Enhancement of Shrimp Production through Ecosystem Remediation*

F.M. Yusoff, M. Shariff and M.S. Kamarudin

Faculty of Science and Environmental Studies
Universiti Putra Malaysia
43400 UPM, Serdang, Selangor
Malaysia

E-mail of Corresponding Author: fatimamy@fsas.upm.edu.my

Key words: water quality, shrimp production, marine culture systems, natural feed, bioremediation.

Introduction

Repeated failure of shrimp culture industry in Taiwan and Thailand in late 1980's and early 1990's, resulted in an estimated loss of more than US$30 million and dereliction of about 45,000 ha of land (Lin, 1989) due to environmental problems in intensive shrimp culture systems. In these systems, increase of feeding and animal excretion results in accumulation of organic load leading to poor pond-bottom condition and water quality. Only 20% of the nitrogen and 10% of the phosphorus from feed are incorporated into the shrimp harvested (Briggs and Funge-Smith, 1994) while the remaining nutrients are retained in pond water and sediment, and ultimately discharged to the surrounding environment.

High nutrient concentrations would cause phytoplankton blooms consisting of undesirable species such as cyanobacteria and dinoflagellates, resulting in water quality deterioration of pond and coastal environment. Thus, effective water quality management is crucial for intensive grow-out since it determines the health and production of the cultured organisms (Yusoff and McNabb, 1989).

The objectives of this study were to identify the factors and trends related to water quality deterioration, and to determine effective management techniques to reduce harmful nutrient levels in intensive shrimp culture pond waters.

Materials and Methods

The ecology of shrimp culture ponds with different trophic status was studied. Studies were also conducted to investigate means of reducing the release of nutrients from the interstitial water. Growth, survival and biochemical composition of tiger shrimp, *Penaeus monodon* juvenile fed with natural and artificial diets were determined. The efficacy of commonly used bacterial products in enhancing water quality and growth of beneficial phytoplankton in commercial shrimp grow-out ponds was also investigated.

Results and Discussion

High concentrations of nutrients in ponds, especially phosphorus and nitrogen caused cyanobacterial blooms, which deteriorated the water quality and resulted in low shrimp production with an average of 2 tonnes/ha/cycle. Cyanobacteria formed approximately 90% of the total phytoplankton populations in ponds with eutrophic waters. In less enriched ponds, diatoms were dominant, contributing approximately 60%, whilst cyanobacteria contributed less than 10% of the total phytoplankton. The addition of nitrogen and silica to pond water would provide a competitive advantage for the development of beneficial diatoms, which would further improve the water quality and increase shrimp production.

The important polyunsaturated fatty acids such as arachidonic acid (20:4n-6), EPA (20:5n-3), DPA (22:5n-3) and DHA (22:6n-3) were significantly lower in the cyanobacteria compared to other algae. The diatoms were dominant and the cyanobacteria were absent in ponds treated with microbial products and control ponds at the beginning of the culture period when the nutrients were low. Cyanobacteria were significantly higher ($p < 0.05$) in the control compared to the treated ponds during the final phase of the culture. Algal bioassay showed that the addition of nitrogen either alone or with silica, to pond water significantly ($p < 0.05$) increased the specific growth rate of the diatom *Chaetoceros calcitrans*. Addition of silica seemed to depress the growth rate of *Oscillatoria* sp. Phosphorus enrichment in aquaculture ponds should be minimized, and the supply of nitrogen and silica should be adequate for promoting the growth of beneficial phytoplankton in aquatic systems.

The use of lime (calcium carbonate) and alum (aluminum sulfate), in addition to aeration, reduced the flux of nutrients from the bottom sediment to the overlying water, thus decreasing the nutrient availability for noxious plankton blooms. Adequate aeration is necessary to ensure that the bottom water maintains the aerobic condition in order to reduce the formation of toxic substances such as ammonia, nitrite, hydrogen sulphide and methane, all of which are detrimental to the cultured organisms. Diluted interstitial water was found to be the good growth medium for the *C. calcitrans* and *N. oculata*. *Chaetoceros calcitrans* showed significantly higher growth rate in diluted interstitial water compared to Conway medium and pure interstitial water.

Laboratory and field studies showed that shrimp had the highest growth when fed with combined natural and artificial diets. In intensive culture ponds, the density of benthic organism such as polychaetes, harpacticoid copepods and insect larvae decreased to low level after 8 weeks due to deterioration of sediment quality. Accumulation of organic matter from excess feeding, animal excretion and die-offs renders the bottom sediment anaerobic, releasing toxic products such as ammonia, nitrite and hydrogen sulphide, which are harmful to benthos as well as cultured organisms.

Cleaning of pond bottom from the previous harvest is important as bad pond bottom resulted in various kinds of diseases and crop failure. The use of bioremediation products with high concentration of beneficial microorganisms increased the mineralization process to maintain healthy environmental condition in pond sediments of aquaculture systems. Further research in developing effective bioremediation product for intensive culture system will be necessary to effectively manage intensive culture systems.

Conclusions

Eutrophic waters containing high phosphorus contents can cause undesirable cyanobacterial blooms resulting in poor shrimp production. Cyanobacteria was poorer in nutritional contents such as protein, essential amino acids, lipids and polyunsaturated fatty acids compared to diatoms or green algae. Addition of nitrogen and silica to pond water provide a competitive advantage for the development of beneficial diatoms.

Shrimp had the highest growth when fed with combined natural and artificial diets. Addition of bacterial products to culture ponds seemed to enhance the growth of beneficial algae, decreased cyanobacterial populations and improved shrimp production.

Benefits from the study

Good water and sediment quality in shrimp ponds could be maintained by managing proper nutrient loadings, increasing bottom layer aeration, reducing nutrient flux from the sediment, and applying effective bioremediation product. The new scientific formulation input resulted in an unprecedented shrimp production of approximately 7-9 tonnes/ha compared to the current average of 1.98 tonnes/ha in Malaysia. Based on a conservative production of 5 tonnes/ha in 4,883ha ponds, and shrimp wholesale price of RM29/kg, the application of the present findings could boost the shrimp earning to 708 million annually, compared to 283 million for the year 1998. In addition, the findings from this study will also minimize pollution in coastal waters and thus assure a sustainable and healthy shrimp culture industry in Malaysia

Literature cited in the text

Briggs, M.R.P., and Smith, S.J. 1994. A nutrient budget of some intensive marine ponds in Thailand. *Aquaculture and Fisheries Management.* 25:789-811.

Lin, C.K. 1989. Prawn culture in Taiwan. What went wrong? *World Aquaculture.* 20:19-20.

Yusoff, F.M, and McNabb, C.D. 1989. Effects of nutrient availability on primary productivity and fish production in fertilized tropical ponds. *Aquaculture.* 78: 303-319.

Project Publications in Refereed Journals

Arulampalam, P., Yusoff, F.M., Shariff, M., Law, A.T. and Srinivasa Rao, P.S. 1998. Water quality and bacterial populations in a tropical marine cage culture farm. *Aquaculture Research.* 29: 101-108.

Habib, M.A.B., Yusoff, F.M., Phang, S.M., Kamarudin, M.S. and Mohamad, S. 1998. Chemical characteristics and essential nutrients of agroindustrial effluents in Malaysia. *Asian Fisheries Journal.* 11: 279-286.

Habib, M.A.B., Yusoff.. F.M., Phang, S.M, Ang KJ, and Mohamad S. 1997. Nutritional values of chironomid larvae grown in palm oil mill effluent and algal culture. *Aquaculture.* 158:95-105.

Hoque, M.T., Yusoff, F.M., Law, A.T. and Syed, M.A. 1998. Effect of hydrogen sulphide toxicity on liver somatic index and Fulton's condition factor of *Mystus nemurus*. *J. of Fish Biology.* 50:23-30.

Shariff, M., Yusoff, F.M., Devaraja, T.N. and Srinivasa Rao, P.S. 2001. The effectiveness of a commercial microbial product in poorly prepared tiger shrimp, *Penaeus monodon* Fabricius ponds. *Aquaculture Research.* 32: 181-188.

Shishehchian, F. and Yusoff, F.M. 1999. Composition and abundance of macrobenthos in tropical marine shrimp culture ponds. *Journal of the World Aquaculture Society.* 30: 128-133.

Shishehchian, F., Yusoff, F.M., Kamarudin, M.S. and Omar, H. 1999. Nitrogenous excretion of *Penaeus monodon* post larvae fed with different diets. *Marine Pollution Bulletin.* 39: 224-227

Yusoff, F.M. and Chan, S.Y. 1997. Nutrient status of palm oil, rubber and domestic effluents, and their effects on algal growth. *Journal of Bioscience.* 8:42-50.

Yusoff, F.M. and McNabb, C.D. 1997. The effects of phosphorus and nitrogen addition on phytoplankton dominance in tropical ponds. *Aquaculture Research.* 8: 591-597.

Yusoff, F.M., Law, A.T., Goh, Y.J. and Subasinghe, R. 1998 Effects of nitrite and pH on a tropical fish fry, *Puntius gonionotus* (Bleeker). *Pertanika Journal of Tropical Agricultural Science.* 21: 29-36.

Yusoff, F.M., Law, A.T., Teo, H.Y. and Hoque, M.T. 1998. Effects of hydrogen sulfide on the early developmental stages of Javanese carp, *Puntius gonionotus* (Bleeker). *Asian Fisheries Journal.* 11: 231-238.

Yusoff, F.M., Matias, H.M., Anton, A. and Mohd. Zaki, M. 1998. Phytoplankton populations in intensive marine shrimp culture ponds using treated and untreated water source. *Science International (Lahore).* 10: 245-248.

Yusoff, F.M. H.B. Matias, K. Zarina and Phang, S.M. 2001. Use of interstitial water extracted from shrimp pond bottom sediments for marine algal culture. *Aquaculture.* 201: 263-270.

Yusoff, F.M. M.S. Zubaidah, H.B. Matias, and T.S. Kwan. 2001. Phytoplankton succession in intensive marine shrimp aquaculture ponds. *Aquaculture Research*: In Press.

Project Publications in Conference Proceedings

None.

Graduate Research

Muhammad Tafazzal Hoque. 1997. Biological markers in catfish *Mystus nemurus* (C&V) exposed to hydrogen sulphide. [Ph.D.] Universiti Putra Malaysia.

M. Ahsan Habib. 1998. Culture of selected microalgae in agro-industrial effluents and their use in the production of enriched rotifers. [Ph.D.] Universiti Putra Malaysia.

Farshad Shishehchian. 2000. Utilzation of phytoplankton and benthos as food source for *Penaeus monodon* juvenile and its effects on water quality. [Ph.D.] Universiti Putra Malaysia.

* *An update of the abstract published in UPM Research Report 1998.*

I.R.P.A. INTENSIFICATION OF RESEARCH IN PRIORITY AREAS

Research funded by the Intensification of Research in Priority areas (IRPA) - Supported by IRPA RM-7 (1996-2000), Cycle 1996, Grant 01-02-04-0165.