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Soil and water characteristics of traditional paddy and shrimp fields of Kerala

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ABSTRACT

A comprehensive study was undertaken to assess soil and water quality of three different farming areas in Trichur and Ernakulam districts of Kerala during traditional paddy cultivation period from June to December 2000 and the extensive shrimp culture season from January to April 2001. Studies revealed that organic carbon in soil was higher during *Pokkali* paddy crop *vis a vis* extensive shrimp culture. Soil was acidic during both the crops. There was no difference in other soil parameters such as electrical conductivity and redox potential. Water parameters like salinity, ammonia and nitrite values were marginally higher during extensive shrimp culture than during paddy crop. However, pH, chemical oxygen demand, phosphates and total phosphorous were not different between the two crops. The soil and water parameters, except soil pH, were observed to be within optimum range for shrimp farming.

Keywords: Kerala, Physico-chemical parameters, Shrimp farming, Soil characteristics, Traditional paddy culture, Water quality

Introduction

The declining trend of marine fisheries and increased consumer demand for seafood have necessitated aquaculture of marine species (Krishnani and Ponniah, 2009). The current worldwide growth rate of aquaculture business (8.9 – 9.1% per year) is needed in order to cope with the problem of shortage in protein food supplies (Ponniah and Krishnani, 2009; Krishnani *et al.*, 2010). Shrimp farming is an expanding, high-value commercial enterprise in coastal areas of the country, which has emerged as a main source of employment and income for hundreds of thousands of people. India is the second major aquaculture producing county in the world, where aquaculture has steadily transformed itself into a profitable business. In Kerala, traditional/extensive shrimp culture is in practice and the total area under traditional farming system is 12,986.6 ha, of which 84% is under *pokkali* fields (Pillai *et al.*, 2002).

The successful growth, propagation, survival, reproduction and harvest of shrimps are heavily dependent upon the quality of the pond soil and water, degradation of which often limits the production in aquaculture systems (Krishnani *et al.*, 1997; Gupta *et al.*, 2001). Ammonia is the major end product of protein catabolism and remains in the form of unionized ammonia (NH_3) and ionized ammonia (NH_4^+), the proportion of which varies with pH and temperature. Unionized ammonia is toxic to aquatic life, whereas ammonium ion is nontoxic. Ammonia can be oxidized into toxic nitrite. Nitrite is an intermediate product in bacterial nitrification and denitrification processes. An imbalance in either of these processes can lead to elevated ambient nitrite concentrations. Adverse pond conditions such as low DO and accumulation of ammonia, nitrite and other nutrient load may cause eutrophication and stress, which is unfavorable to the animals but favorable to the disease causing agents (Krishnani *et al.*, 1997; Gupta *et al.*, 2001; Joseph *et al.*, 2003; Parimala *et al.*, 2007). In the present study, soil and water characteristics and the management practices followed in three farming areas in Kerala were studied to understand their possible role in the production and productivity of the fields.

Materials and methods

Study areas and traditional practices

Three traditional farming areas, one at Poyya in Trichur District and two at Pizhala and Appangad in Ernakulam District were selected to study their physico-chemical characteristics. At all the three places, traditional *pokkali* variety of paddy is raised during June to December and shrimp from January to April. Details of the shrimp culture practices in all the three farming areas are given in Table 1. As a regular practice, liming was done before stocking in all the three farming areas with calcium

Table 1. Details of *P. monodon* culture in the selected fields in Kerala

Farm	Poyya	Pizhala	Appangad
District	Trichur	Ernakulam	Ernakulam
Type of culture	Extensive	Extensive	Extensive
Area of farm (ha)	1.8 ha and14 ha-Natural seed)	17 ha (3 ha-hatchery seed	1 ha
Species stocked	*P. monodon*	*P. monodon*	*P. monodon*
Feed	Higashi (hfil brand)	Higashi (hfil brand)	Higashi (hfil brand)
Pond preparation			
Liming	Calcium carbonate	Calcium carbonate	Calcium carbonate
Bleaching	Bleaching powder	Bleaching powder	Bleaching powder
Treatment	Mohua/ Tea seed cake	Mohua/ Tea seed cake	Mohua/ Tea seed cake
Fertilisation	Urea and SSP	Urea and SSP	Urea and SSP
Month of stocking	January, 2001	January, 2001	January 2001
Stocking density (PL ha^{-1})	20,000	50,000	30,000
Growth (g)	27	35-40	25-32
Harvesting	April, 2001	April, 2001	April 2001
Yield (kg ha^{-1})	250	400	300

carbonate @ 200 kg ha^{-1}, three times (total 600 kg ha^{-1}) and the fields were subsequently fertilized with urea and single super phosphate. Mohua oil cake and tea seed cake were also applied for killing unwanted fishes and other organisms. Bleaching powder was applied for cleaning the ponds. After stocking, during the first 10 days, the post-larvae were fed with boiled egg yolk and later with commercial feed @ 4 kg day^{-1}. Probiotics were also applied in the field during the culture period.

Collection and analysis of soil and water samples

Samples of soil and water were collected from shrimp farms at monthly intervals from June 2000 to April 2001. Water samples were collected from 2 cm above the bottom soil surface by siphoning. Sampling of soil was done at four points from each place. Composite soil samples were then air dried, ground to fine powder with the help of a wooden hammer, passed initially through a 2 mm sieve and finally through a 0.2 mm mesh sieve and stored in air tight polythene bags for analysis. Redox potential (E_h) of the wet soil samples were measured immediately after collection with a redox potential meter. pH and electrical conductivity was measured as per Jackson (1973), organic carbon by chromic acid wet digestion method (Walkley and Black, 1934) and total nitrogen by Macro kjeldahl method (Piper, 1966). Salinity, pH, chemical oxygen demand (COD), ammonia, nitrite, phosphates and total phosphorous in water were estimated following standard methods (Strickland and Parsons, 1968; APHA, 1989). Unionized ammonia was calculated based on total ammonia, pH and temperature.

Results

The changes in soil quality parameters such as pH, electrical conductivity (EC), redox potential and organic carbon during traditional paddy culture and extensive shrimp culture at Poyya, Pizhala and Appangad are shown in Fig. 1 and ranges are given Table 2 and 3. It is clearly evident that there was no significant difference in soil pH, redox potential and EC between paddy cultivation and shrimp culture at Poyya. During shrimp culture period, the pH was low due to acid sulphate soil. It ranged from 4.8 to 5.13. Redox potential and electrical conductivity were in the range of –150 to –190 mV and 4.04 to 5.44 dS m^{-1}, respectively. At the time of paddy culture, organic carbon content in soil was comparatively higher (0.22 - 3.74%) than extensive shrimp culture (0.81 - 1.02%). Except soil pH, all other parameters were within safe permissible levels for shrimp farming as suggested by Boyd (1995) and Smith (1996).

Variation in water quality parameters such as pH, salinity, ammonia, nitrite, chemical oxygen demand (COD), phosphate and total phosphorous observed during traditional paddy culture and extensive shrimp culture at Poyya, Pizhala and Appangad are presented in Fig. 2 and ranges are given in Tables 2 and 3. During paddy culture at Poyya, salinity (4-12 ppt), ammonia (0.006-0.314 ppm), nitrite (0.001-0.031 ppm), phosphate (0.008-0.067 ppm) and total P (0.069-0.221) were comparatively low (Table 3). At the time of extensive shrimp culture, pond water was slightly acidic (pH 6.18 - 6.48) and salinity ranged from 16-17 ppt. Other parameters such as total ammonia nitrogen (TAN), unionized ammonia nitrogen, nitrite - N and COD ranged from 0.438 to 2.369 ppm, 0.0005 to 0.0057 ppm, 0.005 to 0.436 ppm and 16 to 40 ppm respectively. The values of phosphates and total P were 0.113 to 0.523 ppm and 0.251 to 0.802 ppm (Table 3). Water parameters were within safe permissible levels as indicated by Chen (1985), Law (1988) and Chen and Lei (1990).

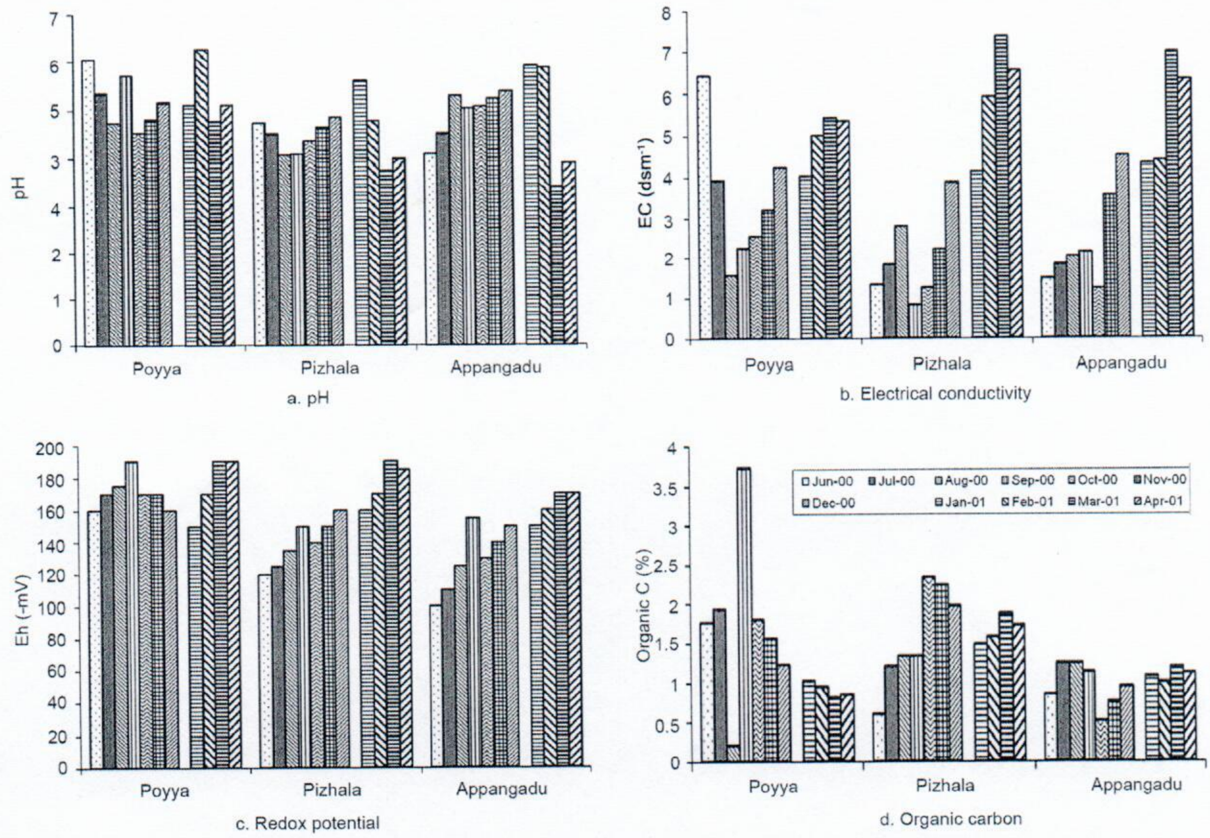

Fig. 1. Variation in soil parameters during traditional paddy and extensive shrimp cultures at different farming areas in Kerala.

During traditional paddy culture at Pizhala, soil organic carbon content was comparatively higher (0.621-2.349%) (Fig. 1d) and other soil parameters like EC (0.83-3.9 dS m^{-1}) (Fig. 1b) and redox potential (-120 to –160) (Fig. 1c) and water parameters such as salinity (1-7 ppt), ammonia (0.003-0.168 ppm) and nitrite (0.001-0.032 ppm) were comparatively less (Table 2). During extensive shrimp culture, soil pH was acidic (pH

Table 2. Soil and water characteristics of shrimp fields during traditional paddy culture

Soil parameters	Poyya		Pizhala		Appangad	
	Creek	Field	Creek	Field	Creek	Field
Eh (mV)	-95 to -120	-160 to -190	-80 to -130	-120 to -160	-80 to -120	-100 to -155
pH	3.43 - 6.22	4.55 - 6.05	4.26 - 5.2	4.08 - 4.87	3.65 - 5.03	4.1 - 5.36
EC (dS m^{-1})	1.07 - 4.87	1.58 - 6.41	0.7 - 3.65	0.83 - 3.9	1.24 - 3.94	1.24 - 4.52
Org. C (%)	0.273 - 3.72	0.22 - 3.74	0.78 - 1.947	0.621 - 2.349	0.405 - 0.783	0.519 - 1.248
Water parameters	**Poyya**		**Pizhala**		**Appangad**	
	Creek	Field	Creek	Field	Creek	Field
pH	6.05 - 6.73	6.1 - 6.91	6.33 - 6.74	6.23 - 6.81	6.52 - 6.7	6.5 - 6.98
Salinity (ppt)	1-17	4 - 12	3 - 11	1 - 7	3 - 10	5 - 10
TotalNH_3_N (ppm)	0.005 - 0.582	0.006 - 0.314	0.003 - 0.172	0.003 - 0.168	0.004 - 0.259	0.007 - 0.7
Unionized NH_3-N (ppm)	Nil-0.0025	Nil - 0.002	Nil - 0.0007	Nil - 0.0008	Nil - 0.001	Nil - 0.0053
NO_2-N (ppm)	0.002 - 0.031	0.001 - 0.031	0.001 - 0.032	0.001 - 0.032	0.001 - 0.019	0.005 - 0.024
COD (ppm)	7-24	7 - 40	14 - 34	12 - 30	5 - 60	7 - 75
PO_4-P (ppm)	0.005 - 0.085	0.008 - 0.067	0.018 - 0.178	0.008 - 0.181	0.025 - 0.125	0.035 - 0.15
Total P (ppm)	0.035 - 0.429	0.069 - 0.221	0.035 - 0.257	0.015 - 0.321	0.043 - 0.252	0.049 - 0.285

Table 3. Soil and water characteristics of shrimp fields during extensive shrimp culture

Soil Parameters	Poyya		Pizhala		Appangad	
	Creek	Field	Creek	Field	Creek	Field
Eh (mV)	-110 to-120	-150 to-190	-120 to-130	-160 to -190	-110 to-130	-150 to-170
pH	3.91-4.54	4.8-5.13	3.64-6.05	3.76-5.6	3.82-5.93	3.42-5.92
EC (dS m^{-1})	2.97-7.28	4.04-5.44	2.86-3.83	4.15-7.38	2.32-4.9	4.33-6.99
Org. C (%)	0.42-0.84	0.81-1.02	0.9-1.17	1.5-1.89	0.39-1.23	1.0-1.2
Water Parameters	**Poyya**		**Pizhala**		**Appangad**	
	Creek	Field	Creek	Field	Creek	Field
pH	6.36-6.54	6.18-6.48	6.27-6.35	6.37-6.5	6.5-6.6	6.33-6.49
Salinity (ppt)	15-18	16-17	13-14	15-16	17-18	15-19
Total NH_3-N (ppm)	0.424-1.744	0.438-2.369	0.276-0.3	0.27-0.35	0.194-0.439	0.103-0.31
Un-ionized NH_3 -N (ppm)	0.0007-0.0048	0.0005-0.0057	0.0004-0.0005	0.0005-0.0009	0.0005-0.0014	0.0001-0.0007
NO_2-N (ppm)	0.057-0.067	0.005-0.436	0.027-0.208	0.006-0.199	0.005-0.11	0.01-0.347
COD (ppm)	31-35	16-40	9-21	16-28	28-32	25-31
PO_4-P (ppm)	0.075-0.457	0.113-0.523	0.095-0.12	0.075-0.17	0.069-0.101	0.09-0.111
Total P (ppm)	0.234-2.019	0.251-0.802	0.163-0.253	0.19-0.25	0.159-0.25	0.156-0.25

3.76 to 5.6). Redox potential, EC and organic carbon ranged from –160 to –190 mV, 4.15 to 7.38 dS m^{-1} and 1.5 to 1.89% respectively. Water was slightly acidic (6.37- 6.5) and the salinity ranged between 15 and 16 ppt. Total ammonia nitrogen (TAN), unionized ammonia, nitrite - N and COD ranged from 0.27-0.35 ppm, 0.0005-0.0009 ppm, 0.006 to 0.199 ppm and 16-28 ppm, respectively (Fig. 2). The respective range of phosphate and total P were 0.075 to 0.17 ppm and 0.19 to 0.25 ppm (Table 3). There was no difference in soil pH, water pH, phosphates, total P and COD between the two cultures at Pizhala.

During traditional paddy culture and extensive shrimp culture at Appangad, there are no differences in soil parameters such as pH, redox potential, organic carbon content and water parameters like pH, phosphates and total P between both the cultures (Fig. 1 and 2). Electrical conductivity of soil (1.24 - 4.52 dS m^{-1}), salinity (5-10 ppt) and nitrite (0.005-0.024 ppm) in water were comparatively low during the traditional paddy culture period. However, ammonia (0.007-0.7 ppm) and COD (7-75 ppm) in water were comparatively high (Table 2). During extensive shrimp culture, soil pH and redox potential ranged from 3.42 to 5.92 (Fig. 1a) and –150 to –170 mV (Fig. 1c) and EC and organic carbon content were in the range of 4.33 to 6.99 dS m^{-1} (Fig. 1b) and 1.0 to 1.2% (Fig. 1d), respectively. Pond water salinity and pH ranged from 15-19 ppt and 6.33- 6.49 respectively. The respective range of other water quality parameters such as total ammonia nitrogen (TAN), unionized ammonia, nitrite - N and COD were 0.10-0.31 ppm, 0.0001-0.0007 ppm, 0.01 to 0.347 ppm and 25-31 ppm (Table 3).

Discussion

Studies on variation in soil and water characteristics during traditional paddy culture and extensive shrimp culture reveals that organic carbon content was higher during traditional paddy culture, whereas nitrogenous compounds such as ammonia and nitrite were higher during extensive shrimp culture, which could be attributed to the shrimp feed protein catabolism and subsequent nitrification.

Lethal concentrations for short-term exposure (24 to 72 h) range from 0.4-2.0 mg l^{-1} of unionized ammonia (Boyd, 1982), while the sub-lethal level ranges from 0.1 to 0.3 mg l^{-1} for aquatic organisms. Hence, free ammonia should be maintained below 0.05 mg l^{-1}. A high ambient level of unionized ammonia can affect osmoregulation and oxygen transport in the aquatic species and a sub-lethal ammonia level can cause pathological changes in different organs and the tissues of organisms. These nitrogenous metabolites increase blood pH, reduce the oxygen content in the blood, affect gills, create stress, resulting in reduced feeding and increased chances for incidence of viral disease. Therefore, the shrimp farming management practices regarding feeding and water quality should be optimized to reduce the effect of total ammonia, on the receiving environment (Porrello *et al.*, 2003).

Management of acid sulphate soil by physical and chemical methods

The pH of acid sulphate soil is a major limiting factor for taking up scientific shrimp farming in *pokkali* fields. This problem is more pronounced in all the three fields studied. In spite of acidic soil, shrimp production was

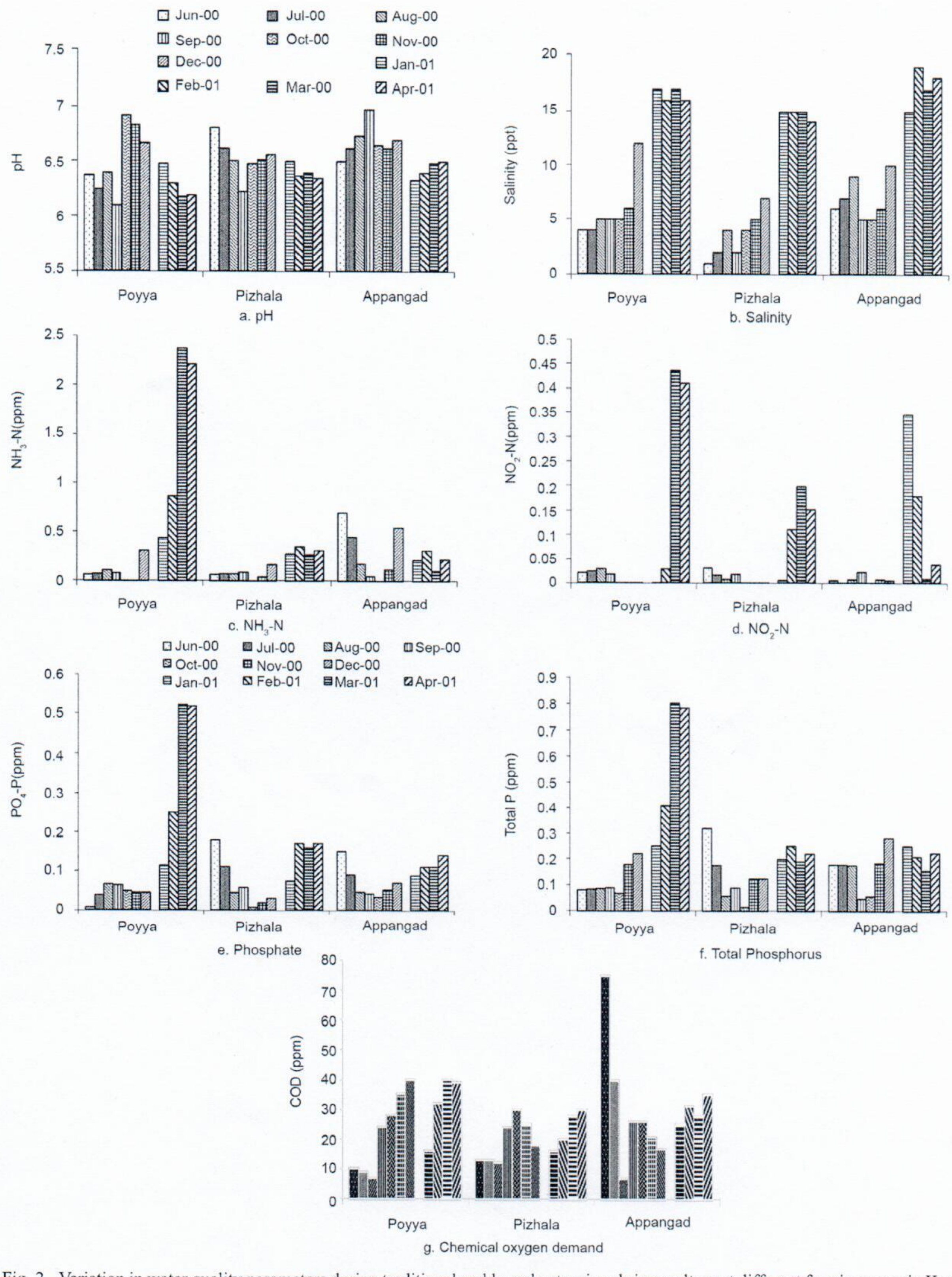

Fig. 2. Variation in water quality parameters during traditional paddy and extensive shrimp culture at different farming areas in Kerala

250 to 400 kg ha^{-1}, which may be due to better management of acidic soil and optimum and desirable ranges of soil and water quality parameters throughout the shrimp culture period. This problem can be further overcome by both physical and chemical methods. Repeated flushing of the fields after paddy harvest will mitigate the problem of acidity to some extent. Minimal or less disturbance of the soil at the time of field preparation, stocking, feeding and harvest will also ensure lesser severity of the effect of acidity. Chemical neutralisation of acid by calcite, dolomite, magnesite and slaked lime can be followed in such situations. Slaked lime may cause pH to overshoot, which may cause problems. As the neutralisation of the acid sulphate soil is too difficult or expensive, an alternate strategy is to allow the material to oxidise deliberately and to leach out the oxidation products. This is only recommended for coarse textured sands and gravels, which are relatively highly permeable to air and water and which contain relatively small amounts of pyrite. The time required for complete oxidation and leaching cannot be predicted since it depends on prevailing climatic conditions.

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