The Effects of Pond Management Strategies on Nutrient Budgets: Thailand

Interim Work Plan, Global Experiment, Thailand

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Introduction

The PD/A CRSP pond experiments have involved a variety of pond input schemes for fish production, including fertilizers, formulated feed, and a combination of both. With high fertilization rate, the nutrients assimilated in fish biomass were estimated to be less than 20% for nitrogen and 10% for phosphorus (Edwards, 1992). Most of those lost nutrients are distributed in water, fish biomass, and sediments of the pond systems. It is generally believed that a large proportion of nutrients received in ponds ends up in pond muds and discharged effluents. To reduce the nutrient losses in discharged water, it is essential to estimate the nutrient budgets to assess the fate of nutrients added to the pond culture systems. Development of nutrient budgets would permit quantification of potential pollution impact of a specific pond management strategy. The objective of this experiment was to compare nitrogen and phosphorus budgets in ponds with different fertilization and feeding schemes.

Materials and Methods

The experiment was conducted in six 280-m^2 earthen ponds at Bang Sai station in Ayutthaya Province, Thailand. Two experimental treatments, each conducted in triplicate, were: (A) Ponds were fertilized throughout the experimental period and commercial feed (30% crude protein) was added beginning day 80; and (B) Ponds were fertilized until day 80 and followed by commercial feed (30% crude protein) only. Sex-reversed, all male Nile tilapia with an average weight of 23-24 g were stocked at 3 fish/m^2 (840 per pond) on 16 November 1995. All ponds were fertilized weekly with urea (1.7 kg/pond/week) and TSP (1.0 kg/pond/week) to make a 4:1 N/P ratio. Feeding commenced in both treatments on day 80 of the culture period. Feeding rate was adjusted weekly for each pond according to the total amount of feed consumed during one hour in the morning (1000-1100 h) and afternoon (1400-1500 h) on the first day of each week. The average amount of feed consumed in each treatment was used as daily ration for the treatment over the remainder of the week. The water depth of each pond was maintained at 1 m by topping off weekly to replace losses to seepage and evaporation.

Fish growth was measured every two weeks by sampling 40 fish from each pond. Individual weight and length were taken. The chemical and physical conditions of pond water were also monitored according to standard CRSP protocols stated in the Work Plan. Fish were harvested on 25 April 1996, after 160 days of culture.

The nutrient budgets for N and P in ponds during the experimental period were calculated based on inputs from water, stocked fish, fertilizer and feed, losses in fish harvest, discharge water, and sediment. Sediment samples were collected from the top 5 cm of each pond bottom following initial pond bond filling and immediately before fish harvest and were analyzed for total nitrogen, total phosphorus, moisture, and bulk density. Total nitrogen and phosphorus content were analyzed for commercial fish feed and for fish sampled at stocking and harvest.

Data were presented for each treatment in weight and percentage of the nutrient derived from the total inputs and losses. One way analysis of variance was used to sort out the effect of treatment on water quality, fish growth, production, nutrient content in discharge water, and total output of nutrient. Differences were considered significant at an alpha level of 0.05.

Results and Discussion

Water Quality

Among pond water quality parameters measured (Table 1), DO values of both treatments were most variable ranging from 1.0-10.6 mg/l with occasional drops below 0.5 mg/l towards the end of the culture cycle (Figure 1). The mean total alkalinity value in treatment A and B was 104.3 ± 21.7 and 88.4 ± 2.4 mg/l $CaCO_3$, respectively. The highest value was observed in the first week, and values for total alkalinity declined toward the end of culture period (Figure 2). Mean TAN concentration in both treatment A and B was 0.72 ± 0.31 and 0.24 ± 0.03 respectively (Figure 3). Mean chlorophyll-*a* concentration in treatment A and B was 139.7 ± 36.2 and 110.8 ± 15.5 µg/l, respectively, and it showed a relatively stable concentration in all ponds towards the later half of the culture period (Figure 4). Total Kjeldahl nitrogen and total phosphorus concentrations in treatment A and B followed a similar trend up to

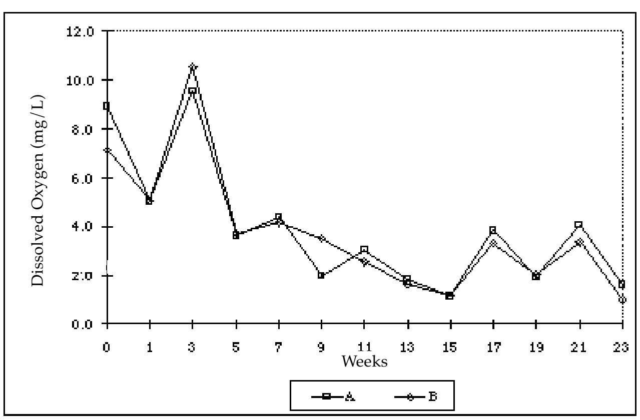

Figure 1. Fluctuation of dissolved oxygen (mg/l) in both treatments over the culture period.

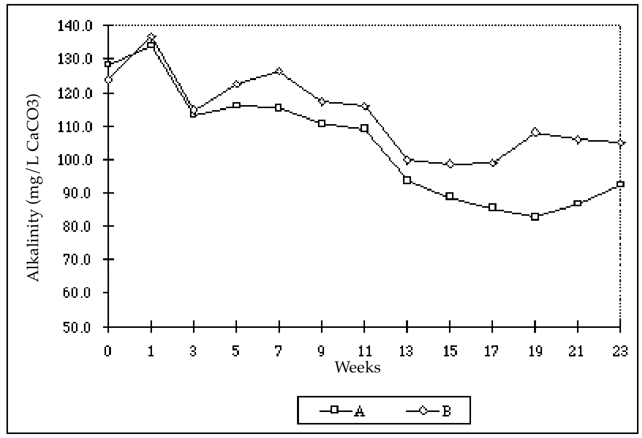

Figure 2. Fluctuation of alkalinity (mg/l $CaCO_3$) in both treatments over the culture period.

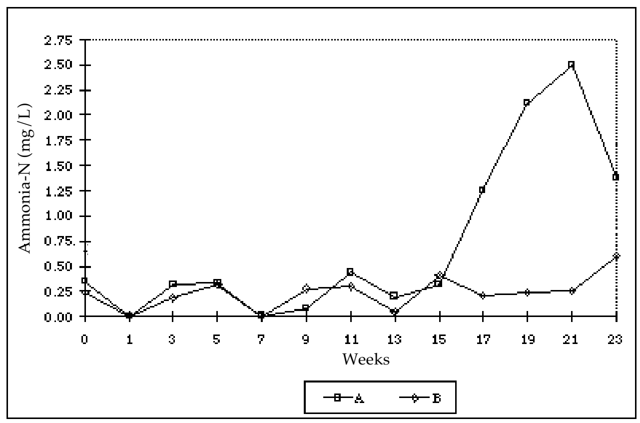

Figure 3. Fluctuation of total ammonia nitrogen (mg/)in both treatments over the culture period.

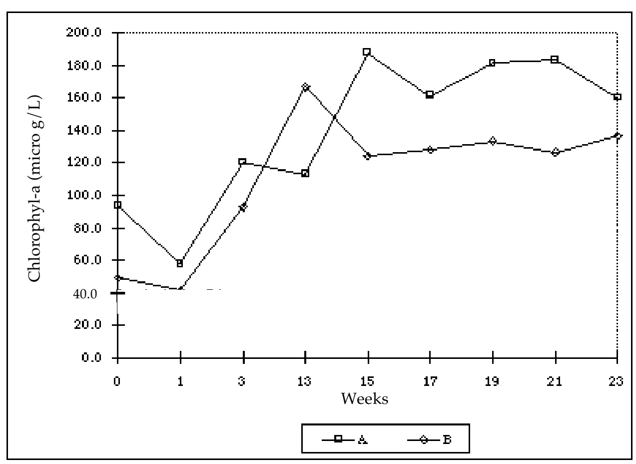

Figure 4. Fluctuation of Chlorophyll-*a* (µg/l) in both treatments over the culture period.

Table 1. Mean values of water quality parameters in treatment A and B over the culture period.

Variable	Treatment A	Treatment B
DO (mg/l)	3.5 ± 0.3	3.5 ± 0.2
Temperature (°C)	27.4	27.4
pH (range)	7.0-8.7	7.4-8.6
Alkalinity (mg/l)	104.3 ± 21.7	88.4 ± 2.4
TKN (mg/l)	5.6 ± 0.3	4.4 ± 0.2
TAN (mg/l)	0.72 ± 0.31	0.24 ± 0.03
NO_2- N (mg/l)	0.13 ± 0.02	0.06 ± 0.02
TP (mg/l)	0.57 ± 0.09	0.50 ± 0.06
SRP (mg/l)	0.07 ± 0.03	0.07 ± 0.02
Chlorophyll-*a* (μg/l)	139.7 ± 36.2	110.8 ± 15.5
TSS (mg/l)	151.2 ± 19.1	154.4 ± 20.2
TVS (mg/l)	45.2 ± 11.1	41.8 ± 2.3
Secchi Disk Visibility (cm.)	14.1 ± 1.2	12.8 ± 1.5

Values are mean ± S.E. (n= 3 for each treatment). For each pond water quality data for all sampling times were averaged.

week 13, but with the commencement of feeding, higher N and P levels were observed in treatment A than in treatment B (Figures 5 and 6). Statistical analysis showed that there were no significant difference for TAN, TP and chlorophyll-*a* concentrations between the treatments ($P > 0.05$). The results of this experiment show that different pond inputs in treatment A and B did not significantly affect major water quality parameters.

Fish Production

Fish growth performance in treatment A was significantly better than that of treatment B ($p < 0.05$) (Table 2). The final maximum mean weight was 314 g with a total yield of 227.8 ± 4.4 kg per pond in treatment A, compared to 248 g/fish and total yield of 182.4 ± 16.9 kg per pond in treatment B.

Daily weight gain in both treatments was similar up to day 80, but the final yield was greater in the treatment with continuous fertilization plus feeding than the treatment with feed input alone. The low feed conversion ratio (0.83-1.28) in this study confirms that the fish growth benefited from natural diet stimulated by fertilization. Green (1992) reported that fish production at El Carao, Honduras was 5305 kg/ha in 150 d, and the feed conversion was 1.8 when feed (24% protein) was the only input offered to tilapia stocked at 2 fish/m^2. However, he

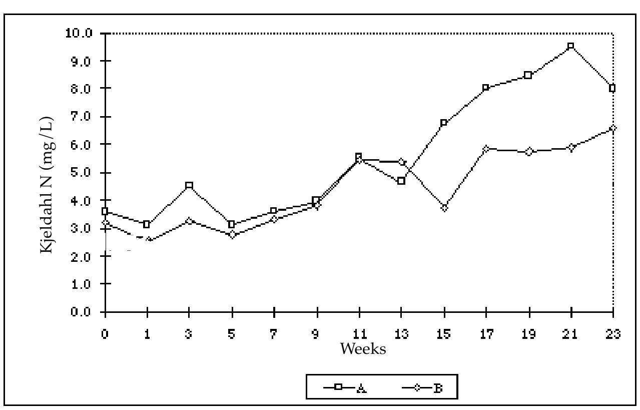

Figure 5. Fluctuation of total Kjeldahl nitrogen in both treatments over the culture period.

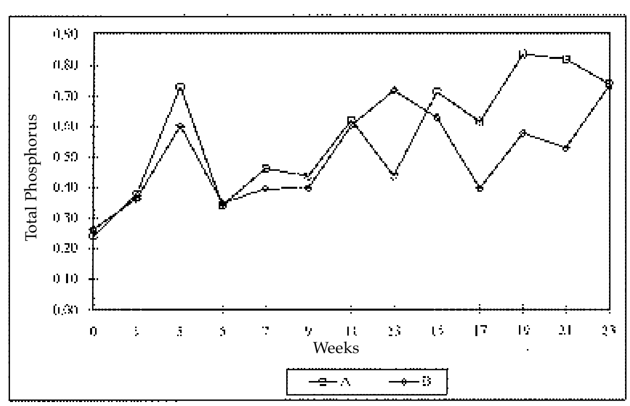

Figure 6. Fluctuation of total phosphorus (mg/l) in both treatments over the culture period.

observed that the natural productivity stimulated by pond fertilization was sufficient to permit rapid fish growth during the first two months of culture.

Nutrient Budget

The estimated N and P budgets in both treatments showed that fertilizer was the major source of nutrient inputs and the second was commercial feed (Table 3). The total input of N and P was significantly higher in treatment A than in treatment B ($p < 0.05$), and the amounts of N and P input from water, fish, fertilizer, and feed for both treatments are compared in Figures 7 and 8.

Nitrogen and phosphorus losses in various components of the pond system are shown in Figures 9 and 10. Fish harvest removed 15.45-20.04% N and 10.02-15.10% P from the total inputs and there was no significant difference between treatments ($p > 0.05$). Losses of N and P in discharged water at harvest ranged from 7.19-10.81% and 2.00-3.84% of the total inputs, respectively, and the nutrient content in effluent water at harvest was not significantly different between treatments ($p > 0.05$).

The nutrient budget showed that major portions of the total N and P inputs to the ponds were not accounted for in the estimated losses. The unaccounted loss of N and P for all ponds ranged between 70.66-78.01% and 81.88-87.25% of the total inputs, respectively. Chien et al. (1989) mentioned that sediment plays an important role in the balance of an aquaculture system; it can act as a buffer in water nutrient concentration. Avnimelech et al. (1984) emphasized that the sediment layer of few centimeter depth contains more nutrients than the content of the water column. The large amount of unaccounted for nitrogen was probably related to losses through

Table 2. Inputs and fish growth performance in treatment A and B for tilapia cultured for 16 weeks.

Variable	Treatment A	Treatment B
STOCKING		
Density (fish/m^2)	3	3
Total No.	840	840
Mean Weight (g)	23 ± 0.5	24 ± 0.2
Total Weight (kg/pond)	19.6 ± 0.3	20.3 ± 0.2
HARVEST		
Total No.	731 ± 11	733 ± 17
Survival	87.0 ± 1.3	87.3 ± 2.0
Mean Weight (g)	312 ± 1.8	248 ± 17.5
Total Weight (kg/pond)	227.8 ± 4.4	182.4 ± 16.9
Weight Gain (kg/pond)	208.2 ± 4.5	162.1 ± 17.0
DWG (g/fish/day)	1.78 ± 0.0	1.38 ± 0.1
Net Yield (t/ha/year)	16.7 ± 0.4	13.0 ± 1.4
FCR	0.87 ± 0.05	1.10 ± 0.1
INPUTS		
Feed (kg/pond)	182.1 ± 8.8	174.7 ± 5.9
UREA (kg/pond)	39.1 ± 0.0	20.4 ± 0.0
TSP (kg/pond)	23.0 ± 0.0	12.0 ± 0.0
REPRODUCTION		
Total No.	211 ± 140	458 ± 218
Mean Weight (g)	68.0 ± 20.0	47.0 ± 21.0
Total Weight (kg/pond)	11.2 ± 6.0	16.4 ± 7.0

Table 3. Comparison of nutrient budgets for N and P between treatment A and B over the culture period of 16 weeks.

	Treatments							
	A				*B*			
	Nitrogen (kg)	*%*	*Phosphorus (kg)*	*%*	*Nitrogen (kg)*	*%*	*Phosphorus (kg)*	*%*
Inputs								
Water	1.30 ± 0.08	4.62 ± 0.23	0.08 ± 0.01	1.16 ± 0.17	1.22 ± 0.05	6.36 ± 0.26	0.09 ± 0.02	1.89 ± 0.40
Fish	0.43 ± 0.01	1.53 ± 0.05	0.16 ± 0.01	2.37 ± 0.11	0.46 ± 0.01	2.42 ± 0.09	0.17 ± 0.00	3.79 ± 0.09
Fertilizer	17.99 ± 0.00	63.98 ± 1.07	4.60 ± 0.00	67.22 ± 0.88	9.38 ± 0.00	49.07 ± 0.67	2.40 ± 0.00	52.38 ± 0.70
Feed	8.41 ± 0.41	29.86 ± 0.93	2.00 ± 0.10	29.25 ± 1.02	8.07 ± 0.27	42.15 ± 0.84	1.92 ± 0.06	41.94 ± 0.87
Total	28.13 ± 0.48	100	6.85 ± 0.09	100	19.13 ± 0.26	100	4.58 ± 0.06	100
Losses								
Water	2.29 ± 0.16	8.12 ± 0.47	0.18 ± 0.12	2.58 ± 0.30	1.82 ± 0.11	9.53 ± 0.68	0.15 ± 0.01	3.32 ± 0.29
Fish	4.43 ± 0.19	15.75 ± 0.65	0.90 ± 0.11	13.14 ± 1.58	3.59 ± 0.23	18.79 ± 0.99	0.61 ± 0.03	13.33 ± 0.67
Total	6.72 ± 0.34	23.87 ± 1.07	1.08 ± 0.11	15.72 ± 1.53	5.41 ± 0.13	28.32 ± 0.53	0.76 ± 0.03	16.65 ± 0.87
Unaccounted	21.41 ± 0.42	76.13 ± 1.07	5.77 ± 0.19	84.28 ± 1.58	13.71 ± 0.21	71.68 ± 0.53	3.82 ± 0.09	83.35 ± 0.87
Nutrient Released by Soil	9.95 ± 0.80	35.49 ± 3.39	0.32 ± 0.80	16.96 ± 0.38	6.68 ± 1.45	34.72 ± 7.08	0.58 ± 1.38	33.40 ± 19.61

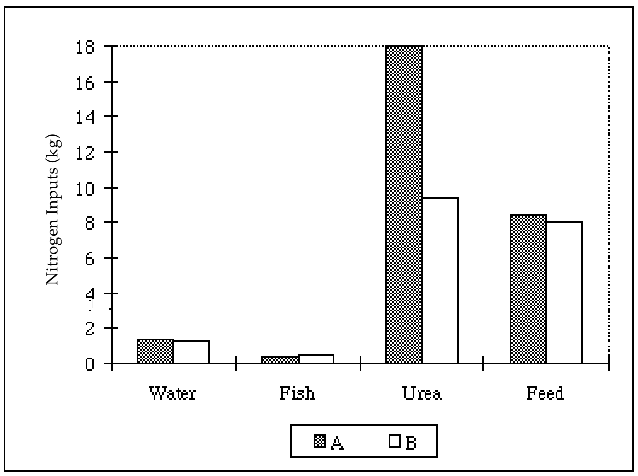

Figure 7. Comparison of nitrogen inputs (kg) in both treatments over the culture period.

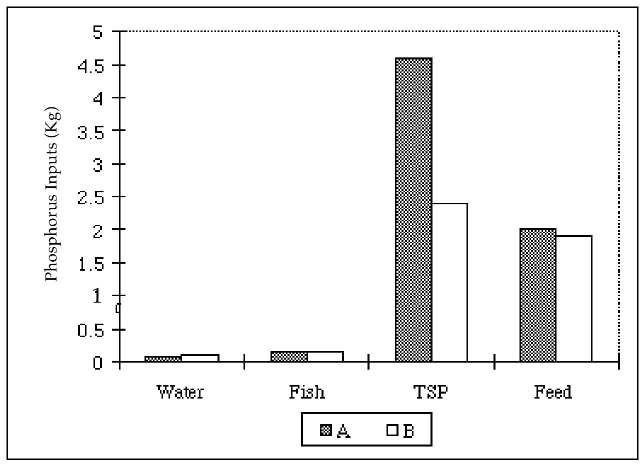

Figure 8. Comparison of phosphorus inputs (kg) in both treatments over the culture period.

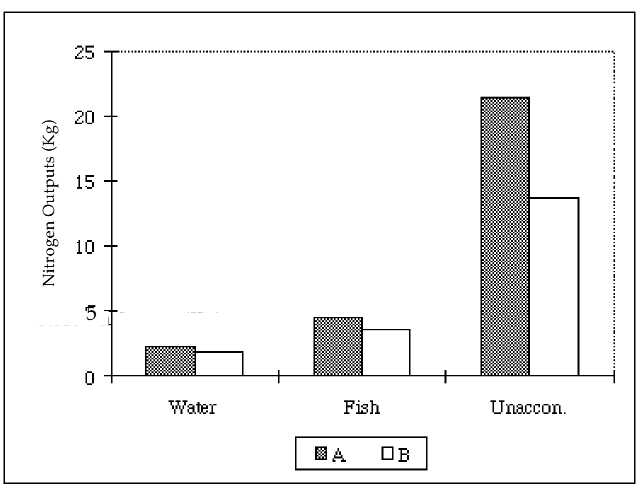

Figure 9. Comparison of nitrogen losses (kg) in both treatments over the culture period.

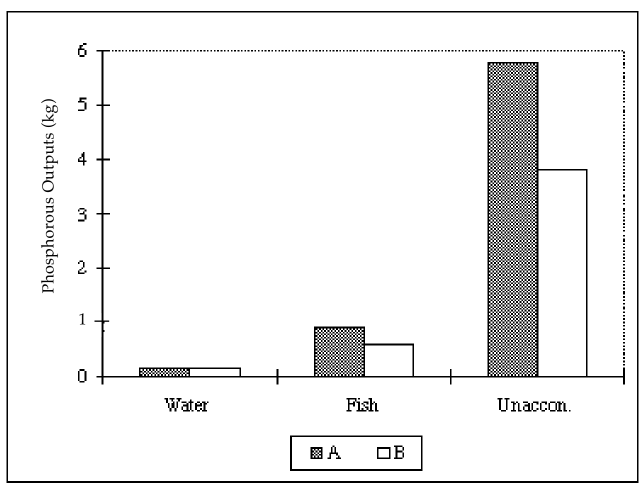

Figure 10. Comparison of phosphorus losses (kg) in both treatments over the culture period.

denitrification process in the sediment. Diab and Shilo (1986) reported that when ponds were refilled, anaerobic conditions developed beneath the soil surface, and nitrate was converted to nitrogen gas by denitrification. Sedimentation is generally considered a main mechanism for P loss in ponds because muds are known to have a strong affinity for phosphorus (Shrestha and Lin, 1996). Boyd (1985) explained that the amount of unaccounted for phosphorus would be analytically undetectable when incorporated in muds. Contrary to many earlier observations that pond muds served as nutrient sinks, the results of the present study show that large amounts of nitrogen and phosphorus (23.68-47.51% N and 0.34-31.68% P of the total inputs) were released from bottom soil to the water column during the culture cycle. This reverse occurrence might have resulted from large amounts of nutrient deposits in the muds from previous feeding experiments. This nutrient release from muds would be a significant source of nutrient to phytoplankton growth.

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