponds, previously discharge to the water source which contains higher concentrations of nutrients and contaminants and lower concentrations of dissolved oxygen (Csavas, 1994). This phenomenon is becoming widespread within the Dutch Canal system; a system which is the major source of water for more than 70% of the shrimp farms in Sri Lanka (Corea *et al.,* 1995). The effluent water carrying high quantity of nitrogenous compounds, phosphorus and other nutrients also causes hypernutrification and eutrophication with increased primary production and microbial bloom (Mukhi *et al.*, 2001). According to Smith (1996) a reduction in environmental quality of coastal environment can have negative feedback effect on shrimp pond operations. The major impacts on the receiving water bodies are eutrophication, silting, oxygen depletion and toxicity from sulfide, ammonia, and other chemicals used in shrimp cultivation.

Several methods have been proposed to ameliorate the impacts of shrimp pond effluents on the water quality of adjacent brackish water eco systems including, improved pond designs (Dierberg and Kiattisimkul 1996; Sandifer and Hopkins 1996), construction of waste water oxidation – sedimentation ponds, reduction of water exchange rates (Hopkins *et al.*, 1993; Martinez – Cordova *et al.*, 1995), reduction of nitrogen and phosphorus input from feed (Jory, 1995), removal of pond sludge (boyd *et al.*, 1994; Sandifer and Hopkins, 1996) and a combination of semi closed farming systems with settling ponds and biological treatment ponds using poly cultures (Sandifer and Hopkins 1996; Dierberg and Kiattisimkul, 1996). Another proposed method is to use mangrove wetlands as filters of pond discharge prior to the release of effluents to estuarine waters (Robertson and Phillips, 1995).

Aquatic plants are an important component of the purification system in both natural and constructed wetlands. The use of wetlands for processing water pollutants from waste water has been effective in reducing organic matter, suspended sediments, and nutrients in semi tropical and temperate regions (Kadlec and Knight, 1996). The use of mangrove wetlands in tropical regions to treat effluents from shrimp farming is not generally practiced as effluent treatment has not received enough attention of shrimp farmers (Mornoy *et el.,* 1999). Moreover, many shrimp aquaculture ponds have been constructed in or adjacent to mangrove wetlands in the coastal zone (Csavas, 1994).

The efficacy of natural mangrove wetlands as bio filters in improving shrimp pond effluents has not yet studied under the field conditions in Sri Lanka. The present study aimed at examining the potential role of natural mangrove wetlands in improving the water quality of shrimp farm effluents in North Western Province of Sri Lanka.

MATERIALS AND METHODS

The present study was undertaken over ten months starting from September 2008 to July 2009. Three natural wetlands from Nalladarankattuwa, Sinnapaduwa and pulichchikulama which receive shrimp pond effluent water were selected for the study (Table 01). Each wetland was divided into three strata; water inlet, centre and outlet based on wetland structure and shrimp waste water movement along wetland.

Table 01: Characteristics of the selected wetlands

Characteristics	Nalladarankattuwa	Pulichchikulama	Sinnapaduwa
Area selected	1320 m^2	1140 m^2	1267 m^2
Flow rate	1.8 $m^3/s \pm 0.41$	1.0 $m^3/s \pm 0.36$	1.3 $m^3/s \pm 0.38$
Average depth	0.6m ± 0.38	0.6m ± 0.38	0.6m ± 0.38

Water samples were collected from inlets, centres and outlets of each wetland biweekly for analysis. Water temperature, dissolved oxygen, turbidity, salinity, and pH were measured in situ using thermometer and portable meters (SM portable pH/EC/TDS meter, SM600 portable dissolved Oxygen meter and HUTCH 2100P portable meter). Collected water samples were stored on ice and immediately refrigerated at 5°C upon reaching the laboratory. Water samples were filtered using GFC filter papers (8 μm) and filter papers were cold stored to analyze for chlorophyll (APHA, 1998). Biological Oxygen demand, NH_3, total phosphorus, chlorophyll, conductivity and total dissolved solids (TDS) were analysed according to APHA (1998). Standard curves were made for each set of samples analyzed using colorimetric methods.

Characteristics of selected wetlands such as length and width were also recorded. Random points throughout the wetlands were used to determine the average depth of wetlands. Flow meter (Geopach, Japan) was used to measure water velocity in wetlands in each sampling day. Plant community structure and plant density of wetlands were taken using 10m x 10m belt transects and counting wetland plants within transects. Statistical analysis of data was carried out using MINITAB software.

RESULTS AND DISCUSSION

Vegetational characteristics of wetlands

A total of five species of mangroves were found in wetlands including *Rhizophora mucronata, Avicenia marina, Avicennia officinalis, Bruguiera cyclindrca* and *Ceriops tagal*. All wetlands in this study hosted *Rhizophora mucronata* and *Avicenia marina*. Plant density in the wetlands varied between 1580 – 2940 plants/ha. Vegetation characteristics were almost similar in all the strata of wetlands except in the inlets. Inlets were characterized by having low vegetation

(1330 ± 420 / ha) compared to centers and outlets (2230 ± 840 / ha) which may possibly resulted due to higher inflow rates from shrimp farm effluent water.

Water quality parameters

Mean water quality parameters of wetlands are given in the Table 02. Salinity, pH and water temperature were consistent from wetland to wetland with ranges from 8 – 27ppt, 7.3 to 8.1 and 27.5 to 33 °C, respectively. Variation of conductivity and total dissolved solids were not consistent from the inlet area towards the outlet. DO, BOD, turbidity, phosphorus and chlorophyll-a concentration were significantly changed while water was flowing through the wetland (Table 02).

Table 02: Mean ± SE of water quality parameters of sampling locations in the wetlands

Parameter	Inlet	Center	Outlet
BOD (mg/l)	2.9 ± 1.1^{a}	2.2 ± 0.9^{b}	1.8 ± 1.0^{c}
DO (mg/l)	3.7 ± 1.0^{a}	4.0 ± 0.6^{b}	4.3 ± 0.8^{b}
Turbidity (NTU)	14.78 ± 4.4^{a}	14.21 ± 3.8^{a}	13.12 ± 4.2^{b}
Phosphorus (mg/l)	1.35 ± 0.8^{a}	0.66 ± 0.6^{b}	0.459 ± 0.7^{b}
Chlorophyll a (mg/ m^3)	17.7 ± 6.3^{a}	13.8 ± 5.7^{b}	10.8 ± 5.8^{b}
NH_3 (mg/l)	0.052 ± 0.01	0.005 ± 0.002	0.040 ± 0.01
Conductivity (mS/cm)	17.4 ± 8.4	16.0 ± 7.8	0.004±0.002
TDS (ppm)	12707 ± 1042	11650 ± 1456	12269 ± 958
Salinity (ppt)	18 ± 9	18 ± 9	18 ± 9

* Means of each water quality parameter in different columns with different superscripts are significantly different determined by one way ANOVA followed by Tukey's pair wise comparison ($p<0.05$)

Effluent turbidity reduced significantly from the inlet of the wetlands towards the outlet of the wetlands in all the sites (Figure 01). Mean percentage reduction of turbidity was 11.5%.

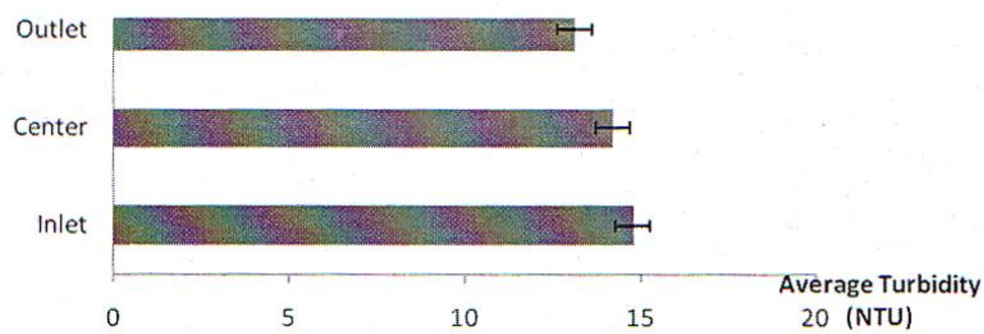

Figure 01: Average Turbidity at each stratum of wetlands

Mean BOD level at the inlet of the wetland (2.9 mg/l) reduced up to 1.8 mg/l at the outlet. Contrary to BOD, dissolved oxygen increased significantly from inlet towards outlet (4.3 mg/l). In average, increment of DO from inlet to outlet was 39% while reduction of BOD was 36% (Figure 02).

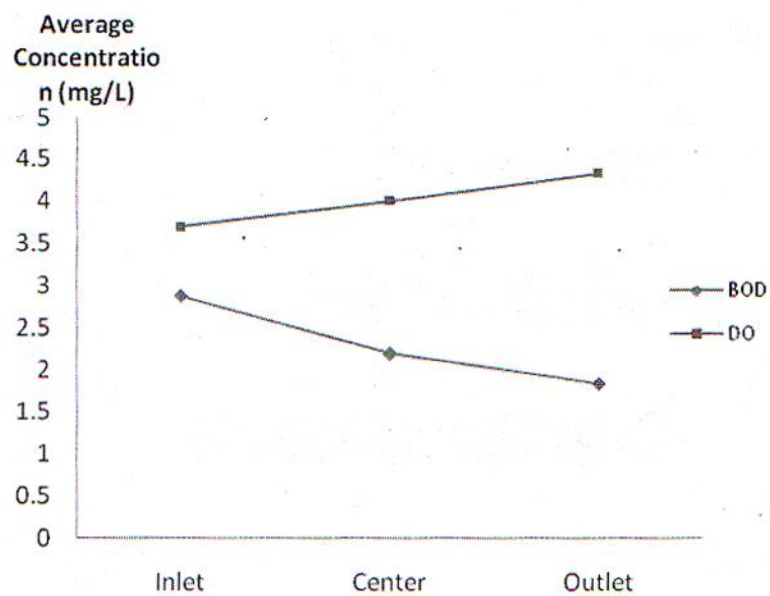

Figure 02: Average BOD and DO levels at each stratum of wetlands

Phosphorus concentration in the incoming water was changed from inlet to outlet with a reduction of 66% of initial concentration from inlet to outlet (Figure 03). Level of Chlorophyll-a also resulted 22% drop while water flowed through the wetland (Figure 04). However, NH_3 concentration in effluents did not show a similar trend during the present study. This might be resulted due to variation of wetlands have yielded variable results with some wetlands demonstrating reduction while others actually released more ammonia in effluent (Kadlec and Knight, 1996) due to microbial action in the wetlands. This might be a possible reason of less significance of ammonia concentration reduction in outlet water. Rates of phosphorus removal were quite higher which might be one of the factors that govern reduction of chlorophyll a concentration.

Among physical parameters observed conductivity, total dissolved solids, pH, Temperature, salinity did not show significant alteration from inlet to outlet of the wetlands. Studies on constructed wetlands for aquaculture waste treatment have shown minimum of 30% open water with consistent water flow (Greenway *et al.*, 2003), depth of 0.2 – 0.6m (Diemont, 2006), size of 7-8% of the production area and hydraulic retention time of 2-5 days (Tillay *et al.*, 2002) is necessary for better performance of treatment wetlands and to control mosquito breeding in wetlands. In this study, the area of wetlands as a percentage of production area from where waste water discharges were approximately 2.8 %. Irrespective of the size of the wetlands, the preliminary results of the study indicated the usefulness of wetlands in treating shrimp pond effluents before they discharge into the natural water environment.

CONCLUSIONS

It was observed that the studied wetland reduced 36% of BOD, 39% chlorophyll, 66% of Phosphorus, 11% of turbidity. Dissolved oxygen concentration at the outlet of wetland was 38%-40% greater than that of inlet. Accordingly BOD, turbidity, phosphorus and chlorophyll-a concentration of shrimp pond effluents were effectively reduced by natural mangrove wetlands and it could also increase level of DO in incoming water as water flows through the wetlands.

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