# Removal of Total Particulate Matter, Particulate Organic Matter, Particulate Nitrogen, Particulate Phosphorus and Phytoplankton from Eutrophic Water by a Freshwater Bivalve Mollusk, *Pilsbryoconcha exilis compressa*

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## ABSTRACT

The ability of a freshwater bivalve mollusc, *Pilsbryoconcha exilis compressa*, to counteract eutrophication problems by filtering particulate matter, particulate nitrogen, particulate phosphorus and phytoplankton out of eutrophic water was evaluated in eutrophic freshwater pond. Parameters measured were total particulate matter (TPM), particulate organic matter (POM), particulate nitrogen (PN), particulate phosphorus (PP) and chlorophyll *a* (Chl *a*) in eutrophic pond water flowing through a 10 m flume covering 5 $m^2$ of artificial bed of *Pilsbryoconcha exilis compressa* stocked at 4 kg bivalve/$m^2$. When eutrophic pond water passed through the bivalve bed, all the measured parameters significantly decreased ($P<0.05$). TPM, POM, PN, and PP decreased from 67.7, 25.0, 1.050 and 0.111 mg/L to 52.7, 20.0, 0.689 and 0.078 mg/L, respectively, while Chl *a* content decreased from 55.2 µg/L to 43.6 µg/L. Average removal rates were 22.2, 19.7, 34.3, 25.5, and 21.0% for TPM, POM, PN, PP and Chl *a*, respectively. Water turbidity decreased from 73.6 to 62.6 NTU with an average reduction rate of 14.9%.

**Keywords:** *Pilsbryoconcha exilis compressa*, freshwater bivalve mollusc, total particulate matter, particulate organic matter, particulate nitrogen, particulate phosphorus, phytoplankton

## INTRODUCTION

The ability of bivalve molluscs to act in a bioremediative capacity has been investigated mostly in marine species. Several reports point out that oysters and mussels are the most potential species to be utilized for the bioremediation of eutrophic coastal waters. Through active filtration, bivalve molluscs remove seston from the overlying water column, thus reducing the concentrations of suspended sediments, detritus, and particulate bound nutrients in estuarine environment (Gerritsen *et al*., 1994; Brumbaugh *et al*., 2000; Mann, 2000). Field studies have shown that oyster beds may reduce chlorophyll *a* concentration in the overlying water column by more than 75% (Dame *et al*., 1984). Currently, oyster reef restoration has been utilized as an

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effective tool to counteract eutrophication problems in coastal waters. For freshwater bivalves, the introduction of zebra mussel (*Dreissenia polymorpha*) effectively reduced turbidity and chlorophyll *a* content of water in Lake Erie while the establishment of the Asiatic clam (*Corbicula fluminea*) in the Potomac River estuary improved water quality resulting in the reappearance of submerged aquatic vegetations and the increase in population of fish and birds (Leach, 1993; Phelps, 1994). Conservation and expansion of natural bed of bivalve molluscs can be used as a tool to encounter eutrophication problems in water bodies. Increasing oyster populations by building oyster reefs are being used to mitigate eutrophication problems in several coastal waters (Gifford et al., 2006; Officer *et al*., 1982). *Pilsbryoconcha exilis compressa* is a native freshwater bivalve mollusc commonly found in all types of freshwater bodies in Thailand including lakes, swamps, ponds, rivers and canals. In this investigation, we studied the ability of this freshwater bivalve to filter total particulate matter, particulate organic matter, particulate nitrogen, particulate phosphorus and phytoplankton out of eutrophic water in order to evaluate its potential as a zooremediator for freshwater bodies facing eutrophication problems.

## MATERIALS AND METHODS

The study was done in a eutrophic freshwater pond at the Faculty of Fisheries, Kasetsart University, Bangkok. The method used for this investigation was adapted from Asmus and Asmus (1991) utilizing polyethylene flume constructed in the pond (Figure 1a). The flume consists of a wooden frame lined with polyethylene sheet. The flume had a size dimension of 10 x 0.5 x 0.5 m. One end of the flume was open to let the water flow in while the other end was closed to form a sump in which a submersible pump was installed to generate flow of water through the flume. The bottom of the flume was lined with a 5 cm layer of sand. Water depth was 25 cm. Freshwater bivalve mollusc, *Pilsbryoconcha exilis compressa* (Figure 1b),



Figure 1. a) Polyethylene flume;
b) Pilsbryoconcha exilis compressa

were put into the flume at a stocking rate of 4 kg/$m^2$. The bivalves were acclimated in the flume for 2 days before starting the experiment. During the experiment, gentle flow of pond water through the flume was generated by pumping water out from the sump connected to one end of the flume. Water flow rate was 0.5 m/min.

A water sample was taken at the inlet at the open end of the flume and a drifting buoy was released simultaneously. When this buoy reached the other end of the flume near the sump, a corresponding water sample was taken. Water samples were analyzed for turbidity, total particulate matter, particulate organic matter, particulate nitrogen, particulate phosphorus and chlorophyll *a*. Water samples were collected three times a day and the samples were deposited and analyzed. The experiment was done for three days. Total particulate matter was analyzed by filtering water samples through G/FC glass fiber filter, dried in an oven at 103-105°C overnight, and weighed. Then the samples were transferred to a muffle furnace and ignited at 550°C for 4 h, cooled in a dessicator, then weighed.

Particulate organic matter was calculated by subtracting sample weight dried at 103-105°C by sample weight after igniting at 550°C. Particulate phosphorus was analyzed by vanadomolybdophosphoric acid method after perchloric acid digestion, while chlorophyll *a* content was analyzed using spectrophotometric determination method after extracting with acetone (APHA *et al*., 2005). Particulate nitrogen was analyzed using Kjeltec 1035 analyzer unit, Tecator; Digestion block, Foss, Model 2520. Turbidity was measured by Turbidimeter HACH 2100Q. Data from the three days experiment were averaged and analyzed statistically to determine the differences among water quality parameters of the incoming pond water and the water that flowed through the flume containing the bivalves.

## RESULTS AND DISCUSSION

When eutrophic pond water flowed through the 10 m flume containing 4 kg/$m^2$ of freshwater bivalve mollusc, *Pilsbryoconcha exilis compressa*, water turbidity decreased significantly ($P<0.05$) from an average value of 73.6 to 62.6 NTU. Water turbidity decreased to 11.2, 8.4 and 13.4 NTU at days 1, 2 and 3, respectively, which were 14.9, 12.1 and 17.5% of the initial values, respectively. The average reduction rate of water turbidity was 14.9%.

Total particulate matter decreased significantly ($P<0.05$) from the average value of 67.7 to 52.7 mg/L ($P<0.05$). Total particulate matter decreased to 15.0, 14.0 and 16.0 mg/L at days 1, 2 and 3, respectively, which were 22.1, 22.6 and 21.9% of the initial values, respectively. Average reduction rate of total particulate matter was 22.2%.

Particulate organic matter decreased significantly ($P<0.05$) from the average value of 25.0 to 20.0 mg/L. Particulate organic matter decreased to 8.0, 3.0 and 4.0 mg/L at days 1, 2 and 3, respectively, which were 30.8, 13.0 and 15.4% of the initial values, respectively. Average reduction rate of particulate organic matter was 19.7%.

Chlorophyll *a* content decreased significantly (P<0.05) from the average value of 55.2 to 43.6 µg/L. Chlorophyll *a* content decreased to 13.4, 10.6 and 10.6 µg/L at days 1, 2 and 3, respectively, which were 23.9, 18.1 and 20.9% of the initial values, respectively. Average reduction rate of chlorophyll *a* was 21.0%.

Particulate nitrogen decreased significantly (P<0.05) from the average value of 1.050 to 0.689 mg/L. Particulate nitrogen decreased to 0.361, 0.274 and 0.449 mg/L at days 1, 2 and 3, respectively, which were 34.4, 26.6 and 42.0% of the initial values, respectively. Average reduction rate of particulate nitrogen was 34.3%.

Particulate phosphorus decreased significantly (P<0.05) from the average value of 0.111 to 0.078 mg/L. Particulate phosphorus decreased to 0.005, 0.031 and 0.061 mg/L at days 1, 2 and 3, respectively, which were 7.1, 24.6 and 44.9% of the initial values, respectively. Average reduction rate of particulate phosphorus was 25.5% (Table 1).

Table 1. Concentrations of total particulate matter (TPM), particulate organic matter (POM), particulate nitrogen (PN), particulate phosphorus (PP), chlorophyll *a* (Chl *a*) and turbidity of eutrophic pond water before and after flowing through a flume covered with an artificial bed of *Pilsbryoconcha exilis compressa*

| | | Day 1 | Day 2 | Day 3 | Mean±S.D. |
|---|---|---|---|---|---|
| TPM (mg/L): | Before | 68.0 | 62.0 | 73.0 | 67.7±5.5[a] |
| | After | 53.0 | 48.0 | 57.0 | 52.7±4.5[b] |
| | Decrease (mg/L) | 15.0 | 14.0 | 16.0 | 15.0±1.0 |
| | % Decrease | 22.1 | 22.6 | 21.9 | 22.2±0.3 |
| POM (mg/L): | Before | 26.0 | 23.0 | 26.0 | 25.0±1.7[a] |
| | After | 18.0 | 20.0 | 22.0 | 20.0±2.0[b] |
| | Decrease (mg/L) | 8.0 | 3.0 | 4.0 | 5.0±2.6 |
| | % Decrease | 30.8 | 13.0 | 15.4 | 19.7±9.6 |
| Chl a (µg/L): | Before | 56.1 | 58.7 | 50.7 | 55.2±4.1[a] |
| | After | 42.7 | 48.1 | 40.1 | 43.6±4.1[b] |
| | Decrease (mg/L) | 13.4 | 10.6 | 10.6 | 11.5±1.6 |
| | % Decrease | 23.9 | 18.1 | 20.9 | 21.0±2.9 |
| PN (mg/L): | Before | 1.050 | 1.032 | 1.068 | 1.050±0.018[a] |
| | After | 0.689 | 0.758 | 0.619 | 0.689±0.070[b] |
| | Decrease (mg/L) | 0.361 | 0.274 | 0.449 | 0.361±0.088 |
| | % Decrease | 34.4 | 26.6 | 42.0 | 34.3±7.7 |
| PP (mg/L): | Before | 0.070 | 0.126 | 0.136 | 0.111±0.036[a] |
| | After | 0.065 | 0.095 | 0.075 | 0.078±0.015[b] |
| | Decrease (mg/L) | 0.005 | 0.031 | 0.061 | 0.032±0.028 |
| | % Decrease | 7.1 | 24.6 | 44.9 | 25.5±18.9 |
| Turbidity (NTU): | Before | 75.1 | 69.3 | 76.4 | 73.6±3.8[a] |
| | After | 63.9 | 60.9 | 63.0 | 62.6±1.5[b] |
| | Decrease (mg/L) | 11.2 | 8.4 | 13.4 | 11.0±2.5 |
| | % Decrease | 14.9 | 12.1 | 17.5 | 14.9±2.7 |

Remark: Average values denoted by different superscript in each parameter are statistically significantly different (P<0.05).

Suspension-feeding bivalve can clear seston particles which are > 3 μm diameter from the water column with high efficiency (Bayne and Newell, 1983 cited by Newell, 2004; Bayne and Hakins, 1992 cited by Newell, 2004). Based on the results of this study, freshwater bivalve mollusc, *Pilsbryoconcha exilis compressa*, is able to filter suspended solids from the water column efficiently as indicated by the decrease of 22.2% of total particulate matter, 19.7% of particulate organic matter, 34.3% of particulate nitrogen, and 25.5% of particulate phosphorus when pond water flowed through the 10 m flume containing an artificial bed of the bivalve. These quantities of filtered particles and particulate nutrients were removed from the water column by filtration of the bivalve. However, the bivalve does not ingest all the particles they filtered. Captured particles are sorted in the pallial organ prior to ingestion, with the less nutritious and excess particles being immediately rejected as pseudofeces (Newell and Jordan, 1983; Newell and Langdon cited by Newell, 2004, 1966; Ward *et al*., 1977). Some parts of the particulate matter including organic and inorganic particles as well as particulate nutrients are transferred to the sediment surface as pseudofeces. Parts of the ingested organic particles are digested and assimilated by the bivalve. The undigested portion is excreted as feces which will also be transferred to the sediment similar to the psuedofeces. These biodeposits will be further utilized by other benthic fauna. Assimilation efficiency of bivalves feeding on different sources of particulate organic matter is approximately 20 to 90% (Bayne and Newell, 1983; Kreeger and Newell, 2001).

The reduction in chlorophyll *a* content of 21.0% indicated that *Pilsbryoconcha exilis compressa* can remove significant amounts of phytoplankton from the water column. According to Haamer (1996), bivalves can counteract a negative symptom of euthrophication by removing phytoplankton from suspension. Leach (1993) reported that chlorophyll *a* concentrations in water in Lake Erie decreased by 43% following the introduction of zebra mussel. Oysters and mussels have also been reported to be able to exert top-down control on phytoplankton in coastal waters (Asmus and Asmus, 1991; Dame, 1996; Dame *et al*., 1984,1991; Jordan and Valiela, 1982).

*Pilsbryoconcha exilis compressa* removed 14.9% of water turbidity by filtering out particulate matter from the water column. The decrease in water turbidity has a lot of effect on aquatic ecosystems by permitting deeper penetration of sunlight into water column. Leach (1993) reported that water turbidity in Lake Erie decreased markedly following the introduction of zebra mussel. Phelps (1994) reported that following the establishment of Asiatic clam (*Corbicula fluminea*) in the Potomac River estuary, water quality improved substantially, with submerged aquatic plants that had been absent for many years reappearing followed by a large increase in fish and bird populations.

## CONCLUSION

Results from this investigation indicated that *Pilsbryoconcha exilis compressa* is capable to remove significant amounts of total particulate matter, particulate organic

matter, particulate nitrogen, particulate phosphorus and phytoplankton from eutrophic waters flowing through its bed. This finding suggests that this freshwater bivalve species can be utilized as a potential zooremediator for the remediation of eutrophic freshwater bodies. Conservation and expansion of natural beds of this mollusc are recommended to counteract eutrophication problems in freshwater bodies receiving excessive nutrient loading. Establishing new beds of this species in selected water bodies is also a possible solution but more investigations are needed to develop proper methods for the establishment of new beds.

## LITERATURE CITED


APHA, AWWA and WEF. 2005. **Standard Method for the Examination of Water and Wastewater 21th ed.** APHA, Washington, D.C.

Asmus, R.M. and H. Asmus. 1991. Mussel beds: limiting or promoting phytoplankton. **J. Exp. Mar. Biol. Ecol.** 148:215-232

Brumbaugh, R.D., L.A. Sorabella, C.O. Garcia, W.J. Goldsborough and J.A. Wesson. 2000. Making a case for community -based oyster restoration: an example from Hampton Roads, Verginia, USA. **J. Shellfish Res.**19(1)397-400.

Dame, R.F. 1996. **Ecology of Marine Bivalves: An Ecosystem Approach.** CRC Press, Boca Raton, Florida.

Dame, R.F., R.G. Zingmark and E. Haskin. 1984. Oyster reefs as processors of estuarine materials. **J. Exp. Mar. Biol. Ecol.** 83:239-247.

Dame, R.F., J.D. Spurrier and T.M. Willium. 1991. Annual material processing by a salt marsh-estuarine basin in South Carolina, U.S.A. **Mar. Ecol. Prog. Ser.** 72:153-166.

Gerritsen, J., A.F. Holland and D.E. Irvine. 1994. Suspension-feeding bivalves and the fate of primary production: an estuarine model applied to Chesapeake. **Estuaries** 17(2)403-416.

Gifford, S., R.H. Dunstan, W.O. Connor, C.E. Coller and G.R. MacFarlane. 2006. Aquatic zooremediation: deploying animals to remediate contaminated aquatic environments. **Trends in Biotechnology** 25(2)60 -65.

Haamer, J. 1996. Improving water quality in a eutrophied fjord system with mussel farming. **AMBIO** 25(5):356 -362.

Jordan, T.E. and I. Valiela. 1982. Anitrogen budget of the ribbed mussel, *Geukensis demissa*, and its significant in nitrogen flow in a New England salt marsh. **Linol. Oceanogr.** 27:75-90.

Leach, J.H. 1993. **Impact of the zebra mussel (*Dressena polymorpha*) on water quality and fish spawning reefs in western Lake Erie.** In Zebra Mussells: Biology, Impact and Control (Nalepa,T.F. and Schloesser, D.W., eds), pp. 381-397. Lewis Publishers.

Mann, R. 2000. Restoring the oyster reef communities in the Chesapeake Bay: a commentary. **J. Shellfish Res.** 19(1)335-339.

Newel, R.I.E. 2004. Ecosystem influences of natural and cultivated bivalve biodeposition and microphytobenthos on sediment nitrogen dynamics: A laboratory study. **Limnology and Oceanography** 47(5):1367-1379.

Newel, R.I.E. and S.J. Jordan. 1983. Preferential ingestion of organic material by the American oyster *Crassostrea verginica*. **Mar. Eco. Prog. Ser.** 13:47-53.

Phelps, H.L. 1994. The Asiatic clam (*Corbicula fluminea*) invasion and system-level ecological change in the Potomac river estuary near Washington, D.C.. **Estuary.** 17:614 -621.

Ward, J.E., J.S. Levinton and S.E. Shumway. 1997. Site of particle selection in a bivalve mollusk. **Nature** 390:131 -132.