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Importance of controlling community structure of living organisms in intensive shrimp culture ponds

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Abstract—Effects of nutrient load from feeds on shrimp production was investigated in two intensive shrimp ponds (A6 and D2) in terms of eutrophication process and changes in community structure of living organisms in the ponds. Our results found that, although feeding was not much different, a practice for A6 was failed regarding shrimp production (48 kg/pond), while that for D2 was successful producing 946 kg/pond. Chlorophyll *a* concentrations varied within the range of 10.3–108 μg/l in A6 and 16–266 μg/l in D2, indicating that the eutrophication status in D2 was higher than in A6. Water quality parameter indicated low concentration of dissolved phosphorus in A6 probably due to the DOP sink to the bottom sediment of high N/P ratio at the beginning which resulted in decrease of N/P ratio of sediment and deficiency of P (high N/P ratio) in water column that disfavored by phytoplankton. The concentrations of N and P were gradually increased in D2 resulting in lowering of N/P ratio to close to the Redfield ratio and the correspondence increasing of phytoplankton biomass and community succession. The appearance of *Noctiluca* for almost 2 months during the middle period of shrimp culture was also the possible cause of stress to shrimps and resulting in low production in A6. The success of production in D2 may relate to the appearance of *Oscillatoria* that was the successive group after short appearance of *Gymnodinium* may imply nitrogen fixation occurring during the end of culture. In addition, our results may indicate the present of nano-phytoplankton that contributed to the high chlorophyll *a* concentration during the last period of shrimp culture. The importance of controlling community of living organisms and some countermeasures were discussed in this paper.

Key words: Community structure, shrimp pond, water quality, sediment quality

Introduction

Shrimp pond meets for study of dynamic changes in community structure under an intensive loading regime by feeding. Water in shrimp pond is typically enriched with both organic matter and inorganic nutrients, and its quality depends on management of the practice, i.e. stocking density of the shrimp, water use, amount and quality of feed and fertilizers (Songsangjinda 1994a). Bottom sediment, especially of the earthen shrimp pond, is the place where all the uneaten feed and feces are accumulated throughout the culture period, and may also significantly affect on the water quality (Burford and Williams 2001, Avnimelech and Ritvo 2003, Songsangjinda et al. 2004). Several reports have indicated that enrichment of aquaculture ponds with organic matter and nutrients changes both quality and quantity of nitrogen and phosphorus compounds in the water column, resulting in variations of phytoplankton community in the ponds (Alonso-Rodríguez and Páez-Osuna 2003, Songsangjinda 1994b) and in the effluent receiving water (Costanzo et al. 2004). Alonso-Rodríguez and Páez-Osuna (2003) reported that moderate but continual development of shrimp farming in conjunction with municipal and agriculture effluents has been accompanied by frequent harmful algal blooms in coastal waters and shrimp ponds which led to un-sustainability of the shrimp culture.

The style of management of shrimp culture has been changed depending on stocking density. Conventional way of shrimp farming was basically relying on water exchange of the grow-out pond to manage algal blooms and to prevent deterioration of water quality from high-protein feeds (Burford et al. 2003b). Furthermore, risk of diseases in shrimp farming increases with stocking intensity (Kautsky et al. 2000). In contrast, eutrophication due to nutrients loaded from feed sometimes may positively affect on the growth and health of shrimp, especially in closed and intensified systems where water exchange is limited. Processes occurring in the intensive shrimp pond like these are deserved to be investigated.

In this paper, we investigate the effects of eutrophication

with loading of elements (C, N and P) from pellet feed on the shrimp production through the changes in community structure of living organisms. Discussion is made for the importance of controlling the community structures of organisms on shrimp production during the practice of black tiger shrimp culture.

Materials and Methods

Study area and pond management

The shrimp farm investigated in this study is located in Songkhla province, southern Thailand with a total area of 64 ha. We selected two ponds, A6 and D2, which have the areas of 0.72 and 0.68 ha, respectively. After the previous harvest, anoxic sludge accumulated in the sediment of Pond A6 was set aside for 2 months, while that of D2 was removed out of the pond. Water from a reservoir of the effluent recirculation system was poured into the both ponds with the depth of 1.4 m 10 days prior to shrimp stocking. Postlarvae at 16 days (PL16) of black tiger shrimp were stocked at the densities of 33 and 34 PL/m^2 for A6 and D2, respectively. Out of total culture period of 151 days, during first 35 days feeding of pellet feed was increased according to feeding table, and thereafter until the harvest the amount of feed was controlled based on observation of remaining feed on a tray. During the study period, we tried to maintain dissolved oxygen (DO) concentration at the level higher than 4.5 mg/l in the morning using 12 sets of aerator per pond. Water was also exchanged at 5–10% of the pond volume when the morning DO was under 3.5 mg/l. The amount of the feeds, and DO concentration were recorded on a daily basis. Daily and cumulative loads in terms of C, N and P from feed were calculated based on the unit concentration of each element contained in the pellet feed. The average contents of C, N and P in the pellet feed used in this study were 39, 6.5, and 0.8%, respectively and the moisture in pellet feed was about 8%.

Water sampling and analyses

Water was sampled from 30 cm depth below the surface every 2 weeks. For these samples, salinity, temperature, pH and DO were determined immediately. Total ammonia nitrogen (TAN), nitrite (NO_2^-), nitrate (NO_3^-), total dissolved nitrogen (TDN), dissolved inorganic phosphorus (DIP), and total dissolved phosphorus (TDP) were analyzed for samples filtered through a glass fiber filter (Whatman, GF/C) according to the methods described in Bendschneider and Robinson (1952), Strickland and Parsons (1972), Sasaki and Sawada (1980), APHA (1985), and Hansen and Koroleff (1999). Total silica (TSi) and dissolved silica (DSi) were analyzed for filtered (Millipore, HA) and unfiltered samples, respectively (Hansen and Koroleff 1999).

Raw (unfiltered) water samples were also used for the determination of total phosphorus (TP) by the method described by Hansen and Koroleff (1999). Concentrations of dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP) were calculated as TDN-(TAN+NO_2^-+NO_3^-) and TDP-DIP, respectively. Particulate phosphorus (PP) was calculated by subtracting TDP value for filtered sample from TP value for unfiltered sample. Particulate organic nitrogen (PON) and particulate organic carbon (POC) were analyzed by the method of high temperature combustion (1,000°C) using a CHN analyzer (LECO: model CHN900). Dissolved organic carbon (DOC) was analyzed from pre-acidified samples under high temperature (700°C) using a TOC analyzer (Elementar; liquiTOC). Total nitrogen (TN) is calculated as PON+TDN, and total organic carbon (TOC) is calculated as POC+DOC, respectively. Chlorophyll *a* concentration (Chl *a*) was determined according to the method of SCOR/UNESCO (Strickland and Parsons 1972).

Sediment sampling and analyses

Sediment samples were collected from 4 locations in each pond on the same day after the water sampling. Interstitial water was extracted using 50 ml 2N KCl and adjusted the volume to 200 ml with GF/C-filtered pond water. TAN, NO_2^-, NO_3^-, DIP and TDN were analyzed for the extracted solutions using the analytical methods described above. TON and TOC of the sediment were also analyzed with the same CHN analyzer described above. TP of the sediment were analyzed for the samples after combustion at 550°C for 5 h as the DIP according to the same method for the analysis of water described above.

Identification of microorganisms

Sixty liters of water sample were filtered using a plankton net with 20 μm mesh size gauze. Collected organisms were preserved with 10% formalin and kept until identification. Phytoplankton and zooplankton were identified according to the monographs with illustrations of planktonic organisms found in South Vietnam (Shirota 1966) and Japan (Yamaji 1979). Protozoa was identified according to the report for those observed in Thailand (Jarupan and Jarupan 1986).

Bacteria were also identified under an fluorescence microscope (BH2; Olympus) for the water samples fixed with 1% glutaraldehyde and then stained with fluorochrome DAPI (4′,6-diamidino-2-phenylindole; Sigma) of the final concentration of 0.5–1.0 μg/ml and filtered with a black-stained 0.2 μm Nuclepore filter. Free living bacteria were counted as the number of stained bacteria retained on the filter using UV excitation at a 100× magnification. Numbers of attached bacteria (attached on the suspended particles) were estimated from difference in the counted number for DAPI-stained samples before and after an ultra sonication at 240 W 19.5 KHz for 15 sec (Kaijo, Ultrasonic generation).

Vibrio bacteria were divided into two groups based on

sucrose utilization (yellow colony) and non utilization (green colony) by the colony formation on 2% salts bromthymol blue teepol agar (BTB) incubated under 30°C for 18–24 h. The numbers of *Vibrio* were counted as viable colony forming units (CFU) with the standard plate count technique.

Statistical analysis

A statistical test was performed to understand a significant difference and relationships between each two observed variable. Analysis of variance (ANOVA) was used with a general linear model procedure, and difference of average values between the two studied ponds were investigated using Duncan's Multiple Range Test. Statistical Analysis System (SAS) package Version 6.12 (SAS Institute 1990) was used for all the statistical analyses, and $p=0.05$ was applied as the level of significance.

Results

Shrimp feeding and production

The total amount of pellet feed used in Pond A6 and D2 were 3,288 and 3,790 kg/pond, showing a small difference of feed input to both ponds. On the other hand, shrimp production in D2 was successful with a harvest of 964 kg/pond and the average shrimp growth rate of 0.09 g/d, while the production failed in A6 (43 kg/pond) with high mortality (Table 1). Amounts of allochthonous elemental load of C, N, and P were 1,183, 195, and 24 kg/pond in A6 and were 1,364, 225 and 28 kg/pond in D2, respectively. The molar ratios of C/N and N/P from pellet feed were calculated about 7 and 18. Chl *a* concentration in the water was also much different among both ponds, showing the range of 10.3–103.9 and 16.1–233 μg/l in A6 and D2, respectively (Table 2).

Water and sediment qualities

Concentrations of TOC, TN and TP in the water column increased in the both shrimp ponds (Fig. 1). The average concentrations of TOC, TN and TP in D2 showed slightly higher values than those of A6, though a statistical test indicated no significant difference between the two ($p>0.05$). The C/N ratio in the water column of A6 and D2 was about 8 and 5 at the end of study. However, the N/P ratio in the water column was about 23 and 40 showing much difference among the ponds. The TP concentration in A6 sharply increased in the middle of culture period and drastically dropped at the end of culture simultaneously with a lowering in Chl *a* concentration. Among the components of N and P, dissolved organic forms were important components of N and P pools in the shrimp ponds (Fig. 2).

Concentrations of sediment C, N and P in A6 were significantly higher ($p<0.05$) compared with those in D2 from the beginning throughout shrimp culture period. TN in the sediment of A6 showed a decrease at the end of shrimp culture while TP was increased (Fig. 3). These results are opposite to the increase of TN and decrease of TP in the water column of A6 during the same period. A high N/P ratio about 233 was found in the sediment of A6 at the beginning and decrease to the ratio about 69 at the end of shrimp culture.

Table 1. Growing data of black tiger shrimp in the intensive shrimp ponds with low production (A6) and high production (D2).

Growing data	A6	D2
Pond area (m^2)	7,200	6,880
Date of shrimp stocking	5/7/2547	5/7/2547
Larval stage	PL 16	PL 16
Stocking density (PL/m^2)	33	34
Day of culture	151	151
Total feed (kg)	3,288	3,790
Total production (kg)	43	946
Production (kg/m^2)	-	0.14
Size (g)	-	14.3
Survival rate (%)	-	28
Food conversion ratio (FCR)	-	4.01

Table 2. Carbon, nitrogen and phosphorus loaded and eutrophication status in the intensive shrimp ponds with low production (A6) and high production (D2).

Parameter	A6		D2	
	Daily	Total	Daily	Total
Nutrient from feed				
Carbon (kg)	0.72–14.40	1,183	0.72–14.40	1,364
Nitrogen (kg)	0.12–2.37	195	0.12–2.37	225
Phosphorus (kg)	0.01–0.29	24	0.01–0.29	28
Eutrophication status	moderate–extremely high		moderate–extremely high	
Chl *a* (ug/l)	10.3–103.9		16.1–233.0	
Feed C/N (molar ratio)		7		
Feed N/P (molar ratio)		18		
Day of culture (day)		151		

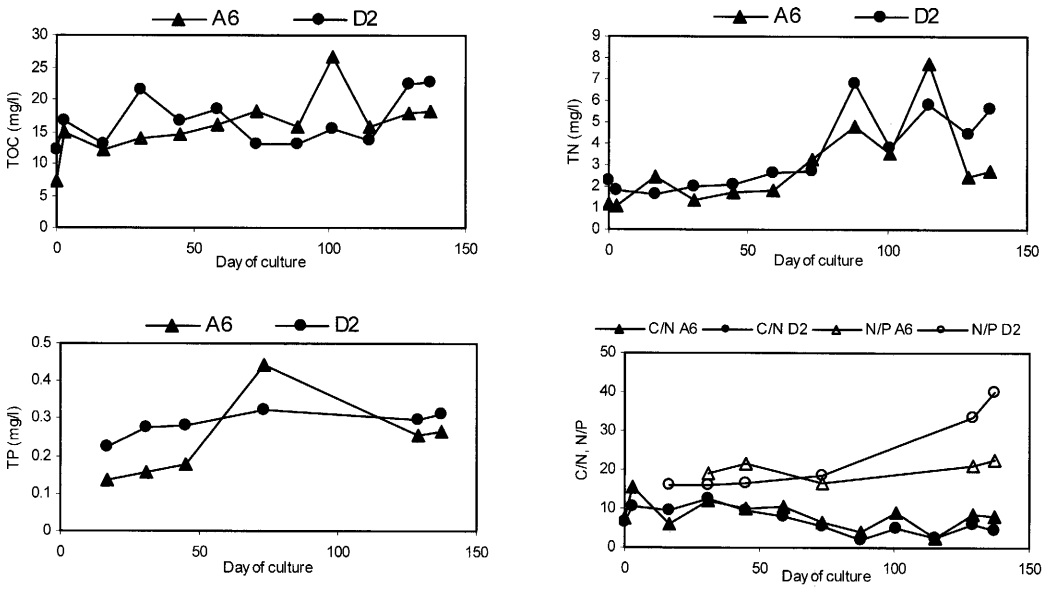

Fig. 1. Variation of TOC, TN, TP, C/N and N/P ratios in two shrimp ponds: A6: Shrimp pond with low production, D2: Shrimp pond with high production.

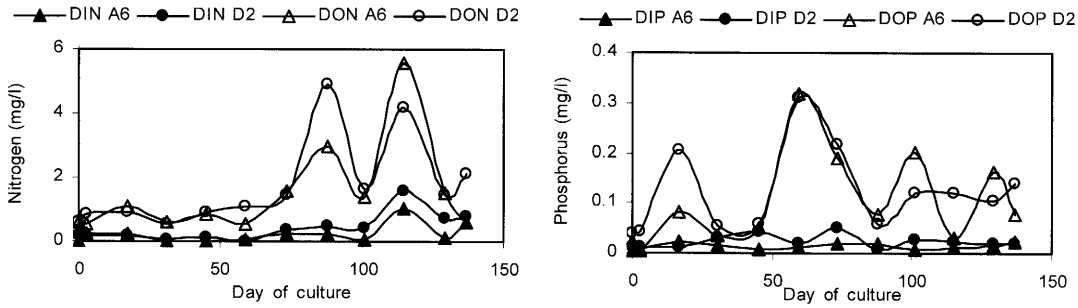

Fig. 2. Variation of dissolved nutrients DIN, DON, DIP and DOP in two shrimp ponds: A6: Shrimp pond with low production, D2: Shrimp pond with high production.

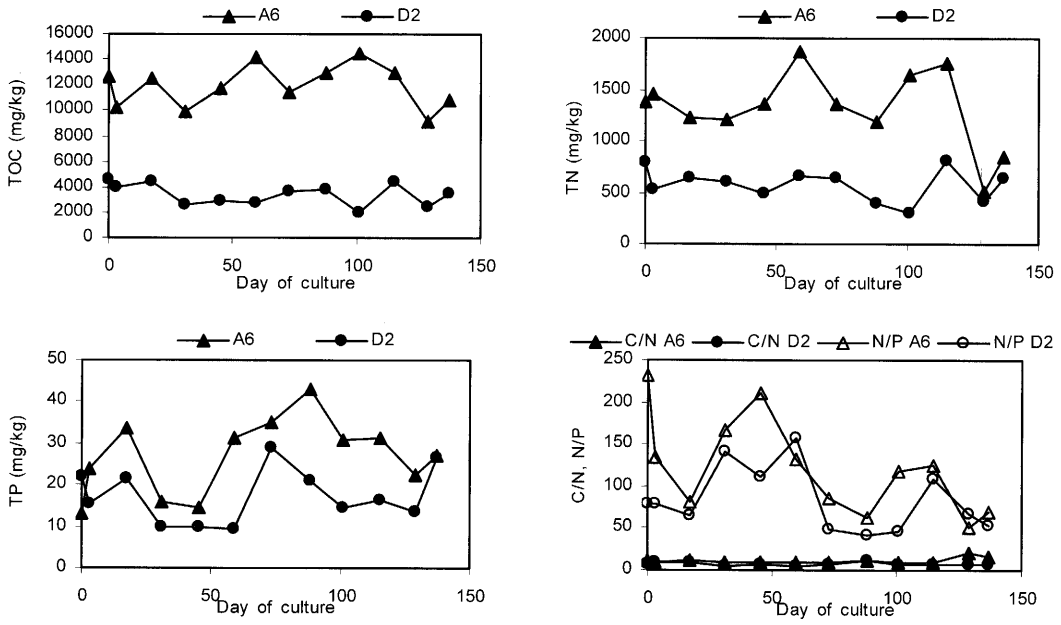

Fig. 3. Variation of sediment TOC, TN, TP and C/N and N/P ratios in two shrimp ponds: A6: Shrimp pond with low production, D2: Shrimp pond with high production.

Table 3. List of living organisms identified from the water samples in the intensive shrimp ponds with low production (A6) and high production (D2). 0=absent, +=number within 0 and ≤25% of total count (for overall the samples), ++=number within >25 and ≤50% of total count, +++=number within >50 and ≤75% of total count and ++++=number >75% of total count).

List of living organism (number of group or genus)			*A6*	*D2*
Phytoplankton	Total count* (cell/ml)		71,811	249,286
	Bacillariophyta	*Pleuro/Gyrosigma* sp.	+	+
	(4)	*Navicula* sp.	+	+
		Coscinodiscus sp.	++	+
		Nitzschia sp.	0	+
	Pyrrophyta	*Protoperidinium* sp.	+	+
	(4)	*Gymnodinium* spp.	0	+
		Ceratium spp.	+	0
		Noctiluca sp.	+	0
	Cyanophyta	*Oscillatoria* spp.	+++	++++
	(3)	*Merismopedia* sp.	+	0
		Microcystis sp.	+	+
Zooplankton (3)	Total count* (ind./ml)		1,681	3,370
	Rotifer		++	++
	Copepod/Nuaplius,		++	+++
	Gastropod larvae		+	0
Protozoa (6)	Total count* (cell/ml)		20,392	5,036
	Tintinnopsis sp.		+	+++
	Favella sp.		+	+
	Metopus sp.		+	++
	Paramesium sp.		+	0
	Euglena sp.		++++	+
	Unknown		+	+
Bacteria	Total count* ($\times 10^7$ cell/ml)		25.62	21.22
	Bacterial type (2)	Free living,	+++	+++
		Attached,	++	++
	Total count * ($\times 10^2$ cell/ml)		166.5	285.5
	Vibrio group	Green Colony	+++	+++
	(2)	Yellow Colony	++	++

* total count=the summation of organisms in each group for overall the samples.

However, C/N ratio in the sediment of both ponds varied in the range of 8–21 and 5–11 in A6 and D2, which were not much different among both ponds.

Community structure of living organisms

Diversity of living organisms in the water of shrimp pond was shown in Table 3. Eleven genera of phytoplankton, 6 genera of protozoa, 3 groups of zooplankton, and 2 *Vibrio* types of bacteria were found during the study period. Only the cyanophyta phytoplankton *Oscillatoria* was most abundant (2.2×10^5 cell/ml) formed a bloom during the high N/P ratio period of the water column especially at 115 days of culture in D2 (Table 3 and Fig. 4a). Zooplankton and protozoa were less abundant overall the samples. Bacteria of each type and group of *Vibriosis* bacteria were comparable in the numbers, and their composition appeared to be less related to the shrimp production (Table 3, Fig. 4b, 4c). However, phytoplankton abundance at the end of this study period did not seem to correspond with the Chl *a* concentration. When the total number of phytoplankton sharply dropped in D2, the high concentration of Chl *a* was still maintained (Fig 4a).

Beside high abundance of cyanophyta, phytoplankton in the group of pyrrophyta (dinoflagellates) might have important role in the shrimp culture. The data summarized in Table 3 revealed that there was clear different in the genus of dinoflagellates found in both ponds. *Protoperidinium* and *Gymnodinium* were found only in D2, while *Ceratium* and *Noctiluca* were found only in A6. The total number of pyrrophyta increased during the period of increasing in DOP concentration (Fig. 5).

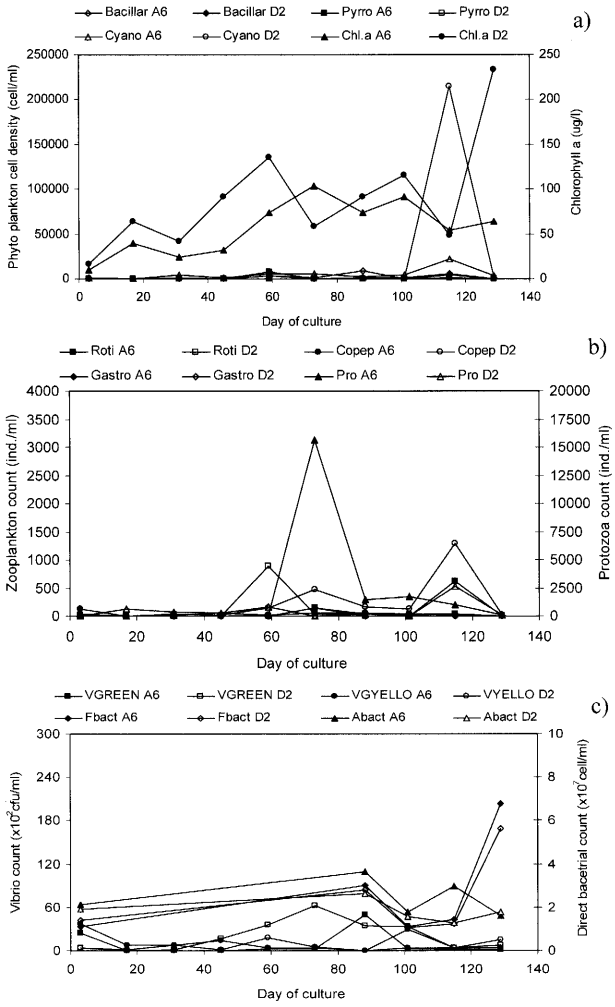

Fig. 4. Variation of living organism communities (a, b and c) in two shrimp ponds : A6: Shrimp pond with low production, D2: Shrimp pond with high production. Bacillar; Bacillariophyta, Pyrro; Pyrrophyta, Cynao; Cyanophyta, Chla.; Chlorophyll *a*, Roti; Rotifer, Copep; Copepod, Gastro; Gastropod larvae, Pro; Protozoa, Fbact; Free living bacteria Abact; Attached bacterial, VGREEN; Green colony *Vibrio*, VYELLO; Yellow colony *Vibrio*.

Discussion

Shrimp production and feeding

Results from this study showed clearly difference in production between the two ponds (Table 1). Although shrimp growth and production were reported to basically relate to stocking density, feeding and water quality (Songsangjinda 1994a), a production in A6 did not relate with the feeding rate (Table 1). In addition, the farm record did not make any note about serious shrimp disease outbreak in A6. This result may indicate that the environmental factors may play a vital role on the variation of production. However, Chayaburakul et al. (2004) reported that slow growth shrimps (weighed 16.8 g or less) were infected with multiple viruses, i.e. monodon baculovirus (MBV), heptopancreatic parvovirus (HPV) and infectious hypodermal and hematopoietic necrosis virus (IHHNV). They also mentioned a possibility of slow growth syndrome in black tiger shrimp that may be caused by unknown pathogen factors or by some other presently unknown, non-pathogenic factors.

The main nutrient source to the shrimp pond is feeding. Our results showed that C/N and N/P ratios of pellet feed are close to the Redfield ratios (6.6 and 16; Redfield, 1958) (Table 2). This suggests that the pellet feed may properly promote phytoplankton growth in the shrimp ponds. However, Chl *a* concentration in both shrimp ponds were different and fluctuated as shown in Fig. 2. The crash of phytoplankton after blooming can be a cause of hypoxic condition due to their decomposition by bacteria in the bottom layer of the pond if farmer do not manage water and sediment qualities of the pond in good manner.

Water and sediment qualities

The average concentrations of TOC, TN and TP overall the shrimp culture period in D2 were not significantly higher than A6 (Fig. 1). This suggests a high fluctuation of nutrients occurring in both ponds. Fluctuation of water quality in shrimp ponds is the results of variation in nutrients loading from feed and biological processes of shrimp and organisms in water column and sediment (Burford and Williams 2001). In the investigation by Briggs and Funge-Smith (1994), ca. 90% of nitrogen input to their pond came from feed but most of the nitrogen (70–80%) was not retained in shrimp body. However, judging from the higher biomass of shrimp in D2 (Table 1), shrimp was considered as a primary organism to process and transform organic matters from pellet feed to other forms in the water column. Instead of shrimp, our study in A6 obviously indicates that other living organisms in water column and sediment played primary roles on process and transform organic matter from pellet feed.

N/P ratio in the water column of both ponds (23 and 40) was much deviated from the Redfield ratio (16) at the end (Fig. 1). It is noted that the deviation of N/P ratio in water column from the Redfield ratio did not relate to the failure of shrimp production because the higher N/P ratio (40) was found in D2. Considering the main component of N and P which were dissolve organic forms, this finding is similar to the study of Burford and Williams (2001) which mentioned that major sources of soluble N in shrimp pond were gill excretion, leaching from formulated feed and solubilization of shrimp faeces. It was shown in our study that DON accumulated after 80 days of the culture period while DOP were decreased (Fig. 2). These DON compounds appear to be ineffectively utilized by the microbial community and, as a result, were likely to accumulate in the pond water.

As mentioned in materials and methods, the pond preparations of these two ponds were different. The anoxic sludge accumulated in the sediment of A6 was set aside for 2 months and may probably be the main factor contributed to

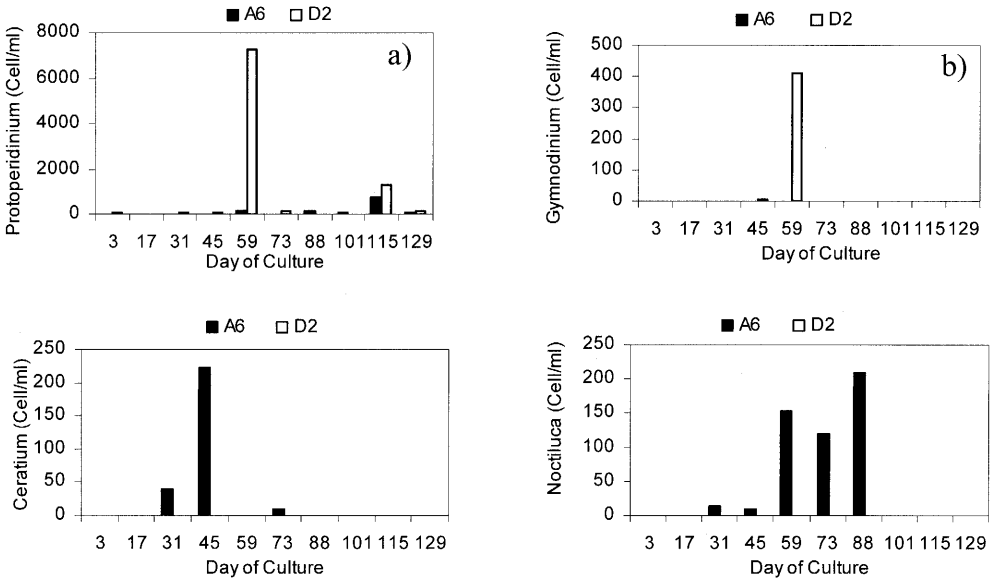

Fig. 5. Variation of phytoplankton in the group of Pyrrophyta in two shrimp ponds a) *Protoperidinium*, b) *Gymnodinium*, c) *Ceratium*, d) *Noctiluca*. A6: Shrimp pond with low production, D2: Shrimp pond with high production.

the difference in the sediment quality and also shrimp production in both ponds. The high N/P ratio of the sediment up to 230 at the beginning in the low production shrimp pond (Fig. 3) may suggest the unsuitable condition for shrimp culture. In the water column with lower N/P ratio of A6 after 70 days of culture (Fig. 1), it may be by trapping of phosphorus by sediment indicated by increase of TP and not by increase in nitrogen in sediment (Fig. 3), which may limit phytoplankton growth evidenced by the low Chl *a* concentration (Fig. 4). Since the C/N ratio in both water and sediment of both ponds were not much different (Table 3), the N/P ratio is considered more important that may control phytoplankton change in the ponds leading to the result of shrimp production in the ponds. Thus, our study reveals that the risk of production failure through the uncontrollable environmental factors and changing in community of the organisms would increase when the pond bottom preparation is in improper procedures.

Community structure of living organisms

The most interesting change in living organism community in the shrimp ponds was the change in phytoplankton community (Figs. 4 and 5). Cyanophyta bloom in shrimp pond is reported in several studies (Songsangjinda 1994b, Alonso-Rodriguez and Paez-Osuna 2003). Since phytoplankton in the group of cyanophyta such as *Oscillatoria* or *Anabaena* has the ability to fix nitrogen when oxygen is present (Alonso-Rodriguez and Paez-Osuna 2003), *Oscillatoria* observed in the Pond D2 bloomed in the condition of high N/P ratio and high correlation with the levels of high N in water column (Figs. 4a and 1). Our finding suggests that the nitrogen fixation may occur in shrimp ponds. The presence of *Oscillatoria* may enhance the uptake of P from the water column resulting in high N/P ratio in the water column.

However, phytoplankton abundance at the end of the study period did not seem to correspond with the Chl *a* concentration (Fig. 4a). The high Chl *a* during the crush of *Oscillatoria* probably indicate a nano-sized phytoplankton that could not be collected with a 20 μm phytoplankton net. Burford et al. (2003a) reported that the fraction of the phytoplankton with size $<10\ \mu$m was present in high numbers and took up significant amount of nitrogen in a shrimp pond. Alonso-Rodriguez and Paez-Osuna (2003) also reported that nannoplankton (2–20 μm length) mainly composed of communities in the latter half of the culture period and total cell number barely exceeded 1×10^6 cells/l.

The number of phytoplankton genera found in the present study was much less than those found in the previous study on black tiger shrimp where the number of phytoplankton genera was about 45 genera (Songsangjinda 1994b). Since the shrimp production was also much higher in the previous study, diversity of living organisms is considered to affect positively on the shrimp production even though the water quality was in the status of more eutrophic.

In natural water like in Hiroshima Bay, phytoplankton composition has shifted from diatom-dominance to dinoflagellate-dominance due to the long-term decrease in DIP load because of the latter group preferably utilizes DOP (Yamamoto et al. 1999). Although the genus *Gymnodinium* includes toxic species (Alonso-Rodriguez and Paez-Osuna 2003), the *Gymnodinium* species found in D2 does not seem to have affected on the shrimp production due to non-toxic or the period appeared was short. *Noctiluca* is the species that has recently formed serious harmful algal blooms in the coastal area of the Gulf of Thailand (Cheevaporn and Menasveta 2003). According to Suvapepan (1995), 43 major

red tides were recorded in the Gulf of Thailand during 1988–1995. Of those, 21 red tides were *Trichodesmium* sp., 17 were *Noctiluca* sp. and the rest were diatoms. Although *Noctiluca* is not the species that produces toxins, long period of the *Noctiluca* bloom (31–88 days) in A6 (Fig. 5) might probably be a stress on shrimps.

Importance on controlling community structure in shrimp pond

Controlling the composition and abundance of living organisms in intensive shrimp culture ponds is difficult because of cycling of elements in the system is very complicated by all these living things. The roles of each group of living organisms are different. Phytoplankton has a role as feed for zooplankton and their community changes are depending on the nutrients loaded from feed. Blooming of phytoplankton provides shade for shrimp but intensive bloom including harmful cyanobacteria (Group of cyanophyta) may lead to results of anoxic conditions in the bottom layer of the ponds as mentioned by Alonso-Rodriguez and Paez-Osuna (2003). Boyd (1989) reported that the dominant group of diatoms could enhance the growth of shrimp better than cyanophyta. Based on farmers' experience, diatom-dominated condition is preferable, because less harmful effects on shrimp production. However, it is very difficult to maintain the same community during entire period of farming in dynamic system where climate change is inevitable.

The genus *Noctiluca* found in this study may indicate a possibility to harm on shrimp production in case of intensive shrimp culture in Thailand, although the review paper of Alonso-Rodriguez and Paez-Osuna (2003) did not mention about that. In their paper, several species of dinoflagellates were found in shrimp ponds located in many places; *Alexandrium tamarense* and *Gymnodinium* were reported to be found in Malaysia, the raphidophyte *Chattonella* and the dinoflagellate *Pyrodinium bahamense* var. *compressum* in Vietnam, and the diatom *Nitzschia navis-varingica* in Ecuador. Those are examples of phytoplankton which cause the negative effect to shrimp production. The heavy blooming of phytoplankton may often lead to loss in production if farmer could not control the negative factors that would result in anoxic condition, deterioration of bottom sediment, and stress of shrimp after their massive die-off. The die-off of *Noctiluca* could release remarkably toxic ammonia produced in the cell (Okaichi and Nishio 1976).

The results observed in A6 are an example of typical failure in pond management where only 49 kg of shrimp production was recorded. This failure is concluded as the results of non-suitable condition in the sediment indicated by high C, N and P together with the high N/P ratio. This condition of sediment tended to be the sink for P but the source for N. This condition appears to be made by improper decomposition of the anoxic sludge accumulated in the bottom. The occurrence of *Noctiluca* for a long time (nearly 2 months) may also have negative effect on the shrimp production. In D2, an example of succeeded production, the farmer had conducted a better management in controlling the phytoplankton community unconsciously through the practice. In this pond, in the latter half of practice, dominant cyanophyta seemed to have been taken over by some nano-phytoplankton at which the increased Chl *a* concentration indicated proceeding of eutrophication. This suggests that eutrophication does not always affect negatively on shrimp production. Even, the presence of cyanophyta might have a benefit in terms of active uptake of toxic ammonium-nitrogen and production of oxygen by photosynthesis (Songsangjinda 1994b).

Hence, our study indicates that community of organisms in shrimp pond plays the important roles on production of shrimp. The initial condition of sediment at the bottom of shrimp pond is considered to be importance by the means of enhancing active interaction between water column and sediment when the nutrients are not in the suitable ratio. Molar ratio of N/P in both water column and sediment significantly relate to the succession of organisms especially after 60–80 days of culture. This study probably reveals that the long term blooming of *Noctiluca* may be able to reduce shrimp production especially after massive mortality. The importance of controlling community structure of organisms in shrimp pond is to maintain less effects of community succession on deterioration of water and sediment qualities and reduction of shrimp growth and production. Shrimp farmer has to pay more attention to the effective pond preparation, feeding management and aeration throughout the culture period.

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