MACROPHYTE BIOFILTER FOR TREATING EFFLUENT FROM AQUACULTURE

Eleventh Work Plan, Water Quality and Availability Research (11WQAR2)
Final Report

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ABSTRACT

A study was conducted at Jaboticabal, Sao Paulo, Brazil to evaluate the effectiveness of a wetland consisting of a 90 m long by 2 m wide ditch as a treatment system for effluent from a 3-ha aquaculture research station. The wetland (vegetated ditch) contained four major species of aquatic macrophytes as follows: Ludwigia elegans, L. sericia, Alternanthera philoxeroides, and Myriophyllum aquaticum. The biofilter action of the wetland caused an annual reduction in 5-day biochemical oxygen demand of 48.1% and a 26.4% reduction in total suspended solids. Although nutrient concentrations were not reduced in water passing through the wetland, the chlorophyll a concentration was about 14% less in the discharge of the wetland than in the incoming aquaculture effluent. Results of this study suggest that a wetland biofilter consisting of a vegetated ditch could cause modest improvements in the quality of aquaculture effluents.

INTRODUCTION

Aquaculture in Brazil has grown rapidly with little concern over environment issues. There are serious problems regarding fish production in ponds because of poor water quality, and pond effluents that enter natural water bodies may cause eutrophication and sedimentation.

Wetlands have been widely used as a means of removing nutrients and suspended solids from wastewaters, and it has been shown that they can be used to treat aquaculture effluents (Schwartz and Boyd, 1995). Wetlands function as a biofilter in which vascular, aquatic macrophytes, and associated communities of algae, bacteria, fungi, and other microorganisms remove nutrients and organic matter from water for use in metabolism (Sipauba-Tavares et al., 2002). Wetlands also filter out suspended solids and increase hydraulic retention time to encourage sedimentation.

The use of aquatic plants in wastewater treatment and recycling of nutrients originating from agricultural activities has been the object of great interest in Brazil in recent years. The procedure also appears suitable and economically feasible for treating effluents from freshwater fish farms (Pinto et al., 1983; Sipauba-Tavares et al., 2002; Sipauba-Tavares et al., 2003). Therefore, this study was conducted to evaluate the effectiveness of a wetland biofilter in improving the quality of aquaculture effluent.

METHODS AND MATERIALS

Study Area

The study was conducted at the Universidade Estadual Paulista (UNESP), Jaboticabal, SP, Brazil (21° 15'S; 48° 18'W). Effluent containing nutrients and suspended and dissolved solids originated from six research ponds at the aquaculture center with areas varying between 2,000 and 9,000 m^2. Some of these ponds received water from other research ponds located further up the watershed. Effluent from the nutrition, frog, and prawn culture sites also entered the six ponds. After passing through the wetland, the effluent ultimately was discharged into the Jaboticabal Creek.

Biofilter Implementation

The biofilter consisted of a wetland containing four major species of macrophytes, i.e., *Ludwigia elegans, Alternanthera philoxeroides, Ludwigia sericea* and *Myriophyllum aquaticum.* The biofilter was 90 m long and had a total area of 178 m^2. Water samples were collected from the water inlet and from the water outlet. A month after the biofilter was established with dense plant growth, limnological variables were analyzed every 15 days during the period March 2003 to March 2004.

Limnological Variables

The analyses were conducted by methods presented in Table 1. Only dissolved oxygen, temperature, pH, and conductivity were measured *in situ*.

RESULTS

Average concentrations of water quality variables in inflow and outflow for the wetland biofilter are provided in Table 2. The pH of water entering the biofilter averaged 6.37 while the outflow had an average pH of 6.92. Mean water temperature and dissolved oxygen concentration did not differ between the inlet and outlet of the biofilter. Discharge of the biofilter usually contained more than 4 mg/L dissolved oxygen. Specific conductance declined slightly while water was in the biofilter indicating a net removal of ions by the system. Average concentrations of total alkalinity, total ammonia nitrogen, nitrate nitrogen, total phosphorus, and soluble reactive phosphorus did not differ between inflow and outflow (Table 2). Nevertheless, retention of water in the biofilter causes a reduction in concentrations of chlorophyll *a*, 5-day biochemical oxygen demand (BOD_5), and total suspended solids (Table 2).

There was considerable variation in concentrations of water quality variables from month to month in both inflow and outflow as illustrated in Figure 1 for BOD_5 and total suspended solids. The annual reduction in BOD_5 and total suspended solids averaged 48.1% and 26.4%, respectively, of the concentrations of these two variables in inflow. However, monthly reductions were sometimes much higher than the average and the outlet water occassionally had greater concentrations of one or the other of the two variables than did inlet water. Rainfall data were not collected, but the period from November to March typically has much more rainfall than the period from April to October. The removal of suspended solids by the biofilter tended to be more efficient during the drier months and especially from June to September (Figure 1). There was less effect of seasonality on concentrations of BOD_5 than on those of total suspended solids.

DISCUSSION

The wetland biofilter of this study was located along a natural drainage channel. It was long and narrow and probably should be considered a vegetated ditch rather than a typical, macrophyte-dominated wetland. It was not possible to obtain reliable data on retention time in the system. However, it receives the inflow from the UNESP experiment ponds and their watershed. Thus, during periods of heavy rainfall, large amounts of water flowed through the biofilter. During periods without rainfall, water flow through the biofilter was greatly reduced.

Some processes in wetlands function to increase pH, e.g., photosynthesis and denitrification, while others tend to lower pH, e.g., organic matter decomposition and nitrification. The increase in pH observed within the wetland probably was the result of photosynthesis, for the lack of decline in nitrate concentration within the biofilter indicated a low rate of denitrification.

It was surprising that the biofilter did not significantly reduce mean concentrations of nitrogen and phosphorus in water passing through it. Other studies have revealed that wetlands can cause reductions in nitrogen and phosphorus concentrations of over 50% (Schwartz and Boyd, 1995; Backer, 1998). Nevertheless, on certain dates, the wetland caused large reductions in nitrogen and phosphorus concentrations. The wetland was established just a few weeks before the study began. Thus, aquatic macrophytes and associated flora and fauna were still developing and have not reached their maximum potential for removing nitrogen and phosphorus (Schwartz and Boyd 1995).

The biofilter caused a reduction in BOD_5 of roughly 50%. According to Kim and Kim (2000), a reduction in chlorophyll *a* (an indication that phytoplankton abundance has declined) in biofilters often is followed by a decline in BOD_5 concentration. The slight decline in total suspended solids concentration in the biofilter also possibly resulted from removal of plankton by the biofilter.

According to Kivaisi (2001) the removal of BOD_5, nitrogen, and phosphorus from wastewater by wetlands has ranged from 75 to 90%, 30 to 50%, and 20 to 60%, respectively. Schwartz and Boyd (1995) reported the wetland could reduce total suspended solids concentrations by 60-90%. By comparison, the wetland used in the present study was less efficient in purifying effluent then typical wetlands. There are several possible reasons for the low efficiency of the wetland. The species of plants used in the wetland were different from those used in other studies. The plants in the UNESP wetland may not have been highly efficient at removing nutrients for growth or in producing a dense layer of roots and debris to function as a biofilter. The narrow wetland had a small water storage capacity limited mainly to a shallow channel about 1 to 2 m in width. Thus, during rainy weather the hydraulic retention time was very short, and the system lost efficiency as a sedimentation area and biofilter. However, we feel that the main reason that the wetland was not highly effective in treating effluent was because the inflowing water was dilute in concentrations of potential pollutants. The water originated from fish ponds and runoff, and concentrations of nitrogen, phosphorus, BOD_5, and total suspended solids were much less than in typical wastewater applied to wetlands for treatment. Dilute effluents are much more difficult to treat by sedimentation and biofiltration than are more concentrated ones (Boyd and Tucker, 1998).

In spite of its low efficiency, the wetland biofilter caused a significant reduction in some variables, and the water exiting the system was of high quality. Many fish farms can release water through ditches that ultimately enter streams or other natural water bodies. These ditches could be planted with aquatic vegetation, and the resulting biofilter would provide a modest degree of water quality enhancement. Moreover, the vegetation would prevent erosion of the ditch to protect farm infrastructure and minimize the suspension of solids by outflowing water.

Conclusions

Results of this study revealed that a wetland biofilter consisting of aquatic vegetation growing in and along the edges of a shallow ditch caused modest improvements in aquaculture pond effluent. Many aquaculture farms have ditches which could be planted with aquatic vegetation and provide some degree of effluent treatment.

Anticipated Benefits

Pond aquaculture is a growing endeavor in Brazil and many other countreis. Only recently has it become apparent that aquaculture effluents can cause eutrophication and sedimentation in receiving water bodies. Governments in some nations are developing aquaculture effluent regulations, and many aquaculture organizations are encouraging producers to voluntarily adopt better management practices. This study suggests that vegetated ditches could provide a modest degree of effluent treatment. The procedure could be used widely, because many farms have discharge ditches which could be planted with vegetation. Therefore, we anticipate that use of vegetated ditches will become a common practice in aquaculture effluent management.

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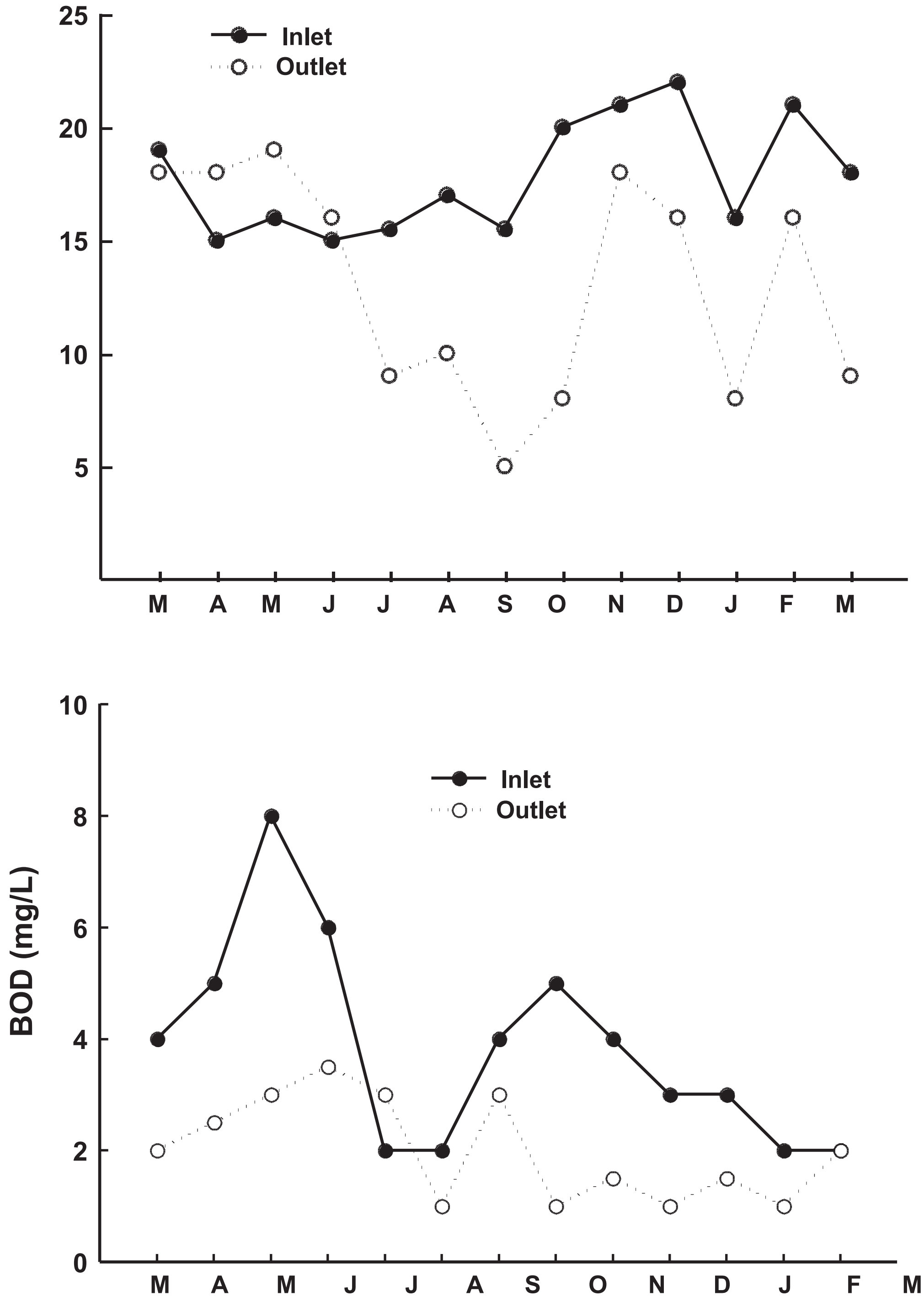
Table 1. Water quality variables and methods of analy-

Variables	Method	Unit	Reference
Dissolved oxygen	Horiba U 10	mg/L	Instruction manual
Temperature	Horiba U 10	ºC	Instruction manual
pH	Horiba U 10	Standard units	Instruction manual
Specific conductance	Horiba U 10	μmhos/cm	Instruction manual
Alkalinity	Acidimetry	mg/L	Mackerett et al. (1978)
Ammonia	Phenate	mg/L	Koroloff (1976)
Nitrate	Cadmium reduction	mg/L	Golterman et al. (1978)
Total phosphorus	Acidic digestion and ascorbic acid	mg/L	Golterman et al. (1978)
Orthophosphate	Ascorbic acid	mg/L	Golterman et al. (1978
Chlorophyll *a*	Acetone extraction	μg/L	Nash (1980)
5-day biochemical oxygen demand	Incubation in dark at 20ºC	mg/L	Boyd and Tucker (1992)
Total suspended solids	Gravimetry	mg/L	Boyd and Tucker (1992)

Table 2. Concentrations of water quality variables in inflow and outflow of wetland biofilter.

Variable	Inflow	Outflow	P
pH	6.37 ± 0.16	6.92 ± 0.37	0.002
Water temperature (ºC)	23.4 ± 2.3	21.8 ± 2.6	0.105
Dissolved oxygen (mg/L)	50 ± 1.5	4.5 ± 1.4	0.308
Specific conductance (μmhos/cm)	102 ± 9	90 ± 15	0.022
Total alkalinity (mg/L)	80.5 ± 10.0	82.3 ± 7.6	0.636
Total ammonia nitrogen (mg/L)	0.55 ± 0.20	0.46 ± 0.21	0.232
Nitrate-nitrogen (mg/L)	0.56 ± 0.14	0.44 ± 0.14	0.061
Total phosphorus (mg/L)	0.52 ± 0.10	0.48 ± 0.10	0.392
Soluble reactive phosphorus (mg/L)	0.053 ± 0.02	0.046 ± 0.02	0.226
Chlorophyll *a* (μg/L)	51.2 ± 7.4	44.8 ± 6.4	0.001
5-day biochemical oxygen demand (mg/L)	3.85 ± 1.81	2.00 ± 0.91	0.005
Total suspended solids (mg/L)	17.8 ± 2.5	13.1 ± 4.9	0.041

Figure 1. Average monthly concentrations of total suspended solids and 5-day biochemical oxygen demand (BOD_5) in inlet and outlet of wetland biofilter.



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