Nutrient Levels in Ponds during the Grow-out and Harvest Phase of *Penaeus monodon* under Semi-intensive or Intensive Culture*

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Abstract

Problems of pollution from nutrients in the effluents of prawn farms have often been highlighted, leading to questions about their sustainability. This study aimed at the monitoring of nutrient and chlorophyll *a* levels in two penaeid prawn grow-out ponds in West Malaysia, one under intensive culture (located in Penang), and the other under semi-intensive culture (pond located in Ban Merbok, Kedah). The nutrient levels and their possible effects on the surrounding coastal waters were analyzed. During the first month of the grow-out phase, the phosphate (PO_4-P) concentration appeared to be very high, but during this period there was no water change in the pond. The nitrite (NO_2-N) levels in the pond in Penang during the grow-out phase and in both ponds during harvest satisfied the criteria for the penaeid prawn pond effluent standards proposed by the Pollution Control Department, Thailand. The nitrate (NO_3-N) levels in the ponds were of the same order as the NO_3-N levels recorded in mangrove estuaries. The parameter of concern in terms of pollution appeared to be mainly the concentration of ammonia (NH_4-N) during the harvest phase. The NH_4-N value during harvest exceeded (Ban Merbok) or was near (Penang) the criteria for concentrations of total ammonia recommended by USEPA (1993). It is suggested that effluents during harvest be channeled into oxidation ponds where the levels of ammonia and suspended matter could be reduced by the nitrification process and sedimentation.

Key words: penaeid prawn, intensive culture, nutrient, pollution, mangrove, coastal water, ammonia environmental impact

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Introduction

The culture of penaeid prawns in Malaysia has a long history dating back to the early 1900s when immigrants brought with them the technique of culture in trapping ponds[4]. Ponds were located in mangrove areas and ranged in size from 2 - 20 ha, with fry and natural food being recruited with the incoming tides. Production from these ponds was low, usually less than 1 tonne/ha/ crop. Due to the low stocking density (< 10 postlarvae/ m^2) and the non-dependence on artificial feed, this practice is considered to be environmentally sustainable. Since prawns from extensive culture feed on natural food from the ponds, and do not generate significant amounts of wastes, they may even be net removers of nutrients and organic matter [5].

Since the 1970s, however, penaeid prawns (mainly tiger prawns) have been generally cultured on a semi-intensive (10- 20 postlarvae/ m^2) or intensive scale (> 20 postlarvae / m^2) due to the increase in the demand and price of land, and the expanding lucrative export market for penaeid prawns. A production of 2 - 8 tonnes/ha/year is usually attained for semi-intensive cultures, whilst close to 4 -10 tonnes/ha/year for intensive culture. Problems of pollution from nutrients in the effluents of prawn farms are commonly highlighted leading to questions about the sustainability of such cultures.

In this study, the nutrient levels were monitored in two ponds: a pond in Penang under intensive culture during the grow-out phase up to the time of harvest; a pond in Ban Merbok, Kedah where the nutrient levels in the water and sediments of the pond were collected immediately after harvest. Nutrient levels in the pond water and sediments, and their possible impacts on the surrounding coastal waters were analyzed.

Materials and Methods

One of the ponds studied, 1 ha in size, was located on mangrove land in Penang. A total of 27 ponds 1 ha in size were located in the farm which covered a total land area of 48.6 ha. The other pond (0.36 ha) monitored was located in Ban Merbok, Kedah, where the nutrient levels were studied during harvest. The intensive culture pond in Penang was stocked on Nov. 30, 1997 at a density of 40 m^2, and the first sampling was performed on Nov. 5, 1997 – seven days after stocking. Sampling was carried out once every three weeks, and the farm operator was interviewed on culture practices each time during the sampling period. The water depth of the pond was 1.1 m. The first water change in the pond was performed three weeks after the culture was initiated. After this period, water was changed once every two or three days depending on the conditions of the water quality. Normally about 10% of the water was changed each time, and slightly more as the grow-out phase progressed. On Jan. 6, 1998, it was observed that lime (calcium carbonate 98%) had been added to the pond at a daily rate of 200 kg/pond for the past four days, and over the next few days until the total alkalinity of the pond water reached a level of around 110 – 112 mg/*l*. During the course of the culture, benzalkonium chloride (BKC) was applied to the pond twice at a rate of 9 *l* each time to prevent leg and fin rot. On Feb. 2, 1998, the pond was harvested by draining the water through the pond outlet.

The semi-intensive culture pond in Ban Merbok was monitored only once during harvest on Nov. 6, 1997. Semi-intensive culture pond (stocked at a rate of 15 postlarvae/m^2) was practiced. During the first month of culture, water was not changed, and thereafter, water change was carried out during the spring tides only, since ponds in Ban Merbok are tidal-dependent. Water change during the spring tides was carried out daily, without change during the neaps. The amount of water changed during the second month of culture was about 5%, 10% for the third month and 20% for the fourth month.

Three samples were collected by using a pail from just below the surface of the pond (from the center, side and water inlet) in Penang each time during the sampling period. During harvest, two samples were collected from the pond, and another two from the canal (about 3 m from the pond) where the pond effluents were drained. The samples were collected during the initial stages of harvest when the pond was drained, and before the pond bottom was cleaned by flushing with a high pressure water jet.

In Ban Merbok, water and sediments were collected during harvest, from the pockets of water left in the drained pond, and also from the canal (about 4m from the outlet of the pond) where the effluent waters drained. In this case also, water was collected before the pond bottom was flushed.

Water collected was filtered immediately through a nylon screen of 200 μm into acid-washed poly-propylene bottles. Sediments were collected using a Birge-Ekman grab sampler. Subsamples of surface sediments (0 - 1 cm) were taken through the flaps at the top of the grab. The water and mud samples were then stored in an insulated chest filled with ice and taken back to the laboratory within two hours of sampling.

In the laboratory, suspended matter from the pond water was recovered through filtration using a 0.45 μm Millipore HA filter or a Whatman GF/C filter. The filtered water samples were kept in a freezer and analyzed within two months after collection. The concentrations of nitrate (NO_3- N), nitrite (NO_2-N), phosphate (PO_4-P) and chlorophyll *a* (Chl. *a*) were determined using the standard methods described by Parsons et al[6]. The concentration of ammonia (NH_4-N) was determined using the modified indophenol method of Sasaki and Sawada[9]. A Shimadzu UV-1601 spectrophotometer was used for the analysis.

The suspended matter on the filters and the sediment samples were dried overnight in an oven at 60 °C, and then kept in a desiccator until analysis. The sediment samples were gently crushed using a pestle and mortar. After acid treatment for the elimination of inorganic carbon, the contents of organic carbon and total nitrogen in the suspended matter and sediment samples were measured with an elemental analyzer (Fisons EA 1108). The content of inorganic phosphorus was measured following the procedures of Andersen[2].

Results and Discussion

The physical parameters and dissolved nutrient levels in the water of the penaeid prawn pond in Penang are depicted in Table 1, and Fig. 1 while Table 2 shows the physical parameters and nutrient concentrations in the penaeid prawn ponds in Penang and in Ban Merbok during harvest. Nutrient contents of the suspended matter and pond sediments in both ponds are listed in Table 3 and Table 4, respectively.

The interim criteria for reactive phosphate in estuarine and marine waters in the ASEAN region for the protection of the coastal and marine environment from eutrophication are recommended to be 45 $\mu g/l$ (1.45 μM) and 15 $\mu g/l$ (0.48 μM)[3]. Based on these levels, the phosphate (PO_4-P) level (5.70 μM) recorded in the pond in the first month of culture where no water change was carried out would appear to be very high (Fig.1). During this phase, inorganic fertilizers are usually added to the pond to initiate plankton bloom. One month after stocking, when the juveniles were no longer dependent on algal food, and when water change in the pond was implemented, the PO_4-P level dropped below the interim criteria level of 1.45μM for coastal water. The level recorded during harvest was slightly higher than that of the recommended criteria.

In Penang and Ban Merbok, the PO_4-P levels in the effluents in the canals were lower than those of the water in the ponds (Table 2). PO_4-P concentrations in the Merbok estuary ranged from 0.3 - 0.6 μM[11]. The PO_4-P levels in the prawn ponds in the present study exceeded these values during the first month of the grow-out phase in the pond in Penang, and also during harvest in both ponds.

Concentrations of dissolved inorganic nitro-gen in tropical waters are usually dominated by ammonia[1]. Tanaka and Choo[12] reported that the highest NH_4-N level recorded in the Sangga Besar River estuary in the Matang mangrove was about 25 μM. The NH_4-N values in both ponds during harvest exceeded this value by about three times in Penang and twenty times in Ban Merbok (Table 2). Water quality criteria for concentrations of total ammonia recommended by USEPA[13] for a temperature of 25 ℃ and pH 7 gave a value of 6.6 mg/*l* total ammonia for a salinity of 20. The ammonia levels during harvest in the Ban Merbok pond reached a value of 495μM or 8.4 mg/*l* (Sal. 16.8, Temp. 26.2, pH 6.97), and therefore exceeded the criteria level by 1.3 fold. The highest ammonia level in the pond in Penang was recorded during harvest (62.9 μM or 1.1 mg/*l*) and this concentration was near the USEPA criteria level of

Table 1. Physical parameters and Chl *a* values in the water of a penaeid prawn intensive culture pond in Penang

Date	Sal.	Temp.(°C)	Turbidity(NTU)	pH	Chl. *a* (μg/*l*)
5.11.97	27.2	28.7	18.0	8.17	41.3
25.11.97	24.3	29.6	29.5	8.33	84.0
16.12.97	27.4	29.3	37.3	8.12	82.6
6.1.98	31.2	28.4	128	7.97	160.2
26.1.98	33.0	29.3	224	7.54	99.9
16.2.98	32.7	31.3	63.8	8.07	89.2
26.2.98	29.3	31.8	32.5	7.14	93.7

Table 2. Physical parameters and nutrient concentrations in penaeid prawn ponds in Penang (Feb. 26,1998) and in Ban Merbok (Nov. 26, 1997) during harvest

Location		Sal.	Temp (°C)	Turbidity (NTU)	pH	Chl. *a* (μg/*l*)	PO_4-P	NO_2-N	NO_3-N	NH_4-N
								(μM)		
Ban Merbok	pond	16.8	26.2	208	6.97	9.6	7.09	0.18	0.11	495
	canal	15.5	24.9	294	6.45	12.8	1.09	0.29	0.93	166
Penang	pond	29.3	31.8	32.5	7.14	93.7	1.71	1.94	4.64	62.9
	canal	29.4	34.1	38.2	7.33	110.5	1.39	1.87	10.16	60.7

Table 3. Contents of organic carbon, total nitrogen and total phosphorus in suspended matter in penaeid prawn ponds in Penang and Ban Merbok

Location		Date	Org-C	Total-N	Total-P
				(mg/*l*)	
Penang	pond	5.11.97	5.00	0.26	0.14
		25.11.97	6.67 (0.34)	1.23 (0.05)	0.34 (0.04)
		16.12.97	6.48 (0.43)	1.39 (0.07)	0.21 (0.03)
		6.1.98	10.6 (0.22)	2.23 (0.05)	0.32 (0.01)
		26.1.98	14.3 (1.41)	2.83 (0.21)	0.67 (0.14)
		16.2.98	7.92 (0.94)	1.68 (0.16)	0.22 (0.03)
		26.2.98	7.68 (0.01)	1.69 (0.11)	0.26 (0.03)
	canal	26.2.98	8.80 (0.31)	1.93 (0.10)	0.32 (0.01)
Ban Merbok	pond	26.11.97	12.6	1.76	0.67
	canal	26.11.97	16.9	1.91	ND

The values within parentheses indicate the standard deviation.
ND-not determined

Table 4 . Contents of organic carbon, total nitrogen and total phosphorus in sediments in penaeid prawn ponds in Penang and Ban Merbok

Location		Date	Org-C	Total-N	Total-P
				(mg/g)	
Penang	pond	5.11.97	10.5 (4.7)	1.46 (0.45)	2.86 (0.58)
Ban Merbok	pond	26.11.97	30.5	4.17	2.08
	canal	26.11.97	57.6	6.20	2.48

The values within parentheses indicate the standard deviation.

1.3 mg/*l* (pH 7.4, Temp. 35 °C, Sal. 30). Satapornavanit (1993) (quoted from Phillips[8]) reported that total ammonia levels ranged from 0.51-1.51 mg/*l* during harvest (Sal. 36-39, temp. 29-32 °C, pH 7.0-8.3), and these values were in agreement with the level obtained in this study.

In Malaysia, the proposed interim national water quality standards for class I waters (Conservation of natural environment water supply I- practically no treatment necessary; Fishery I – very sensitive aquatic species) for NO_2 and NO_3 correspond to natural levels. For class II A waters (Water supply II-conventional treatment required; Fishery II-sensitive aquatic species) the NO_2 levels should not exceed 3 mg/*l* and NO_3 levels, 7 mg/*l*. According to USEPA[13], levels of NO_2-N and NO_3-N below 5mg/*l* and 90 mg/*l* do not exert adverse effects on warm water fish. Suksomjit et al.[10] proposed a value of 1.3 mg/*l* for NO_2 -N in penaeid prawn pond effluents.

During spring tides, Tanaka and Choo[11] recorded a NO_3 -N value as high as 8 μM in the Sangga Besar estuary and 5 μM in the Merbok estuary. NO_2-N

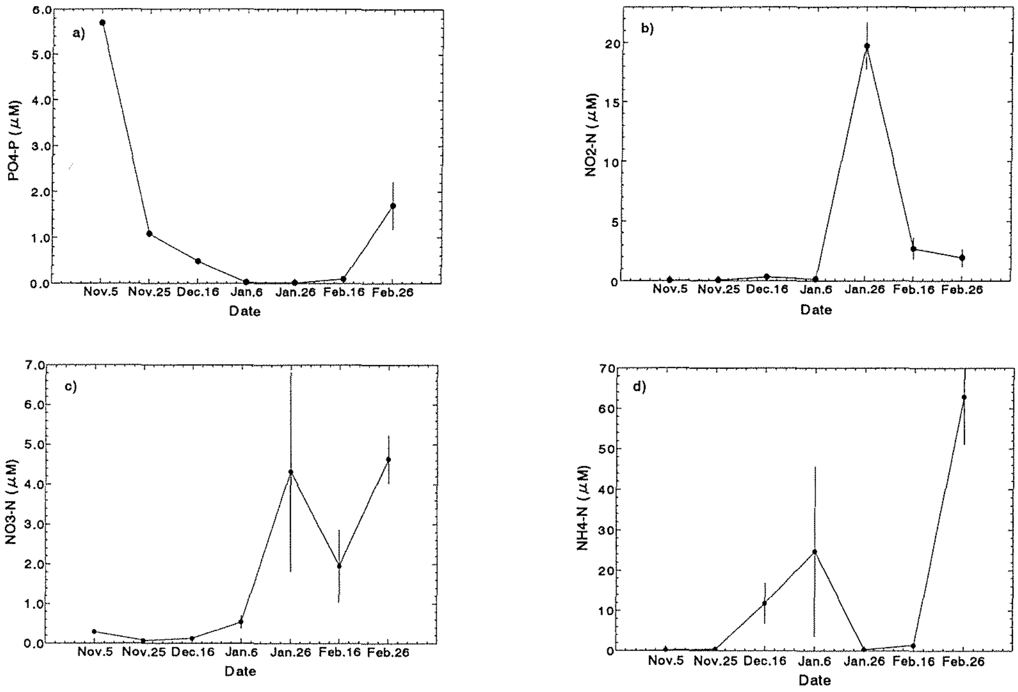

Fig. 1. Changes in nutrient levels in prawn intensive culture pond in Penang during the grow-out and harvest phase. Vertical bars indicate the standard deviation.

levels reached 5 μM in the Sangga Besar, and 4 μM in the Merbok estuaries. The NO_2-N values in the pond from Penang ranged from 0.03 - 2.71 μM, with one exceptionally high value (19.7μM) recorded from the samples taken on Jan. 26, 1998 (Fig.1). This value could be ascribed to the nitrification of NH_4-N whose concentration decreased from 24.7 to 0.36 μM during the period from Jan. 6, 1998 to Jan 26, 1998 and could be due to the lime treatment, which may have affected the bacterial composition in the pond and stimulated the nitrification process. Such a high NO_2-N value of over 10μM was also observed in the estuary of Matang Mangrove Reserve in Malaysia[12] and attributed to the nitrification of NH_4-N. However, the NO_2 -N levels in the pond in Penang during the grow-out phase and in both ponds during harvest satisfied the criteria for the penaeid prawn pond effluent standards proposed by Suksomjit et al[10]. The NO_3-N levels in the pond in Penang ranged from 0.1-10.2 μM, with the highest level recorded during harvest. In Merbok, the NO_3-N level was 0.1 μM in the pond and 0.9 μM in the canal during harvest. These values are of the same order as the NO_3 -N levels recorded in the mangrove estuaries[11].

Suspended matter contains large amounts of nitrogen and phosphorus (Table 3). Chl. *a* concentrations in the intensive culture pond in Penang ranged from 41.3-160.2 *μg/l*, values much higher than those in the semi-intensive culture pond in Ban Merbok (9.6-12.8 *μg/l*) (Tables 1 and 2). Such high concentrations of Chl. *a* indicate the influence of a much higher application of fertilizer in the intensive culture pond than in the semi-intensive culture pond. C/Chl. *a* ratio of natural phytoplankton was in the range of 25-60[7]. Using the C/Chi. *a* ratio of 50, in the intensive culture pond, the phytoplankton carbon accounted for about 41%-75% of organic carbon in the suspended matter, but for only 3.8% in the semi-intensive culture pond. Therefore, nitrogen and phosphorus in the suspended matter in the intensive culture pond in Penang are assumed to be mainly in the phytoplankton and its degradation products. The influence of fertilizer application was also reflected in the chemical composition of surface sediments in the intensive culture pond. The Total-P content in the surface sediment of the intensive culture pond in Penang was even higher than that of Total-N (Table 4), and the C:N:P atomic ratio was about 9.4:1:1.

The parameter of concern in terms of pollution would appear mainly to be the ammonia level during harvest. During the first month of the grow-out phase, PO_4-P levels appeared to be high too, but during this period the pond water was not changed. It is suggested that effluents during harvesting be channeled into oxidation ponds where the level of ammonia and suspended matter could be reduced by the nitrification process and sedimentation.

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集約的・半集約的エビ (*Penaeus monodon*) 養殖場における生育期および収穫期の栄養塩濃度

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適要

エビ養殖場廃水による栄養塩汚染の問題はしばしば注目され、その持続性に関する疑問を惹起している。本研究では西マレイシアの集約的育成池（ペナン）と半集約的（バン・メルボック　ケダ州）育成池の２ヶ所のエビ育成池において栄養塩とクロロフィル *a* について、養殖池内の濃度レベルを測定し、周辺沿岸環境におよぼす影響について考察した。

育成の最初の月には、リン酸塩濃度はかなり高いがこの期間には養殖池の水は交換されない。全期間のペナンの養殖池と収穫期のメルボックの亜硝酸塩濃度はタイ王国汚染管理部によって提唱されたエビ養殖池廃水基準値内であった。また、硝酸塩濃度はマングローブ河口域で観測される濃度と同程度であった。汚染源としては主に収穫時のアンモニウム塩が問題となる。アンモニウム塩の収穫時の濃度は米国環境保全庁による健康および生態系保全のための全アンモニア推奨濃度に対し、メルボックでは推奨基準濃度を超え、ペナンではそれに近い濃度を示した。収穫期の廃水を酸化池に導き、硝化反応による廃水中のアンモニア濃度の低減と沈降による懸濁物の除去が必要であると考えられる。

キーワード：汚染、マングローブ、沿岸水、アンモニア、環境への影響