Nutrients profile and fish growth of some fish culture ponds

Jatindra N. Bhakta[1], Sukanta Rana[1], Susmita Lahiri[1], Bana B. Jana[1] and Sakri Ibrahim[2]

[1]*International Centre for Ecological Engineering, University of Kalyani, Kalyani–741235, West Bengal, India*
[2]*Faculty of Fisheries and Aqua–Industry, University Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia*

ARTICLE INFO

Article history:
Received– 21 April, 2015
Revised– 28 June, 2015
Accepted– 10 August, 2015
Available– 20 December, 2015 (online)

Keywords:
CNP ratio
Fish growth
Nutrient amendment
Sustainable fish culture
Trophic status
Water quality

Corresponding Author:
Jatindra N. Bhakta
E–mail: lsnjbhakta@gmail.com

ABSTRACT

Carbon, nitrogen and phosphorus (CNP) ratio is a significant index of high yielding aquaculture. The study was performed to determine the nutrients profile of different aquaculture ponds and to evaluate the necessary nutrients amendment required for high fish growth in fish farming ponds of different nutrients status and culture practices. Ten ponds – four sewage–fed–fish farming ponds, two carp farming ponds, two large water bodies of carp poly culture and two pangas (*Pangasius pangasius* Ham.) monoculture ponds were considered in this study. Nutrients and water qualities, primary productivity, heterotrophic bacterial population and fish growth of all ponds were examined during four months culture period. The higher daily fish growth rate (1.71 – 1.75 g d^{-1}) was found in the pangas cultured ponds due to favorable CNP ratios (49.6:6.5:1 and 56:6:1) developed by congenial nutrient profile compared to remaining fish cultured ponds suffered by eutrophic and oligotrophic status because of imbalanced nutrients regulated unfavourable CNP ratio. Therefore, the amendment of such imbalanced nutrients status is necessary to maintain the balanced CNP ratio by manipulating nutrients concentrations using the methods of fertilization as well as removal of nutrients from the aquaculture environment to recover the aquaculture system from oligotrophic and eutrophic problems, respectively for beneficial and sustainable fish culture.

1. Introduction

The productivity of ecosystem depends greatly upon nutrients availability in supporting medium. This biological productivity in aquaculture pond is often limited by nutrients deficiency. Application of fertilizer has assumed importance to supplement nutrient deficiency and augment productivity through amplification of autotrophic and heterotrophic components. The carbon (C), nitrogen (N) and phosphorus (P) of water act as limiting factors in biological productivity of the aquaculture ecosystem. Phosphorous and organic carbon play pivotal role in the productivity process of aquatic environment and significantly controlling its physico–chemical properties (Bhakta et al. 2013). The CNP ratio in certain range is supportive for the growth and propagation of phyto– and zoo– planktons which are the key components of aquaculture productivity.

Phyto–planktons are the primary producers in aquatic ecosystem (Bhakta and Jana 2002). With the adoption of proper management measures through fertilizer input (Bhatnagar and Singh 2010), the nutrients status of aquaculture pond environment (soil and water) can be maintained to increase the primary productivity (Boyd 1982b). Bacteria are the most abundant and important biological components involved in the transformation and mineralization of organic matter into bioavailability forms through heterotrophic pathway (Cho and Azam 1988; Pomeroy et al. 1991; Williams 1981), which maintain the nutrients level and regulate the productivity of the aqua–farming ponds (Bhakta et al. 2009).

Any deviation in the molecular ratio of C, N and P of phytoplankton mass from Redfield ratio (C:N:P = 106:16:1) signified elemental limitation and sub–optimal phytoplankton growth (Tett et al. 1985). A N:P ratio > 17 indicated P limitation, N:P ratio < 10 indicated N limitation and the ratio between 10 – 17 indicated either of the nutrients may be limiting (Hellström 1996). N–fixing cyanobacteria tended to dominate in lakes when a mass N:P ratio < 22 (Havens et al. 2003). In freshwater, growth of cladocerans demanded more P (Anderson and Hessen 2005). Sediment that acted as sink for P played an important role in CNP balance in pond but on increasing eutrophication, the P capturing ability of sediment was decreased Hobbs et al. 2005). Application of fertilizer or manure in aquaculture pond could increase natural food and fish yield (Bhatnagar and Singh 2010). Growth and reproduction of bacteria decreased with increasing C and N ratio and C and P ratio in substrate (Goldman et al. 1987).

Rhee (1978) reported that optimal NP ratio in water for the culture of *Scenedesmus* sp was 30:1 by moles and at higher and lower NP ratio, the algae culture was limited. The optimal molar ratio for the cyanobacterium *Anacystis nidulans* P. Richt. was also 30:1 (Sirenko 1972). The critical N:P ratios for the productivity of green algae *Scenedesmus quadricauda* and *Stigeoclonium tenue* (Ag.) Kutz. were estimated to be 22:1 and 17:1, respectively (Vries and Klapwijk 1987). The best N:P ratios for green algae was reported to be > 29 :1 (Smith 1983) whereas, the blue–green algae was dominated mostly at ratios of 5–10 : 1 (Schindler 1977). High N:P weight ratio in nutrient medium (20 – 50 :1) favored the growth of chlorophyta while cyanophyta grew better at low ratio (2–5:1) (Levich and Bulgakov 1993).

From the above understanding it is obvious that aqua–farming ponds may undergo lower biological productivity due to deficiency in essential nutrients, carbon, nitrogen and phosphorus content in pond environment – oligotrophic problem in one hand, and may have the problem of high nutrients enrichment – eutrophication problem, especially in sewage–fed fish culture ponds on the other hand. Generally, these are the major and critical problems of nutrients management which severely effects the fish growth and hampers the fish production in aquaculture environment. From the above points of view, the determination of nutrients profile of an aquaculture pond becomes imperative for the management of proper/optimal nutrients level to sustain the higher fish production.

Therefore, the present study has been attempted to determine the nutrients status of different aquaculture ponds in order to evaluate the necessary nutrients amendment required for high and sustainable fish culture.

2. Materials and methods

2. 1. Study area and fish culture condition

Ten fish ponds were selected on the basis of nutrient status and culture practices to draw a nutrient profile of the ponds and thereby to identify limiting factors responsible for fish production. Of these ten ponds, four ponds were highly eutrophic and located in the sewage–fed–fish farm in Kalyani (Latitude 23°N and Longitude 88.5°E), Nadia district, West Bengal, India; the another 4 ponds (Carp farming ponds and Kulia fish farm) were located within 10 km distance of the sewage–fed–fish in the same district; 2 remaining ponds (monoculture of pangas) were situated in the district of North 24–Parganas, adjacent to Nadia district (Fig. 1).

The sewage fed fish ponds (~1 ha each; called as SFP–1, SFP–2, SFP–3 and SFP–4) were situated in a series along the effluent gradient from the source to outlet. However, there was no sewage flow along the gradient during the period of study. The sewage fed ponds were stocked with advance fry (3 – 6 g) of catla (*Catla catla* L.), bata (*Labeo bata* Ham.), rohu (*Labeo rohita* Ham.) and common carp (*Cyprinus carpio* L.) at 20000 fry ha^{-1} and reared upto fingerling size for four months. No fertilizer and supplementary feed were used during the culture period. Among the remaining six ponds, two ponds (~1.2 ha each) were used for carp farming (called as CFP–1 and CFP–2) and stocked with advanced fry (3 – 6 g) of Indian major carps (catla, bata, rohu and common carp) at 22,000 fry ha^{-1} with different fish species ratios in each pond. Mixed fertilizer of cow dung and poultry dropping was applied at 23000 kg ha^{-1}yr^{-1}. Supplementary feeds of rice bran and mustard oil cake were provided at 7% of the total fish weight per day during the four months culture period. Another two ponds (~1.6 ha each) were used for monoculture of pangas (*Pangasius pangasius* Ham.) called as PFP–1 and PFP–2. Fishes were stocked at 14,000 fry ha^{-1}. Supplementary feeds (rice bran and wheat bran, 1:1) were provided at 8% of the fish body weight per day and the applied dose of fertilizer (a mixture of cow dung and poultry dropping) was 20000 kg ha^{-1}yr^{-1}. Other two large water bodies (~7.082 ha each) located in Kulia fish farm (called as KL–1 and KL–2) were also selected for the study. The ponds were used for traditional composite stocking of four species of carps (catla, bata, rohu and common carp) at 12,000 fry ha^{-1}. No fertilizer and supplementary feeds were used during fish culture. The experiments were carried out for four months (January – April) production period in these ponds.

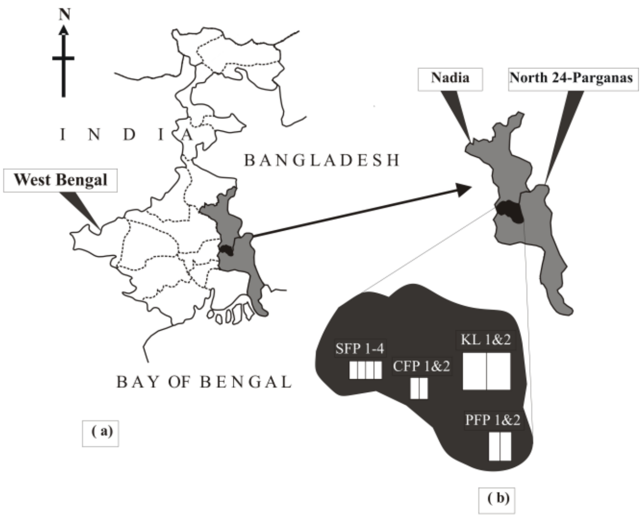

Fig. 1 Figure depicting the location of Nadia and North 24–Parganas districts in the State of West Bengal, India (a) and location of the present study sites (b)

2.2. Examination procedure

Three water samples of each pond were collected at fifteen days interval at 12.00 am and examined for nutrients (ammonium–N, nitrite–N, nitrate–N, orthophosphate, dissolved organic C) and water qualities parameters (temperature, pH, alkalinity, dissolved oxygen and chemical oxygen demand) following the standard methods (APHA 1998). Primary productivity of the phytoplankton was determined using the light and dark bottle method described by Vollenweider (1974).

The conventional spread plate technique was used under aerobic conditions to enumerate viable counts of different nutrient cycling groups of bacteria, such as heterotrophic bacteria (HB), cellulose decomposing bacteria (CDB), denitrifying bacteria (DNB) and phosphate solubilizing bacteria (PSB) following the methods described by Rodina (1972) and Austin (1990). Each dilution of the sample was plated in triplicate, incubated at 35 °C for two days and arithmetical mean counts of the three replicates were considered for evaluation in the present study.

After specified culture period, the fish growth was recorded in each pond.

2.3. Statistical analysis

The mean data of three samples of each culture system were used for statistical analysis. The means were compared following the one way analysis of variance (ANOVA) (Gomez and Gomez 1984) and least significance difference (LSD). The statistical packages (EASE and M–STAT) were used in the computer to perform the various statistical analyses. The level of acceptable statistical significance was specified at $P < 0.05$.

3. Results and discussion

Irrespective of fish species, different types of pond showed a significant difference (ANOVA, $P<0.05$) in fish growth. The average weights of fish ranged from 142 to 210 g in all ponds followed by various culture practices. Daily fish growths were maximum in PFP–1 (1.75 g d^{-1}) and PFP–2 (1.71 g d^{-1}) and minimum in KL–1 (1.18 g d^{-1}) and KL–2 (1.21 g d^{-1}) (Fig. 2).

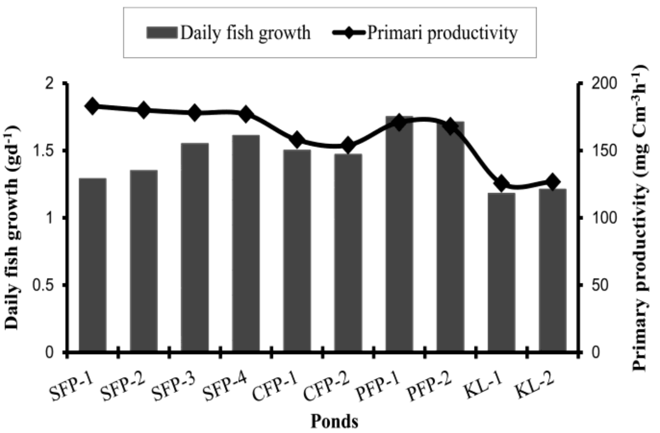

Fig. 2 Relationship between primary productivity and daily fish growth in ten surveyed fish ponds managed under different culture practices

The concentrations of three species of nitrogen and orthophosphate showed a significant (ANOVA, $P<0.05$) different in the ponds of different culture practices. The mean concentrations of ammonium–N, nitrite–N, nitrate–N and Orthophosphate ranged from 0.478 to 1.917 mg l^{-1}, 0.351 to 1.041 mg l^{-1}, 0.038 to 0.104 mg l^{-1} (Fig. 3a,b,c) and 0.208 to 0.412 mg l^{-1} (Fig. 4a) in ten ponds, respectively. The concentrations of ammonium–N, nitrite–N, nitrate–N and orthophosphate were in the order as follows: SFP–1 > SFP–2 > SFP–3 > SFP–4 > PFP–1 > PFP–2 > KL–1 > KL–2 > CFP–1 > CFP–2 (ANOVA, $P < 0.05$). Frequency distribution of ammonium–N revealed that higher concentration classes (1.215 – 1.917 mg l^{-1}) occurred (42%) exclusively in all sewage fed ponds (SFP–1 to SFP–4) followed by next higher class range (0.815 to 1.214 mg l^{-1}) in PFP–1 and PFP–2 (23%) and the lowest concentrations (0.478 – 0.814 mg l^{-1}) in CFP–1, CFP–2, KL–1 and Kl–2 (35%). Frequency distribution of nitrite–N also showed the higher concentrations (0.751 – 1.041 mg l^{-1}) in four sewage pond (36%) and lower range (0.351 – 0.750 mg l^{-1}) in the remaining ponds (64%). The responses of frequency distribution of nitrate–N were similar to that of ammonia–N. Higher concentrations (0.068 – 0.104 mg l^{-1}) were found in four sewage fed ponds (41.5%), whereas lower class range (0.038 – 0.067 mg l^{-1}) occurred in the remaining ponds (58.5%). Frequency distribution of orthophosphate concentrations were skewed towards occurrence (40%) of higher class range (0.299 – 0.412 mg l^{-1}) exclusively in four sewage fed ponds, whereas, lower class range (0.208 – 0.298 mg l^{-1}) was dominant (60%) in the remaining ponds.

Organic C in water varied (7 to 17.5%) by a factor of 2.5 in different fish culture ponds (Fig. 4b). Concentration differences of organic C were significant among the ponds, showing the following order of variations: PFP–1 > PFP–2 > SFP–2 > CFP–2 > CFP–1 > SFP–1 > SFP–3 > SFP–4 > KL–2 > KL–1. Frequency distribution of organic C in water showed three categories of ponds: higher class range (14.5 – 17.5%) was found in PFP–1, PFP–2 CFP–1 and CFP–2, middle class range (8.54 – 14.5%) was dominant (63%) in SFP–2, SFP–3, SFP–4, CFP–1, CFP–2, PFP–1 and PFP–2, and lower class range (7 – 8.5%) was exclusively in KL–1 and KL–2 (20%).

The gross primary productivity (GPP) was highly variable (108 – 196 mg C $m^{-3}h^{-1}$) in all ponds. The gross primary productivity in SFP–1 (183 mg C $m^{-3}h^{-1}$) was 0.5, 2.8, 3.2, 13.6, 15.8, 6.5, 8.1, 31 and 30.7% higher than that of SFP–2, SFP–3, SFP–4, CFP–1, CFP–2, PFP–1, PFP–1, KL–1 and KL–2, respectively. The net primary productivity (NPP) evidenced the similar trend of variations as that of GPP in different ponds. The maximum and minimum values of NPP 127 mg C $m^{-3}h^{-1}$ and 27 mg C $m^{-3}h^{-1}$ were found in SFP–1 and KL–2, respectively (Fig. 2).

Above results clearly demonstrated that daily fish growth was maximum in two pangas farming ponds (PFP–1 and 2), though primary productivity (Fig. 2), and concentrations of water quality and nutrient parameters were higher in the four sewage–fed fish ponds (SFP–1 to 4) than that of remaining six ponds. No strong positive correlation was also found between the daily fish growth and primary productivity ($r = 0.557$). It obviously inferred that despite high and low levels of nutrients concentration, a specific and optimum state of nutrient concentrations in fish culture ponds are of paramount important for optimal pond productivity and sustainable fish growth, which is pronounced by PFP–1 and 2 ponds in the present study.

The CNP ratios varied remarkably in different fish ponds. The values were 33.1:7.5:1, 36.5:7.2:1, 35.1:7:1, 33.:6.8:1, 44.7:.4.3:1, 47:4.3:1, 49.6:6.5:1, 56:2.6:1 and 31:5.5:1 and 33.1:7.5:1 in SFP–1, SFP–2, SFP–3, SFP–4, CFP–1, CFP–2 , PFP–1, PFP–2, KL–1 and KL–2, respectively (Fig. 5).

Using as an indicator of fish growth, it can be implied that the states of all nutrient parameters, ammonium–N

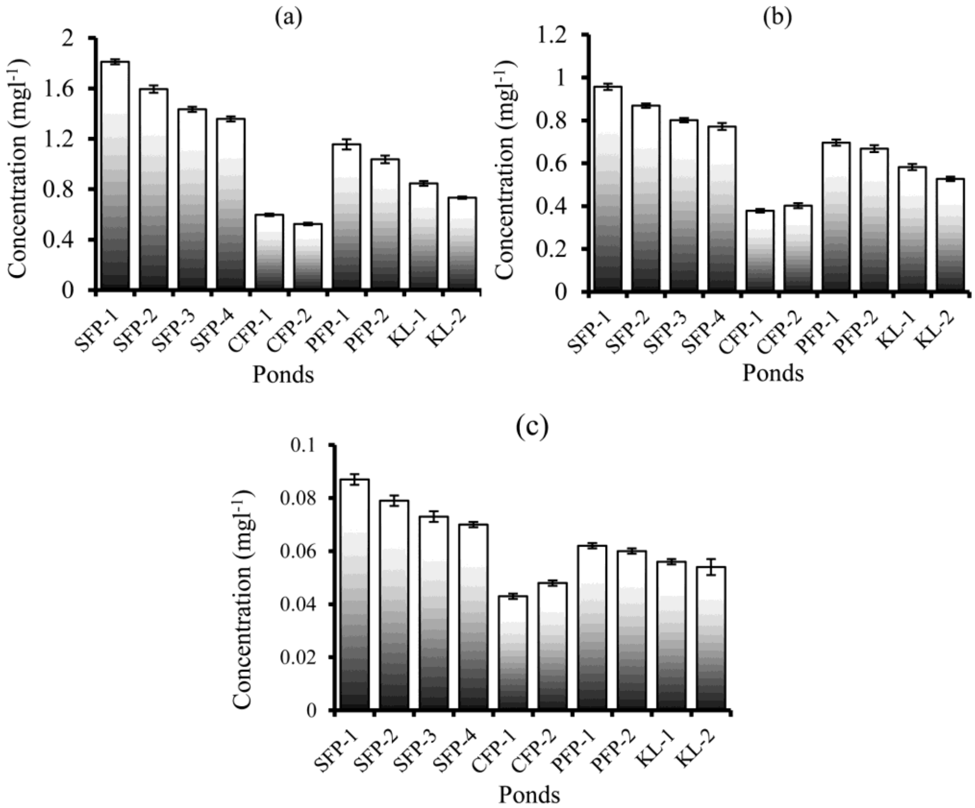

Fig. 3 Mean concentrations of NH_4-N (a), NO_2-N (b) and NO_3-N (c) in water of ten fish culture ponds managed under different culture practices

(0.815 – 1.214 mg l^{-1}), nitrite–N (0.551 – 0.699 mg l^{-1}), nitrate–N (0.060 – 0.063 mg l^{-1}), orthophosphate (0.199 – 0.299 mg l^{-1}) and organic C (13.5 – 14.5%) occurred in two pangas farming ponds were congenial for high fish growth with respect to the balanced CNP ratio (49.6:6.5:1 and 56:6:1). This CNP ratio of ambient water might be balanced and important useful criteria for the assessment of nutrient status required for optimum productivity of ponds because it regulates the balanced qualitative and quantitative development of aquatic food staffs (especially zooplankton and phytoplankton) which are highly suitable for better fish growth than that of other CNP ratio occurred in remaining culture systems. Satomi (1967) observed that the composition of CNP ratio in phytoplankton is approximately 50:7:1 by weight, whereas Seymour (1980) indicated that 1:4 ratio of P:N was advantageous to phytoplankton production in pond. The present survey also revealed that ponds located in sewage fed farm were eutrophic as exhibited by higher concentrations of nutrients and imbalanced CNP ratios than that of the pangas farming ponds. In this context, nutrient amendment is important to obtain the proper and balanced CNP ratio by reducing phosphorus which also helps to develop the congenial aquatic environmental conditions required for increasing the qualitative and quantitative development of planktons in remaining ponds other than pangas farming ponds. High concentrations of both N and P reach in excess of eutrophication thresholds (Penick et al. 2012) and to mitigate eutrophication, it is not nitrogen but phosphorus that should be reduced, unless nitrogen concentrations are too high to induce direct toxic impacts on human beings or other organisms (Wang and Wang 2009). Therefore, it may be concluded that imbalance more that lacking of important limiting factors (C, N and P) would affect the health of fish culture environment to great extent that ultimately inhibit the productivity and fish growth which amendment is needed for beneficial, sustainable and eco–friendly fish culture. Various workers have observed that addition of these elements in the form of fertilizers or manures resulted in an increase in natural food and also fish production (Bhatnagar and Singh 2010; Rabanal 1967; Saha and Chatterjee 1975; Dobie 1967). The observations made on the balanced sheet of nitrogen in some composite fish culture ponds (Sinha et al. 1980) and the tentative nutrient balance of carbon, nitrogen and phosphorus in intensive fish culture with supplementary feeding (Avnimelech and Lacher 1979) are of great importance, which need to be consulted for their rational use in fertilizing fish ponds and increasing pond productivity.

Water qualities were highly variable in different ponds with various culture practices. Water temperature and pH ranged from 28 to 32°C and 7.5 to 8.9 during the period of investigation (Table 1). Nearly 40% of the total surveyed ponds showed pH range between 7.9– 8.1 in PFPs and SFPs 3 and 4 in the present study (Table 1). It appears that these ponds are quite suitable for profitable fish production. In a survey conducted by Datta (1999), it was found that some local ponds had pH within alkaline range (7.1 to 8.6) which was suitable for fish farming.

The total alkalinity and dissolved oxygen of water varied from 18 to 50 mg l^{-1} and 6.2 to 12.75 mg l^{-1} in ten ponds, respectively (Table 1). In PFPs (i.e. 20% of surveyed ponds), the total alkalinity (41 to 50 mg L^{-1}) was appropriate for fish growth according to fish culture protocol, whereas rest of the ten ponds showed the lower values of alkalinity which is necessary for amendment.

The maximum mean value (12.21 mg l^{-1}) of dissolved oxygen was found in SFP–1 followed by other three SFPs, PFPs, CFPs and KLs (Table 1). Frequency distribution of dissolved oxygen showed the high concentration classes (9.8

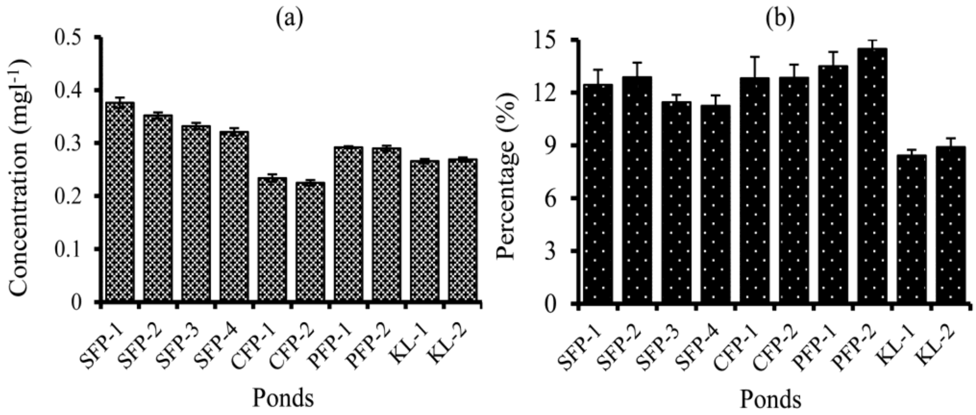

Fig. 4 Mean concentration of PO_4-P (a) and mean percentage of Organic C (b) in water of ten fish culture ponds managed under different culture practices

– 12.82 mg l^{-1}) were dominant (42.6%) in the four sewage fed ponds, whereas, the low concentration classes (6.2 – 9.7 mg l^{-1}) were skewed towards occurrence (56.8%) exclusively in remaining ponds. Because the dissolved oxygen of water ranged from 6.2 to 13.2 mg l^{-1} in all the ponds, it appears that dissolved oxygen in these ponds did not act as limiting factor for existence of aquatic flora and fauna as water bodies with less than 5 mg l^{-1} of dissolved oxygen are often considered unsuitable (Jhingran 1995).

The chemical oxygen demand varied between 44 and 345 mg l^{-1} for all ponds surveyed (Table 1). The highest mean concentration (300 mg l^{-1}) was found in SFP–1 followed by SFP–2, SFP–3, SFP–4, KL–1, KL–2, PFP–1, PFP–2, CFP–1 and CFP–2. Frequency distribution of chemical oxygen demand exhibited the lower class range (44 – 164 mg l^{-1}) exclusively occurred (32.85%) in PFPs and CFPs, whereas, the middle class ranges (165 – 264 mg l^{-1}) were more abundant (51%) in SFP–2, SFP–3, SFP–4, KL–1, KL–2, whereas, the higher class range (265 – 345 mg l^{-1}) was dominant (16%) in all SFPs. In general, chemical oxygen demand is used as indicator for assessment of the organic load in the system (Boyd 1982a). According to this proposition about 20% of the total ponds surveyed especially the SFPs appeared to be rich in organic load with highest concentration range of chemical oxygen demand (261 – 290 mg l^{-1}). On the other hand, it showed limited range in more than 30% ponds (CFP–1, CFP–2, KL–1 and KL–2) and moderate values (261– 290 mg l^{-1}) in PFP (1 and 2). This indicated that chemical oxygen demand was the direct function of organic loading of the pond, which might have a pivotal role in nutrients dynamics of the pond ecosystem.

The population counts of HB, CDB and PSB ranged from 80 to 291 X 10^3 cfu ml^{-1}, 7 to 128 X 10^2 cfu ml^{-1}, 10.5 to 66 X 10^2 cfu ml^{-1}, respectively in different ponds. The mean counts of all types of bacteria exhibited the following order of variation: SFP–1>SFP–2>SFP–3>SFP–4>PFP–2>PFP–1>CFP–1>CFP–2>KL–2>KL–1 (ANOVA, $P < 0.05$). Frequency distribution of HB populations occurring in water showed that higher concentration classes (231 – 300 x 10^3 cfu ml^{-1}) were skewed (39%) towards four SFPs, whereas, lower class ranges (80 – 230 x10^3 cfu ml^{-1}) were dominant (61%) in the remaining six ponds. In CDB, the frequency distribution occurred more frequently (33%) in higher density classes (86 – 146 x 10^2 cfu ml^{-1}) in four SFPs, whereas, middle density class range (26 – 85 x 10^2 cfu ml^{-1}) was dominant (45.5%) in the PFP–1, PFP–2 CFP–1 and CFP–2; and lower density class (6 – 25 x 10^2 cfu ml^{-1}) exclusively observed (21%) in KL–1 and KL–2. Frequency distribution of PSB counts were also skewed towards dominance (40%) of higher class range (35 – 70 x 10^3 cfu ml^{-1}) exclusively in four SFPs, whereas, lower class range (10 – 34 x 10^3 cfu ml^{-1}) were dominant (60%) in the remaining ponds. To manipulate the optimum bacterial population and productivity in the aquaculture ponds, proper fertilizer dose is required (Bhakta et al. 2006). It can be suggested that total bacterial population occurred in PFPs may be appropriate to maintain proper CNP ratio regulating the nutrients dynamics required for optimum productivity. On the other hand, the imbalance/excess bacterial population occurring in SFPs may be negatively regulating the nutrients dynamics in releasing the nutrients resulting in imbalanced CNP ratio, which amendment is required by proper management. The ponding system not only reduces the nutrients and organic loads by 50 – 90%, the bacterial loads are also reduced by 2–3 log units at 100 kg COD $ha^{-1}d^{-1}$ (Bhowmik et al. 1994). It has been suggested that bacterial growth efficiency decreases with increasing C:N and C:P ratio in the substrate (Goldman et al. 1987). The increase of the C:N ratio resulted in a shift of the bacterial community structure in term of reduction of taxa richness and diversity indices (Luigi et al. 2014). The transformation of nitrogen from organic to inorganic forms with C:N ratio of 40% C and 0.5% N decomposes slowly, whereas, materials with a narrow C:N ratio of 40% C and 4% N decay quickly (Boyd 1982b; Boyd 1995; Datta 1999; Boyd 1982a).

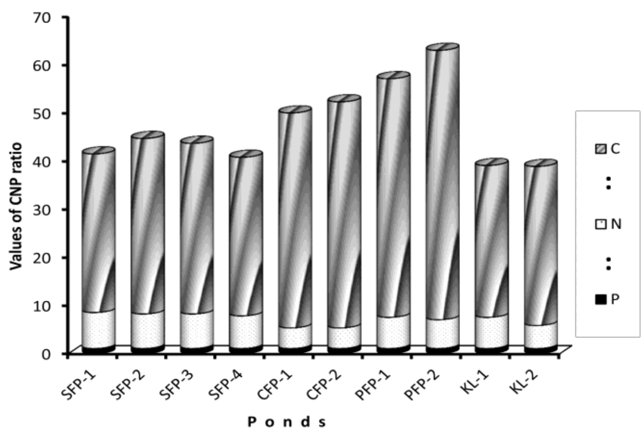

Fig. 5 Figure depicting the location of Nadia and North 24–Parganas districts in the State of West Bengal, India (a) and location of the present study sites (b)

Table 1 Mean values (±S.E.) of physicochemical parameters and bacterial population of water in fish culture ponds

Parameters	Ponds									
	SFP-1	SFP-2	SFP-3	SFP-4	CFP-1	CFP-2	PFP-1	PFP-2	KL-1	KL-2
Temperature (C)	30.2 0.5	30.5 1	30 0.8	31 0.51	30.5 0.49	31 0.1	30.4 0.9	30.5 0.88	31 0.6	30.6 0.3
pH	7.9	7.8	8.3	8.1	7.8	8.0	7.8	8.0	8.3	8.3
Total alkalinity (mg l^{-1})	22.75 2	26.21 3	25.51 1.5	26.24 4	24.6 2	29.41 1.6	49.14 4	42.44 2.5	24.7 3.1	21.05 1
DO (mg l^{-1})	12.2 0.16	11.6 0.22	10.9 0.15	10.3 0.17	7.9 0.37	9.9 0.16	9.1 0.21	9.7 0.18	7.8 0.32	7.1 0.24
COD (mg l^{-1})	300 12	256 8	226.8 11	196.7 7.2	103 9	76.4 9.8	146.8 11	136.8 5	186.7 1.9	151.1 5
HB (x 10^5 cfu ml^{-1})	272.4 5.4	256.2 7.5	232.1 8.4	211.2 5.2	176.4 7.9	170.4 8.1	191.5 6.7	197 9.7	140.5 10	157.4 10
CDB (x 10^4 cfu ml^{-1})	195.8 5.5	183.8 6.8	165.7 2.7	146 2.7	67.2 2.8	80.4 2.2	123.7 3.8	138.2 4.1	85.1 1.7	115.2 1.4
PSB (x 10^3 cfu ml^{-1})	57.5 3.6	49.1 2.7	45.7 2.4	36.5 2.2	23.3 1.5	21.4 1.2	27.6 1.6	30.9 2.0	13.3 0.9	16.7 0.8

DO, dissolved oxygen; COD, chemical oxygen demand; HB, heterotrophic bacteria; CDB, cellulose decomposing bacteria; PSB, phosphate solubilizing bacteria

4. Conclusions

This study demonstrated that higher fish growth was influenced by congenial nutrient status and favorable CNP ratios (49.6:6.5:1 and 56:6:1), whereas unfavorable CNP ratios and nutrient status resulted in lower fish growth in fish culture systems. Moreover, on account of above discussion derived from the critical appraisal of results of present study, the following conclusions can be drawn: (i) a specific and optimum state of water and nutrient qualities of fish culture ponds are of paramount importance in determining their potentials for optimal pond productivity and higher/maximum fish growth, (ii) a balanced CNP ratio of ambient water is useful and critical criteria for the assessment of optimal nutrient status of ponds for higher fish growth because it regulates the qualitative and quantitative development of aquatic food staffs by manipulating the optimum microbial populations playing pivotal role in nutrients dynamics of the fish ponds, (iii) important nutrients (C, N and P) concentrations and imbalanced CNP ratio lead to develop the eutrophic and oligotrophic status of culture systems, which in turn adversely affect on the fish culture environment and fish growth and (iv) besides, imbalanced CNP ratio more that lacking of important limiting factors (C, N and P) may severely affects the health of fish culture environment that ultimately inhibits the productivity and fish growth which amendment is needed for beneficial and sustainable fish culture. Finally, it may be concluded that nutrient amendment is the first and foremost necessary step to obtain the proper and balanced CNP ratio by manipulating nutrients concentrations using the methods of fertilization as well as removal of nutrients from the aquaculture environment to recover the aquaculture systems from the problems of oligotrophic and eutrophic status, respectively.

Acknowledgments

This study was supported by a research grant of the Indian Council of Agricultural Research (ICAR), New Delhi, India to BBJ. The authors are grateful to ICAR for providing senior research fellowships to carry out this study.

References

Anderson TR, Hessen DO (2005) Threshold elemental ratios for carbon versus phosphorus limitation in *Daphnia*. Freshwater Biol 50:2063–2075

APHA (1998) Standard Methods for the Examination of Water and Wastewater, 20th edn. American Water Works Association and Water Pollution Control Federation, American Public Health Association, Washington, DC

Austin B (1990) Methods in aquatic bacteriology. John Wiley and Sons, New York

Avnimelech Y, Lacher M (1979) A tentative nutrient balance for intensive fish ponds. Bamidgeh 31(1):3–8

Bhakta JN, Jana BB, Munekage Y, Reimer JJ (2013) Distributional relationship between phosphorus, organic matter and organic carbon in mud of coastal shrimp–farming ponds. Environm Engineer Manag J, in press

Bhakta JN, Bandyopadhyay PK, Jana BB (2006) Effect of different doses of mixed fertilizer on some biogeochemical cycling bacterial population in carp culture pond. Tur J Fish and Aqu Sci 6:163–169

Bhakta JN, Biswas JK, Bhakta P, Munekage Y, Jana BB (2009) Fish stocking density induced growth responses of some biogeochemical cycling bacterial population. Braz J Aquat Sci Technol 13(2):45–50

Bhakta JN, Jana BB (2002) Influence of sediment phosphorus on utilization efficiency of phosphate fertilizer: a mesocosm study. Aquacult Res 33(3):203–215

Bhatnagar A, Singh G (2010) Assessment of Culture Fisheries in Village Ponds: a Study in District Hisar, Haryana, India. Int J Environ Res 4(1):57–64

Bhowmik ML, Pandey BK, Sarkar UK (1994) Microbial and chemical changes in water and in sediments of an experimental wastewater–fed fish pond. In: Paul Raj S (eds.), Proceeding of the National Symposium on Aquaculture for 2000 A.D, 1994, India

Int J Env Tech Sci - www.heritagefoundationtrust.in/international-journal

Boyd CE (1982a) Water quality management for pond fish culture. Elsevier Scientific Publishing Company, New York

Boyd CE (1982b) Water quality management for pond fish culture, Development in Aquaculture and Fisheries Science. Elsevier Scientific Publishing Company, New York

Boyd CE (1995) Bottom Soils, Sediment, and Pond Aquaculture. Chapman and Hall, New York

Cho BC, Azam F (1988) Major role of bacteria in biogeochemical fluxes in the ocean's interior. Nature 332:441–443

Das SK, Jana BB (1996) Pond fertilization through inorganic sources: An overview. Ind J Fish 43(2):137–155

Datta S (1999) Diversity pattern of tropical pond ecosystem: Nutrient dynamics and functional relationships. PhD Thesis, Aquaculture and Applied Limnology Research Unit, Department of Zoology, University of Kalyani, India

Debeljak L, Turk M, Fasaic K, Popovic J (1990) Mineral fertilizers and fish production in carp ponds. In: Berka R, Hilge V (eds) Proceedings of the FAO–EIFAC Symposium on Production Enhancement in Still Water Pond Culture, Czechoslovakia, Research Institute of Fish Culture and Hydrobiology

Dobie J (1967) Experiments in the fertilization of Minnesota fish rearing ponds. FAO Fish Report 44(3):274–284

Goldman JC, Caron DA, Dennett MR (1987) Regulation of gross growth efficiency and ammonium regeneration in bacteria by substrate C:N ratio. Limnol and Oceano 32:1239–1252

Gomez KA, Gomez AA (1984) Statistical procedures for agricultural research. John Wiley and Sons, New York

Havens KE, James RT, East TL, Smith VH (2003) N:P ratios, light limitation and cyanobacterial dominance in a subtropical lake impacted by non–point source nutrient pollution Environ Pollut 122:379–390

Hellström T (1996) An empirical study of nitrogen dynamics in lakes. Water Environ Res 68:55–65

Hobbs W, Irvine K, Donohue I (2005) Using sediments to assess the resistance of a calcareous lake to diffuse nutrient loading. Arch Hydrobiol 164:109–125

Jana BB, Sahu SN (1994) Effects of frequency of rock phosphate application in carp culture Aquacult 122(4):313–321

Jana BB, Chakrabarty D (1997) Relative status and contribution of sediment phosphorus and nitrogen in carp culture system fertilized with various combinations of rock phosphate. Aquacult Res 28:853–859

Jhingran VG (1995) Fish and fisheries of India. Hindustan Publishing Corporation, New Delhi.

Levich AP, Bulgakov NG (1993) Possibility of controlling the algal community structure in the laboratory. Biology Bullatin of the Academy of Sciences of the USSR 20(1):114–123

Luigi M, Angelina LG, Filippo I, Sebastien T, Liu Y, Jean–Paul B (2014) C/N ratio–induced structural shift of bacterial communities inside lab–scale aquaculture biofilters. Aquacult Eng 58:77–87

Pasek M, Papineau D, Harnmeijer J (2008) The Evolution of the Biogeochemical Cycling of Phosphorus and Other Bioessential Elements. Astrobiology 8(2):356–361

Penick MD, Grubbs SA, Meier AJ (2012) Algal biomass accrual in relation to nutrient availability and limitation along a longitudinal gradient of a karst riverine system. Int Aquat Res 4:20

Pomeroy LR, Wiebe WJ, Deibel D, Thompson RJ, Rowe GT (1991) Bacterial responses to temperature and substrate concentration during the Newfoundland spring bloom. Mar Ecol Pro Ser 75:143–159

Rabanal HR (1967) Inorganic fertilizers for pond fish culture. FAO Fish Report 44(3):164–178

Rhee G–Yull (1978) Effects of N:P atomic ratios and nitrate limitation on algal growth, cell composition and nitrate uptake. Limnol Oceanogr 23:10–25

Rodina AG (1972) Methods in aquatic microbiology. University Park Press, Baltimor

Saha GN, Chatterjee DK (1975) Urea for enhancing the production of zooplankton in fish ponds. Soci Cult 41(7):320–322

Satomi Y (1967) Physiological significance of carbon sources in fertilized fish ponds. FAO Fish Report 44(3):257–264

Schindler D W (1977) Evolution of phosphorus limitation in lakes. Science 196:260–262

Schroeder GL (1980) Fish farming in manure–loaded ponds. In: Pullin RSV, Shehadeh ZH (eds), ICLARM Conference Proceedings 4, International Centre for Living Aquatic Resource Management, Manila and Southeast Asian Regional Centre for Graduate Study and Research in Agriculture, College Los Banos, Philippines

Seymour EA (1980) The effects and control of algal blooms in fish ponds. Aquacult 19:55–74

Sinha VRP, Khan HA, Chakraborty DP, Gupta MV (1980) Preliminary observations on nitrogen balance of some ponds under composite fish culture. Aqua Hungari 2:105–116

Sirenko LA (1972) A physiological background for blue–green algae reproduction in reservoirs. Naukova Dumka, Kiev, pp 1–204

Smith VH (1983) Low nitrogen to phosphorus favour dominance blue–green algae in lake phytoplankton. Science 221:669–671

Tett P, Droop MR, Heaney SI (1985) The Redfield Ratio and Phytoplankton Growth Rate. J Mar Biol Assoc UK 65:487–504

Vollenweider RA (1974) A Manual on methods for measuring primary production in aquatic environments, IBP Handbook **vol. 12,** Blackwell Scientific Publications, Oxford

Vries PJR de, Klapwijk SP (1987) Bioassay using *Stigeoclonium tenue* Kutz. and *Scenedesmus quadric* cauda (Turp.) Breb. as test organisms; a comparative study. Hydrobiologia 153:149–157

Wang H, Wang H (2009) Mitigation of lake eutrophication: Loosen nitrogen control and focus on phosphorus abatement. Progr in Natur Sc 19:1445–1451

Williams PB (1981) Microbial contribution to overall marine plankton metabolism: direct measurements of respiration. Oceanol Acta 4:359–364