

## **Changes in phosphate fractions in prawn aquaculture system at different stages of cropping**

P. MUHAMED ASHRAF AND A.G. GOPALAKRISHNA PILLAI

*Central Institute of Fisheries Technology, Cochin 682 029, India*

### **ABSTRACT**

Studies were conducted to evaluate the flux of phosphate fractions in prawn aquaculture systems in one cropping season and its relation with water and sediment characteristics. The results from the samples of two scientific and one natural culture ponds revealed that there was no loosely bound P in all the three stages of cropping. Al bound P increased significantly at the harvest stage compared to initial stage. This was attributed mainly to readsorption of P on aluminium hydroxides. The utilisation of iron bound P was in the late juvenile stage and that of Ca bound P at the harvest stage. The inorganic P increased from juvenile to late juvenile stage and at harvest it recorded 22.5-36.7% decrease than the late juvenile stage. In the natural pond total P was reduced due to mineralisation of P. 50% of the organic bound P was mineralised in natural pond during initial to late juvenile stage whereas, organic P has only minor role in scientific systems.

### **Introduction**

Prawn aquaculture has a prominent role in India's export earnings. Recently, pollution due to aquaculture and its impact on environment has caused great concern. Microvegetation algae or phytoplankton constitute the major part of primary production. Phosphorus, nitrogen and light are responsible for primary production and organic phosphorus for controlling the rate of phytoplankton growth and biomass production (OECD, 1982). A major fraction of the P applied in ponds, is fixed due to its adsorption by sediments, the remaining being loosely bound soluble inorganic forms or organic deposition utilised by fish food viz., phytoplankton, macrophytes and bacteria (Boyd and

Musig, 1981).

It is assumed that Calcium bound P (Ca-P), the Fe (OOH) adsorbed pool and organic phosphates are present in lake sediments. Organic phosphates slowly get mineralized and become part of the inorganic bound pools. The distribution of P over Ca and Fe bound pools depends on pH, P concentration and the percent Fe (OOH) in sediments (Golterman, 1988). Phosphorus availability in sediments upon submergence depends on reduction of ferric compounds, organic transformations influencing release of phosphate ions from the exchange between organic anions and phosphate ions in Fe-P and Al-P compounds and increased P diffusion under submergence condition. This study aims to analyse the

flux of phosphorus in prawn aquaculture systems in one cropping season and its relation with water and sediment characteristics.

### Materials and methods

Three aquaculture farms were selected from Varapuzha village of Vypeen islands for this study. Among these, two ponds (S1 and S2) followed scientific methods of culture and the third, purely natural cropping (N1) for a period of 90 days. The ponds S1 and N1 are of one ha each and S2, 2 ha. The stocking density of *Penaeus monodon* in S1 and S2 is 30,000 per ha. About 1500 kg feed per farm was used in scientific ponds and the feeds used are Higashimaru's PL, Grower A and B and Starter B in different stages of growth. Urea and superphosphate was applied in both S1 and S2 ponds during pond preparation. In the natural system of cropping the sluice gate valves were opened during high tide allowing the prawns to enter the field. Here water exchange takes place with tidal variations. In the scientific culture, seeds were purchased from outside and stocked with supplementary feeds and other required inputs. Water exchange was carried out daily between 0.00 and 4.00 hrs. After harvest, fields were used for the traditional rice culture known as Pokkali culture.

Sediment and water samples were collected three times during the prawn culture; at the initial stage (juvenile), middle stage (late juvenile) and at the time of harvest. The soil samples were collected from five to six points, mixed thoroughly and divided into four portions and one portion selected for the study by quartering method. The sediments were air dried and lumps crushed by wooden hammer. Serial fractionation of P, total and inorganic P were analysed as per the

procedure of Hosomi *et al.* (1982), Shrestha and Kwei Lin (1996) and Ramanibhai and Bhavani (1997). The extractants were analysed for P by ascorbic acid method (APHA, 1980). Textural characteristics of sediments were analysed by pipette method (Day, 1965). Organic carbon was estimated by Walkley and Black method (Allison, 1965), pH by Jackson, (1973). Analysis of chemical characteristics of water like NO<sub>2</sub>-N, total N, salinity, pH, dissolved oxygen and turbidity were done as per Strickland and Parson (1972). Mechanical analysis of soil (S2) at harvest stage could not be carried out since the sample was lost. Statistical analysis of data for correlation and two-way anova was done using Excel available with Microsoft Office software.

### Results and discussion.

Sediment and water samples were collected from ponds S1, S2 and N1 during initial (juvenile), middle (late juvenile) and final (harvest) stages of cropping. The loosely bound P was less than detectable limits (<0.01ppm) in all the three stages. All added phosphates are adsorbed over clays, organic and inorganic complexes in the soil solution. The aluminium bound P at juvenile stage was 40, 58 and 104 ppm in S1, S2 and N1 respectively. The aluminium bound P decreased (about 35%) in the late juvenile stage in all the ponds compared to the juvenile stage (Fig. 1). At harvest there was a significant increase of A1-P i.e. 183, 180 and 226 ppm P in S1, S2 and N1 respectively. On examining the water P concentration, which was nil initially shot up to a maximum at late juvenile and decreased at harvest (Fig. 2). This indicated the readsorption of P that occurred on clays and aluminium hydroxides (Ponnamperuma, 1985) at harvest. According to Ponnamperuma (1985) flooding a soil increased soluble P concentration in the soil that reaches a

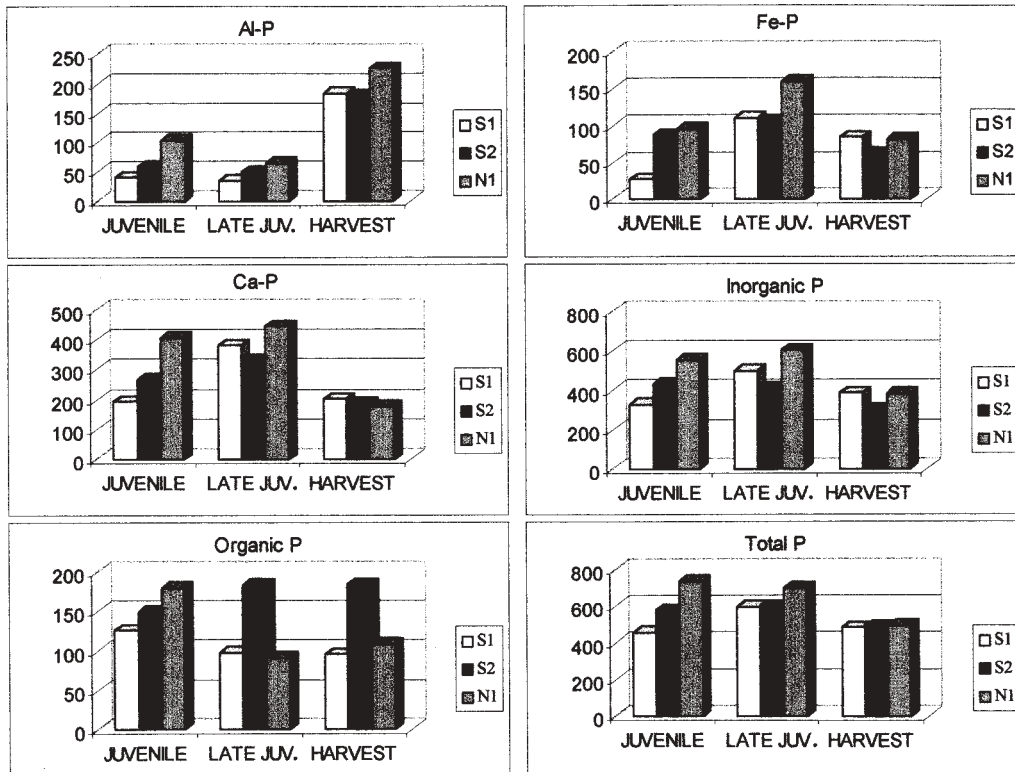


Fig. 1. P fractions in ppm in sediments at different stages of cropping

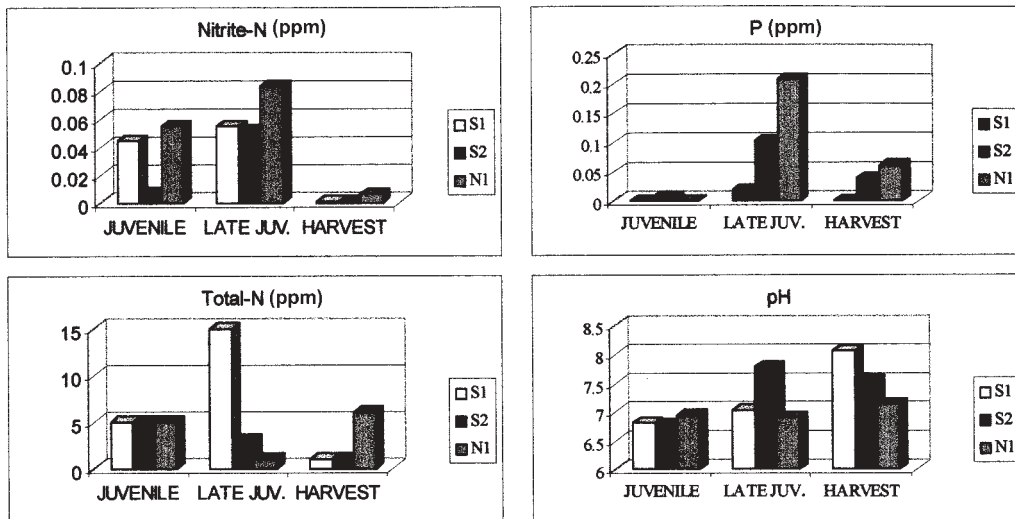


Fig. 2. Variation of NO<sub>2</sub>-N, Total-N, P and pH at different stages of cropping

maximum before falling. The subsequent falling of P concentration after reaching

a peak has been attributed to readsorption of P on clays and aluminium

TABLE 1. The ratio of organic carbon: organic P at different stages of cropping.

Pond	Initial	Late juvenile	Harvest
S1	453.9	601.0	348.1
S2	458.5	222.8	326.6
N1	358.0	331.0	397.1

hydroxides. The reduction in clay content from late juvenile (9.56%) to harvest (4.13%) stage may be contributed to the maximum adsorption of P by aluminium. P resorption may also be influenced by microbial degradation of organic anions at the exchange sites. (Tian-ren *et al.*, 1989).

The Fe bound P fraction, the easily available form, was 27, 87 and 95 ppm in S1, S2 and N1 respectively at the initial stage, which increased to a maximum (105 (S1), 110 (S2) and 159 (N1) ppm P) at the late juvenile stage. At harvest it

was reduced to the initial level (61-84 ppm P). The probable mechanism is, on prolonged flooding ferrous ferric hydroxide ( $Fe_3(OH)_8$ ) precipitation takes place (Ponnampereuma *et al* 1967) in the soil which has not only a large surface area with high sorption capacity but also it is labile and easily available to the plants and other organisms (Holford and Patric, 1979). Comparing the soil pH and Fe bound P, the former turned acidic in the late juvenile stage and the latter enhanced significantly. Here the suggested mechanism is the reduction of

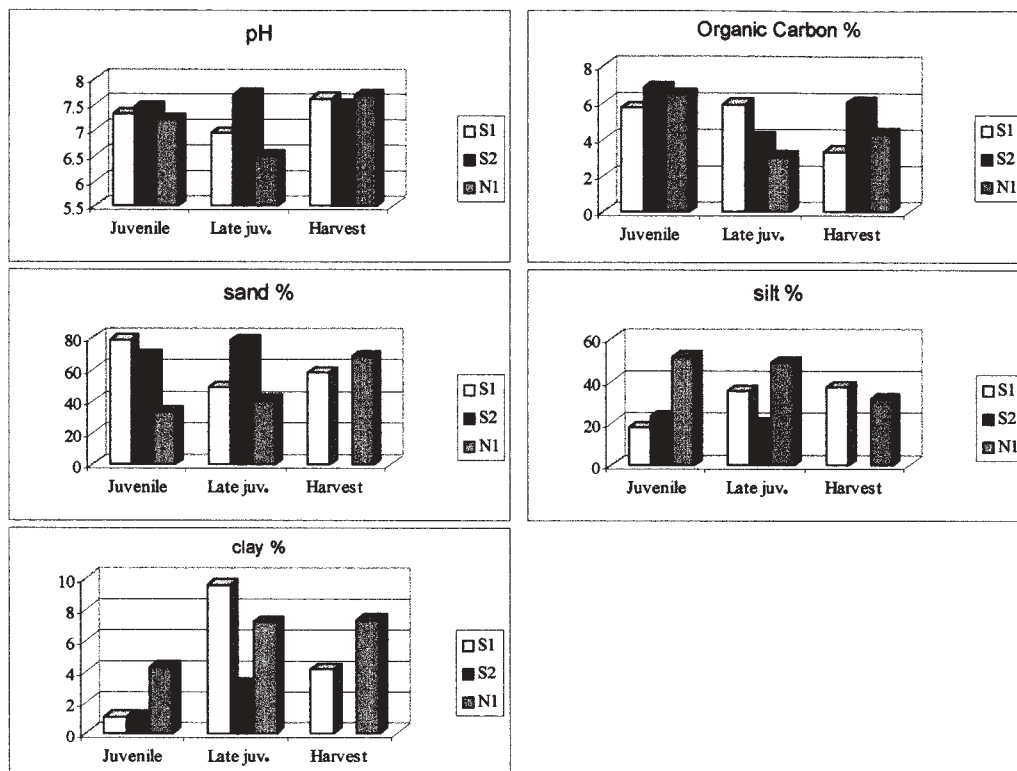


Fig. 3. Chemical and physical characteristics of sediment at different stages of cropping

TABLE 2. Correlation between P fractions and soil parameters during juvenile stage

	Al-P	Fe-P	Ca-P	In-P	Total P	Org. P	pH	Org.C	Sand	Silt	Clay	Water P
Al-P	1											
Fe-P	0.7925	1										
Ca-P	0.9979	0.8303	1									
In-P	0.9830	0.8909	0.9928	1								
Total P	0.9842	0.8879	0.9935	0.9999	1							
Org. P	0.9886	0.8750	0.9963	0.9994	0.9996	1						
pH	-0.6212	-0.0144	-0.5692	-0.4669	-0.4727	-0.4966	1					
Org.C	0.4508	0.9016	0.5076	0.6069	0.6017	0.5796	0.4193	1				
Sand	-0.9967	-0.7408	-0.9894	-0.9650	-0.9667	-0.9734	0.6822	-0.3775	1			
Silt	0.9904	0.7007	0.9794	0.9483	0.9503	0.9585	-0.7234	0.3233	-0.9983	1		
Clay	0.9600	0.5901	0.9399	0.8924	0.8953	0.9071	-0.8157	0.1830	-0.9794	0.9894	1	
Water P	-0.2402	0.4015	-0.1770	-0.0581	-0.0646	-0.0919	0.9099	0.7581	0.3176	-0.3719	-0.5023	1

TABLE 3. Correlation between P fractions and soil parameters during late juvenile stage

	Al-P	Fe-P	Ca-P	In-P	Total P	Org. P	pH	Org.C %	Sand	Silt	Clay	Water P
Al-P	1											
Fe-P	0.8180	1										
Ca-P	0.5307	0.9216	1									
In-P	0.5484	0.9295	0.9997	1								
Total P	0.8618	0.9967	0.8872	0.8967	1							
Org. P	-0.0511	-0.6162	-0.8735	-0.8631	-0.5505	1						
pH	-0.3613	-0.8318	-0.9820	-0.9778	-0.7842	0.9497	1					
Org.C %	-0.9911	-0.7343	-0.4134	-0.4324	-0.7867	-0.0820	0.2341	1				
Sand	-0.1781	-0.7116	-0.9284	-0.9205	-0.6525	0.9918	0.9818	0.0457	1			
Silt	0.4511	0.8823	0.9958	0.9936	0.8414	-0.9143	-0.9951	-0.3285	-0.9585	1		
Clay	-0.3774	0.2238	0.5844	0.5673	0.1443	-0.9055	-0.7271	0.4971	-0.8440	0.6561	1	
Water P	0.9967	0.8616	0.5972	0.6138	0.8998	-0.1312	-0.4351	-0.9772	-0.2566	0.5214	-0.3017	1

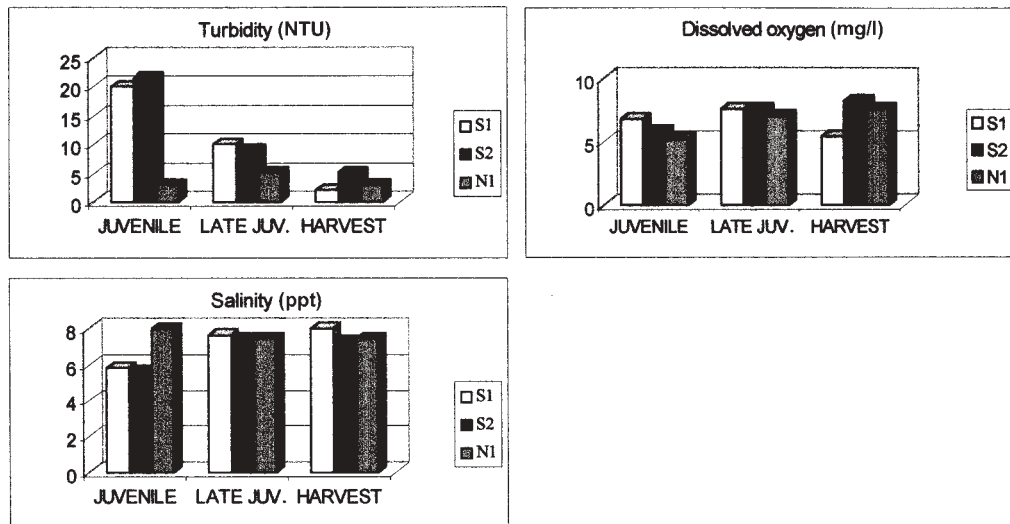


Fig. 4. Variation of salinity, turbidity and DO at different stages of cropping

free hydrous iron oxides and liberation of sorbed and coprecipitated P in flooded acidic soil (Willet, 1986). The reduction of P at harvest stage due to the increased pH, which decreases the positive surface charge of clay and ferric oxide, favoured the desorption of Fe bound P from excess ferric oxide surfaces. The solubility of  $\text{FePO}_4 \cdot 2\text{H}_2\text{O}$  through hydrolysis was also enhanced due to increased pH.

The calcium bound P was higher in N1 compared to S1 and S2 initially, i.e. 192, 265 and 405 ppm P in S1, S2 and N1 respectively. Calcium bound P was enhanced in the late juvenile stage of by about 97% and 23% in S1 and S2 respectively whereas, in N1 it was only 9%. There was a drastic reduction of Ca-P during final stage i.e. 47.0, 43.7 and 60.0% respectively in S1, S2 and N1. The solubilities of Ca bound P increased under flooded condition which may be due to the organic acids released during anaerobic decomposition (Tsutsuki and Ponnampurna, 1987) and complex formation by  $\text{Ca}^{2+}$  ions which disturbs the solubility equilibria of Ca-P (Willet, 1986). There is a significant positive

correlation of Ca-P with silt (+0.93 to +1.0) (Table 2,3 and 4) in all the three stages which indicate that the latter has an important role in the adsorption and desorption of Ca-P in aquaculture sediments. Considering the correlation with pH and clay, the former was negatively correlated during juvenile (-0.57) (Table. 2) and late juvenile stage (-0.98) (Table 3) and the latter had a significant positive association initially (+0.94) but at harvest it recorded perfect negative association (-1.0) (Table 4). According to Golterman and De Oude (1991) the distribution of phosphate over the Ca and Fe bound pools depend on pH, phosphate concentration and the percent Fe (OOH) in sediments.

The level of inorganic P comprising of loosely bound P, Ca-P, Fe-P, Al-P etc. was 328, 429 and 553 ppm respectively in S1, S2 and N1 at the initial stage. A significant increase of inorganic P ( $p < 0.05$ ) was observed at late juvenile stage except at S2 where there was a slight decrease. At harvest the inorganic P got reduced to 22.5, 26.8 and 36.7% in S1, S2 and N1 respectively compared to

TABLE 4. Correlation between P fractions and soil parameters during harvest stage

	Al -P	Fe-P	Ca-P	In-P	Total P	Org. P	pH	Org.C %	Sand	Silt	Clay	Water P
Al -P	1											
Fe-P	0.4320	1										
Ca-P	-0.7291	0.3021	1									
In-P	0.5437	0.9918	0.1778	1								
Total P	0.7498	-0.2727	-0.9995	-0.1475	1							
Org. P	-0.4344	-1	-0.2996	-0.9921	0.2701	1						
pH	0.8088	0.8797	-0.1874	0.9332	0.2175	-0.8810	1					
Org.C %	-0.2164	-0.9739	-0.5102	-0.9370	0.4835	0.9733	-0.7491	1				
Sand	1	-1	-1	-1	1	1	1	1	1			
Silt	-1	1	1	1	-1	-1	-1	-1	-1	1		
Clay	1	-1	-1	-1	1	1	1	1	1	-1	1	
Water P	0.7237	-0.3097	-0.9999	-0.1856	0.9992	0.3071	0.17961	0.5170	1	-1	1	1

late juvenile stage. Comparing the juvenile and harvest stage there was a drastic reduction of inorganic P except in S1, where there was an increase during harvest stage. Inorganic phosphorus accumulated in sediments through sedimentary P adsorption. Increased P buffer capacity during late juvenile stage is attributed to P adsorption from soil solutions by the precipitated and poorly crystalline ferrous hydroxides or carbonated  $Fe^{2+}$  ions formed by soil reduction. (Tian - ren *et al.*, 1989).

The total P comprises of inorganic P and organic P that varied between 454 - 733 ppm during initial stages. There was an increase of total P at the late juvenile stage in scientific ponds in contrast to a slight decrease in natural system as there was no nutrient addition. At the harvest stage there was a considerable decrease of total P with respect to late juvenile stage that implies the heavy nutrient demand and its utilisation at this stage.

Organic bound P is the difference between total P and inorganic P (Sanyal and DeDutta, 1991). Organic bound P varied irregularly in the scientific ponds. In natural system about 50% reduction was observed at late juvenile stages compared to the initial and a slight increase at the harvest stage. The major form of organic phosphate accumulation in sediment is ionositol phosphate comprising of hexakis and pentakis phosphates (up to 60%), nucleic acids and phospholipids (Anderson, 1980). In flooded soil mineralisation of organic P has been considered as a major source of P (Uwasawa *et al.*, 1988a) except in flooded organic soil (Uwasawa *et al.*, 1988b). The data revealed that Organic P played a minor role by mineralisation in scientific systems but in natural system there was a drastic reduction of organic bound P and organic carbon

content. This agrees with the findings of Uwasawa *et al.* (1988b).

The ratio organic carbon to organic P is given in table 1. In the scientific system the average ratio was 456 at juvenile stage and it was reduced to 337 at the harvest stage which implies that mineralisation of organic P has taken place even though the change was irregular in late juvenile phase. In the natural system the trend was reverse where the mineralisation occurred at juvenile to late juvenile stage and there is an immobilisation of organic P which has taken place due to high organic matter.

The soil mechanical analysis data are depicted in fig 2. In the N1 pond, sand and clay content were low during initial stages, which got doubled at the harvest stage, whereas, silt reduced to about 40% at the harvest compared to the initial stages. In S1 there was a reduction in sand content, whereas silt and clay content were enhanced. This may be attributed to the disturbance on the soil surface by continuous water exchange.

#### *Water Parameters.*

Phosphate concentration in water was almost nil at the juvenile stages, increased significantly at the late juvenile stage and got reduced to 0-0.06 ppm at the harvest stage (Fig. 3). Compared to the juvenile, the increase in the late juvenile stage was almost 200 times in the natural pond, but it was 18 and 95.5% in S1 and S2 respectively. According to Vallentyne (1974) the demand of P by phytoplankton in lakes is 800 ppm and the supply from water is 0.01 ppm. Phytoplankton effectively utilised the water P. It is possible that the process of phosphate assimilation, adsorption by suspended inorganic matter and flocculation process due to the salinity

change induce a sedimentary storage of phosphates leading to relatively low dissolved concentration in the pond (Elisabete *et al.*, 2000). According to Boyd (1992) P in mud is released in large amounts to the water when iron and aluminium phosphates dissociate under reducing conditions in the hypolimnion of ponds. Total nitrogen is 5 ppm in all the ponds initially, enhanced to 15, 3 and 10 ppm during late juvenile stages in S1, S2 and N1 respectively and at harvest it came down heavily in scientific ponds. In the natural pond it was 6 ppm. Nitrogen fertilisers normally are not adsorbed into soil; large quantities will leach into water. The unused N will undergo denitrification and thereby volatilizes to the atmosphere. The nitrogen availability in the pond ecosystem is bound in living organisms and decaying organic matter. From juvenile to late juvenile stage the consumption of phytoplankton by prawn is less compared to harvest stage.

Salinity at the initial stage was 5.81 (S<sub>1</sub>) and 5.6 ppt (S<sub>2</sub>) in scientific ponds and 7.97 in the natural environment (Fig. 4). During late juvenile and harvest stages it was 7.40 to 7.97 ppt in all the cases. Dissolved oxygen and pH were initially 5.2-6.8 mg/l and 6.7-6.9 respectively. The dissolved oxygen enhanced in the late juvenile stages and varied during the harvest stage. Similar was the case with pH. Turbidity in S2 pond was very high initially where red tides were affected. In the late juvenile stage it was 10 and 9 NTU in S1 and S2 respectively and 5.0 in N1. At the end of the season all the ponds were in normal stage.

The study reveals that the availability of different forms of P in soil solution in an aquaculture system depend on pH, organic matter, clay, silt etc. The less available aluminium bound P



increased at harvest stage and effective utilisation of Fe bound P occurred during late juvenile stage. The Ca bound P and organic P played an important role during harvest stage. The dynamics of soil P influenced the availability of P in water at different stages of cropping. The biological productivity in scientific ponds is mainly by utilizing inorganic bound phosphorus, whereas, in natural pond it was mainly through mineralisation of organic matter.

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