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STUDIES ON SEASONAL VARIATIONS IN PRIMARY PRODUCTIVITY AND RELATED WATER QUALITY PARAMETERS IN FRESHWATER FISH PONDS IN COASTAL ANDHRA PRADESH, INDIA

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ABSTRACT The present study was designed to demonstrate the seasonal variations in physico-chemical parameters in fish ponds and carried out for one year at monthly intervals in ten fish ponds. Maximum value of Gross Primary Production (GPP) and Net Primary Production (NPP) is observed during pre-monsoon and subsequently the lower values during monsoon season correspond to the attenuation of light. A significant variation in seasonal community respiration was noticed during the study period. Seasonal fluctuations in gross and net primary production values were quite apparent in surface waters and showed a bimodal type of distribution. The values were generally high during post winter months (March to June) and low during winter (January) and monsoon months (July and August). The dissolved oxygen content and chlorophyll-a were correlated with increase in temperature and light transparency during the pre-monsoon period whereas the phosphate concentrations were measured maximum in monsoon followed by pre-monsoon and post-monsoon suggested the accumulation of inorganic nutrients through terrestrial catchments.

KEYWORDS : Gross primary production; Net primary production; Community respiration; chlorophyll –a; phosphate, Dissolved oxygen; Temperature.

INTRODUCTION:

Primary productivity is functionally related to organic matter which is created by producers in an ecosystem wherein low energy inorganic carbon is converted to high energy organic carbon through carbon fixation and forms the basis for metabolic cycle in a pond ecosystem under the influence of phytoplankton populations [1]. Primary productivity is a potential index of energy equilibrium in tropical and subtropical ecosystems as considered as an important parameter for understanding water quality [2]. Chlorophyll bearing phytoplankton (primary producers) that fix the energy of the sunlight while driving the flow of energy to the higher tropic level, provide the basic information for assessing the productive function of the system [3]. Environmental factors such as light and nutrient cycles which primarily influence the rate of photosynthesis and determine primary productivity are subjected to seasonal and climatological fluctuations due to variations in growth of phytoplankton populations [4,5].

Phytoplankton populations and their subsequent photosynthetic productivity will fluctuate due to a number of factors, most of which are part of seasonal changes [5,6]. reported that the seasonal variation in primary production in relation to limnological features. There is a correlation between the standing crop of phytoplankton (chlorophyll content) and primary production [7-9].The exogenous factors such as light penetration, density of plankton and temperature in ecosystem are the factors that influence the primary productivity [10]. Addition of nutrients like carbon and nitrogen might greatly stimulate the rate of phytoplankton multiplication, this cannot go beyond to the extent of carrying capacity of the ecosystem as the limit set is also dependent on available phosphates. Phytoplankton are the major source of dissolved oxygen in fish ponds as well as - directly as consumers and indirectly as the source of detritus upon which most bacterial respiration is based - the major sink for oxygen [11-13]. The present study was designed to demonstrate the seasonal variations in physico-chemical parameters of fish ponds, carried out for one year at monthly intervals in ten ponds to reveal favourable season and factors affecting on it.

MATERIALS AND METHODS :

Water samples were collected from ten fish culture ponds for a period of twelve months during January to December, 2016 in Krishna district (16.4410° N, 80.9926° E), Andhra Pradesh, India wherein culture of Indian major carps (*Labeo rohita and Catla catla*) and striped catfish (*Pangasianodon hypophthalmus*) are predominantly carried out. All ponds measured with an average size of 2.92 hectares with a range of depth from 1.5 to 3 mt. Different quantities of fertilizers and manures are applied during fish grow-out practice. Water samples were taken from each pond using PVC tube with inner diameter of 5.8 cm at five locations following [13]). Physico-chemical parameters such as dissolved oxygen (DO) in the samples was fixed and analyzed according to the modified methodology of Winkler [14], Iodometric titration by Carrit and Carpenter [15] . Temperature was measured using a handheld thermometer (range 0- 50°C) and Phosphorus (PO_4^{3-}) was analyzed on filtered samples following the standard spectrophotometric procedures [16]. The analytical precision is expressed as standard deviation ±0.07%.

Acetone extraction method of Parsons et al. [17] was followed for determining chlorophyll-a. A known volume of water sample was filtered through Whatman GF/F paper. Chlorophil-a on the filters was first extracted with 90% acetone, at 4°C in dark for 24 h, and then the pigment concentration was measured using a Shimadzu spectrophotometer (Model - UV 1700, Shimadzu) at different wave lengths 750, 664, 647 and 630 nm. The extinction was corrected for a small turbidity blank by subtracting the 750 nm from the 664, 647 and 630 nm.

Rate of primary production in fish ponds was estimated at the surface level by *in situ* incubation of water samples in light and dark bottles [18,19] with an incubation period of 3 hours. The principle of this method is that the amount of CO_2 consumed in carbon assimilation is proportional to the oxygen liberated by plants, so that the amount of carbon assimilated can be calculated from the amount of oxygen produced. Oxygen in the initial bottle was estimated immediately and the light and dark bottles were incubated for three hours, and after that, oxygen was determined by Winkler's method [20, 21] . Gross primary productivity is calculated from the difference of dissolved oxygen in the light bottle and the initial bottle per duration of exposure. The productivity obtained is converted to gC/m^3/hr by multiplying with 0.375.

RESULTS AND DISCUSSION

Data recorded in various experimental stations during pre-monsoon (March-June), monsoon (July to October) and post-monsoon (November to February) seasons are computed as arithmetic mean values of Gross Primary Production (GPP), Net Primary Production (NPP), Community respiration (CR) are presented in Tables 1- 6. Minimum GPP values of 0.06 g C/m^3/hr were recorded in ponds 4, 9 during the month of July and maximum values of 0.17g C/m^3/hr were observed in pond 6 in the month of March with an average value of 0.11 g C/m^3/hr (Table 1). The least mean values during pre-monsoon, monsoon and post-monsoon were 0.115±0.00577, 0.075±0.01732 and 0.09±0.00816 (mean ± SD) as against maximum mean values of 0.1475±0.02217, 0.1075±0.00957 and 0.125±0.01291 correspondingly. Significant variations were observed between seasons and ponds (Table 2; Fig 1).

Table 1. Monthly Gross primary production from Jan to Dec in various experimental ponds

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pond1	0.11	0.12	0.15	0.16	0.14	0.13	0.09	0.09	0.09	0.10	0.11	0.12
Pond2	0.12	0.12	0.14	0.15	0.13	0.11	0.08	0.09	0.08	0.09	0.10	0.11
Pond3	0.10	0.11	0.12	0.12	0.15	0.13	0.09	0.09	0.08	0.09	0.11	0.12
Pond4	0.08	0.09	0.11	0.12	0.12	0.11	0.06	0.07	0.07	0.09	0.09	0.10
Pond5	0.10	0.11	0.14	0.15	0.15	0.12	0.09	0.08	0.09	0.10	0.11	0.12
Pond6	0.13	0.14	0.17	0.16	0.14	0.12	0.11	0.10	0.10	0.12	0.11	0.12
Pond7	0.10	0.10	0.13	0.15	0.12	0.13	0.08	0.07	0.09	0.11	0.12	0.12
Pond8	0.11	0.12	0.12	0.15	0.15	0.13	0.10	0.09	0.10	0.08	0.11	0.12
Pond9	0.10	0.11	0.13	0.14	0.13	0.12	0.06	0.10	0.07	0.07	0.11	0.10
Pond10	0.11	0.12	0.14	0.14	0.13	0.13	0.09	0.09	0.09	0.10	0.11	0.12

Table 2 : Seasonal Gross primary production in various experimental ponds.

S. No	Pre-monsoon (March-June)	Monsoon (July to October)	Post-monsoon (November to February)
Pond1	0.145±0.01291	0.0925±0.00500	0.115±0.00577
Pond2	0.1325±0.01708	0.085±0.00577	0.1125±0.00957
Pond3	0.13±0.01414	0.0875±0.00500	0.11±0.00816
Pond4	0.115±0.00577	0.0725±0.01258	0.09±0.00816
Pond5	0.14±0.01414	0.09±0.00816	0.11±0.00816
Pond6	0.1475±0.02217	0.1075±0.00957	0.125±0.01291
Pond7	0.1325±0.01258	0.0875±0.01708	0.11±0.01155
Pond8	0.1375±0.01500	0.0925±0.00957	0.115±0.00577
Pond9	0.13±0.00816	0.075±0.01732	0.105±0.00577
Pond10	0.135±0.00577	0.0925±0.00500	0.115±0.00577

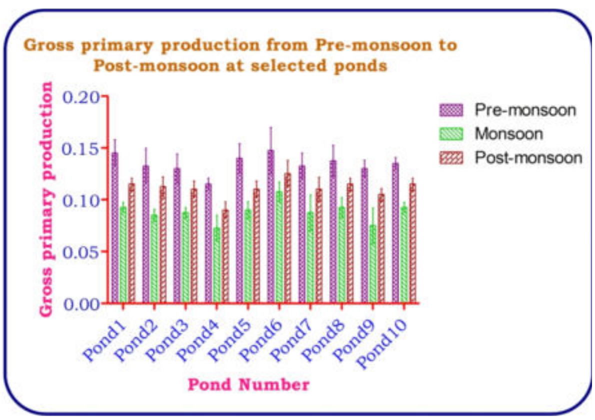

Figure 1: Histogram shows the variation in GPP between the seasons and ponds

The Net Primary Productivity (NPP) values ranged from 0.04 g C/m^3/hr at ponds 4, 9 in the month of July, pond 7 in the month of August, pond 4 in the month of September, pond 2 in the month October to 0.12g C/m^3/hr at pond 6 in the month of April, with an average value of 0.07 g C/m^3/hr were observed. The least mean values during pre-monsoon, monsoon and post-monsoon were 0.06±0.00816, 0.0475±0.00957 and 0.06±0.00816and maximum mean values were reported during pre-monsoon, monsoon and post-monsoon 0.0975±0.01708, 0.0775±0.00500 and 0.0925±0.01708 respectively. However, there were significant variations observed between seasons and ponds (Table 4 and represented in Fig 2).

Table 3: Net primary production from January to December at selected ponds

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pond1	0.08	0.09	0.09	0.08	0.08	0.09	0.07	0.08	0.08	0.08	0.07	0.09
Pond2	0.06	0.08	0.07	0.08	0.09	0.09	0.06	0.05	0.05	0.04	0.07	0.08
Pond3	0.08	0.08	0.07	0.06	0.08	0.10	0.07	0.06	0.06	0.07	0.07	0.08
Pond4	0.06	0.05	0.06	0.07	0.06	0.05	0.04	0.05	0.04	0.06	0.07	0.06
Pond5	0.06	0.07	0.08	0.05	0.06	0.07	0.05	0.05	0.05	0.06	0.07	0.08
Pond6	0.10	0.11	0.10	0.12	0.08	0.09	0.06	0.07	0.06	0.08	0.07	0.09
Pond7	0.08	0.08	0.09	0.08	0.08	0.09	0.05	0.04	0.06	0.07	0.07	0.09
Pond8	0.08	0.09	0.09	0.08	0.08	0.09	0.07	0.08	0.08	0.08	0.07	0.09
Pond9	0.07	0.08	0.09	0.08	0.07	0.06	0.04	0.07	0.06	0.05	0.07	0.07
Pond10	0.06	0.07	0.09	0.08	0.08	0.09	0.07	0.06	0.05	0.07	0.07	0.09

Table 4 Net primary production from Pre-monsoon, monsoon and post-monsoon at selected ponds

S. No	Pre-monsoon (March-June)	Monsoon (July to October)	Post-monsoon (November to February)
Pond1	0.085±0.00577	0.05±0.00816	0.0825±0.00957
Pond2	0.0825±0.00957	0.065±0.00577	0.0725±0.00957
Pond3	0.0775±0.01708	0.0475±0.00957	0.0775±0.00500
Pond4	0.06±0.00816	0.0525±0.00500	0.06±0.00816
Pond5	0.065±0.01291	0.0675±0.00957	0.07±0.00816
Pond6	0.0975±0.01708	0.055±0.01291	0.0925±0.01708
Pond7	0.085±0.00577	0.0775±0.00500	0.08±0.00816
Pond8	0.085±0.00577	0.055±0.01291	0.0825±0.00957
Pond9	0.075±0.01291	0.0625±0.00957	0.0725±0.00500
Pond10	0.085±0.00577	0.05±0.00816	0.0725±0.01258

*Each value is represented as mean ± SD (n=4).

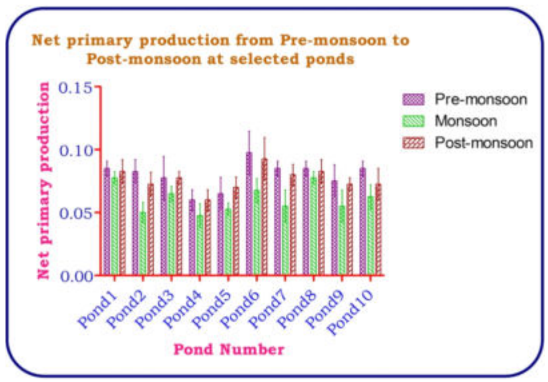

Figure 2: Histogram shows the variation in NPP between the seasons and ponds

The community respiration (CR) value is the difference of Grass primary productivity and Net primary productivity obtained and is varied between 0 g C/m^3/hr at pond 8 in the month of October to 0.10 g C/m^3/hr at the pond 5 in the month of April, with an average value of 0.04 g C/m^3/hr were recorded. In the present investigation net and gross ratio are calculated as minimum 0.33 at pond 5 in the month of April and maximum 1.0 at pond8 in the month of October.

The least mean values during pre-monsoon, monsoon and post-monsoon were 0.0475±0.01500, 0.015±0.00577 and 0.03±0.01155and maximum mean values were reported during pre-monsoon, monsoon and post-monsoon 0.075±0.02380, 0.04±0.00816 and 0.0425±0.00957 respectively. However, there were significant variations observed between seasons and ponds (Table 6 and represented in Fig 3).

Table 5 Community respiration from January to December at selected ponds

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pond1	0.03	0.03	0.06	0.08	0.06	0.04	0.02	0.01	0.01	0.02	0.04	0.03
Pond2	0.06	0.04	0.07	0.07	0.04	0.02	0.02	0.04	0.03	0.05	0.03	0.03
Pond3	0.02	0.03	0.05	0.06	0.07	0.03	0.02	0.03	0.02	0.02	0.04	0.04
Pond4	0.02	0.04	0.05	0.05	0.06	0.06	0.02	0.02	0.03	0.03	0.02	0.04
Pond5	0.04	0.04	0.06	0.10	0.09	0.05	0.04	0.03	0.04	0.04	0.04	0.04
Pond6	0.03	0.03	0.07	0.04	0.06	0.03	0.05	0.03	0.04	0.04	0.04	0.03
Pond7	0.02	0.02	0.04	0.07	0.04	0.04	0.03	0.03	0.03	0.04	0.05	0.03
Pond8	0.03	0.03	0.03	0.07	0.07	0.04	0.03	0.01	0.02	0.00	0.04	0.03
Pond9	0.03	0.03	0.04	0.06	0.06	0.06	0.02	0.03	0.01	0.02	0.04	0.03
Pond10	0.05	0.05	0.05	0.06	0.05	0.04	0.02	0.03	0.04	0.03	0.04	0.03

Table 6 Community respiration from Pre-monsoon, monsoon and post-monsoon at selected ponds

S. No	Pre-monsoon (March-June)	Monsoon (July to October)	Post-monsoon (November to February)
Pond1	0.06±0.01633	0.015±0.00577	0.0325±0.00500
Pond2	0.05±0.02449	0.035±0.01291	0.04±0.01414
Pond3	0.0525±0.01708	0.0225±0.00500	0.0325±0.00957
Pond4	0.055±0.00577	0.025±0.00577	0.03±0.01155
Pond5	0.075±0.02380	0.0375±0.00500	0.04±0.00000
Pond6	0.05±0.01826	0.04±0.00816	0.0325±0.00500
Pond7	0.0475±0.01500	0.0325±0.00500	0.03±0.01414
Pond8	0.0525±0.02062	0.015±0.01291	0.0325±0.00500
Pond9	0.055±0.01000	0.02±0.00816	0.0325±0.00500
Pond10	0.05±0.00816	0.03±0.00816	0.0425±0.00957

*Each value is represented as mean ± SD (n=4).

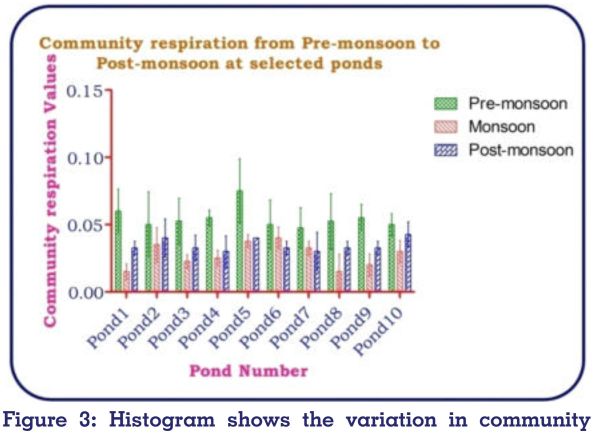

Figure 3: Histogram shows the variation in community respiration between the seasons and ponds

GPP increasing though rainy to summer and low in rainy, NPP increasing towards rainy and winter but low in rainy season. C/R decreased in rainy and increased in summer and winter. Seasonal fluctuations in gross and net primary production values were quite apparent in surface waters and showed a bimodal type of distribution. The values were generally high during post winter months (March to June) and low during winter (January) and monsoon months (July and August). A close relationship was found between the transparency and primary production values. Primary production revealed positive relationship between water temperature and chlorophyll-a. High production was observed when temperatures ranged from 27–33° C by Kharti [6].

Seasonally, the minimum GPP was recorded in monsoon and maximum GPP during summer. On monthly basis minimum value was observed in July and maximum in April. The higher value of GPP and NPP respectively during summer may be due to penetration of more light into water body [22].

Community respiration (CR) means deducting the net primary productivity from gross primary productivity and converted into carbon dioxide release. CR values were higher in Pre monsoon season that enhance the biological activities of microbes especially in summer due to decomposition of organic matter. Radwan [23] reported maximum primary productivity in pre monsoon season and lower in post monsoon and monsoon.

Variations in water temperature in the ponds examined at the time of primary production determinations. Overall water temperature ranged from 24.20°C at pond1in the month of January to 32.90°C at ponds 4, 5, 8 in the month of June. Average water temperature is 28.89 °C. The least mean values during pre-monsoon, monsoon and post-monsoon were 31.00 ±1.324, 28.20 ±0.952 and 25.45 ±1.085and maximum mean values were reported during pre-monsoon, monsoon and post-monsoon 31.65 ±1.559, 30.13 ±1.384 and 26.65 ±1.085 respectively. However, there were significant variations observed between seasons and ponds.

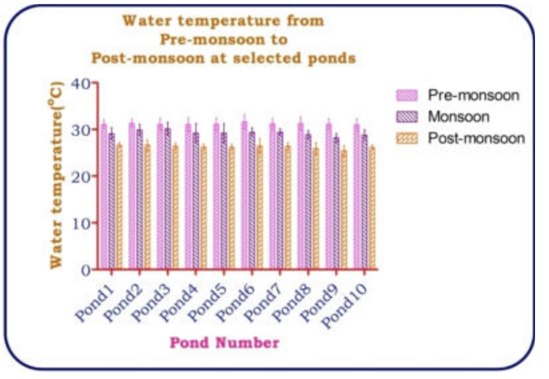

Figure 4: Histogram shows the variation in water temperature between the seasons and ponds

In the present study temperature was observed to be maximum during June, the summer season and minimum during January, the post monsoon season in all the ponds. Similar temperature pattern was observed in many water bodies [24, 25]. In shallow ponds the temperature is usually dependent on the air temperature, and such dependent changes have been reported in Nagchoon pond, Madhya Pradesh [26] The mean air and water temperature values are generally high during summer season, and such seasonally changes have been recorded by Prakash et al. [27].

The other important parameter in water quality variables is dissolved oxygen (DO) useful for assessment and reflects the physical and biological processes prevailing in the aquatic ecosystem. Tamot et al [28] reported that DO concentration in water was primarily dependent upon temperature, dissolved salts, wind velocity, pollution load, photosynthetic activity and respiration rate. The variation in dissolved oxygen during the study period from January to December is observed (fig.5)

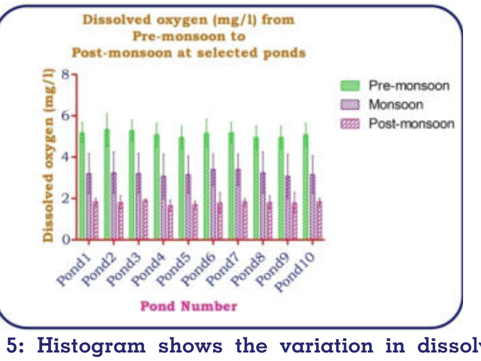

Figure 5: Histogram shows the variation in dissolved oxygen between the seasons and ponds

The dissolved oxygen ranged from 1.3 mg/l at pond 4 in the month of January, pond 6 in the month December to 6.30 mg/l at pond 2 in the month of June. Overall average dissolved oxygen is 3.37 mg/l. The least values of mean values during pre-monsoon, monsoon and post-monsoon were 4.95 ±0.551, 3.08 ±1.072 and 1.65 ±0.265 and maximum values of mean values during pre-monsoon, monsoon and post-monsoon were 5.33 ±0.780, 3.40 ±0.753 and 1.90 ±0.082 respectively. Dissolved oxygen is the most important chemical parameter in aquaculture. Low dissolved oxygen levels are responsible for more fish kills, either directly or indirectly, and then all other problems combined. Like human, fish require oxygen for respiration. DO showed negative relationship with water temperature throughout the study period. Similar results were found by Islam [29] and Rajakumar [30].Seasonally dissolved oxygen and primary productivity levels showed positive relationship in the present study.

The plant pigments of algae consist of the chlorophylls (green color) and carotenoids (yellow color). Chlorophyll-a is the most dominant chlorophyll pigment in the green algae (Chlorophyta) but is only one of several pigments in the blue-green algae (Cyanophyta), yellow- brown algae (Chrysophyta), and others. Despite this, chlorophyll-'a' is often used as a direct estimate of algal biomass although it might underestimate the production of those algae that contain multiple pigments [31]. The Chlorophyll-a ranged from 3.84 mg/m^3 at pond 3 in the month of November to 12.98 mg/m^3 at pond 10 in the month of March. The range of chlorophyll-a 3.84 – 12.98 mg/m^3 is higher than values reported for lakes [32]. Overall average Chlorophyll-a is 8.69 mg/m^3. The average chlorophyll-a in ponds was 8.694 mg/l, indicates low algal biomass and can increased through fertilization.The least mean values during pre-monsoon, monsoon and post-monsoon were 5.23 ±0.552, 4.69 ±0.287 and 4.15 ±0.336 and maximum mean values were reported during pre-monsoon, monsoon and post-monsoon 12.69 ±0.271, 12.08 ±0.621 and 11.56±1.218 respectively. However, there were significant variations observed between seasons and ponds.

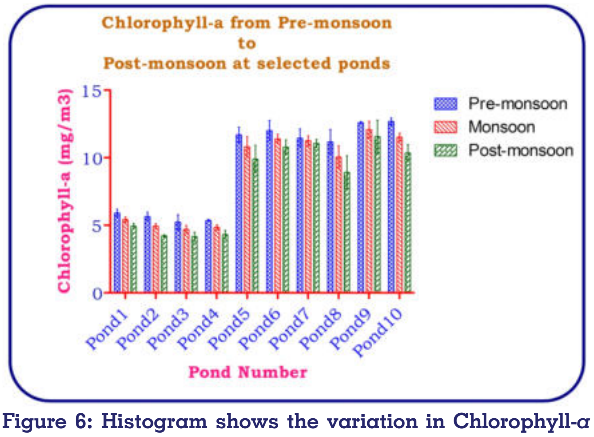

Figure 6: Histogram shows the variation in Chlorophyll-a between the seasons and ponds

Production of chlorophyll –a is increased as temperature increased in summer supported by Hepher[33]. Chlorophyll-a showed maximum concentration was in June, and the minimum in April at the surface while it was minimum at 1m depth and bottom in January. Gross primary production increased from March onwards, attaining its peak in April at the surface and 1m which coincides with the summer peaks of Chlorophyll-a observed by Kharti [6]. The primary productivity of a water body is a function of autotrophs associated with utilization of radiant energy. The solar energy that required for biological activities is first converted to chemical energy by the process of photosynthesis primarily executed by phytoplankton and macrophytes. In the present study, the maximum value of GPP and NPP is observed during Pre-monsoon and subsequently the lower values during Monsoon season which corresponds to the intensity of light energy. Lower rate of primary production during rainy season is the result of limitation of sunshine period and low light energy due to interruption of clouds. Subsequently, the dilution effect of rain on phytoplankton density and as well as the increased in allochthonous turbidity from nearby area are prime causes of lowering primary productivity during Monsoon season.

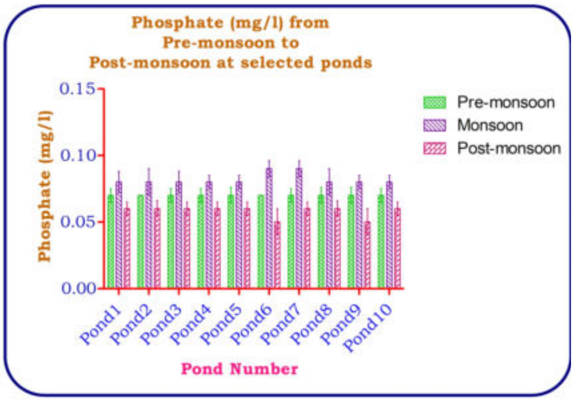

Figure 7: Histogram shows the variation in Phosphate between the seasons and ponds

The ponds in the present study exhibited much difference in their productivity values which were moderate and comparatively higher than that reported by Hepher[33], Gosh [34] David & Rao [35], Agarwal [36], Riemann [37],Rask et al [38], Ayyappan et al [39]), Sharma and Sahai [40], Reddy and Prasad [41], Shibu [42] and Joseph [43]. The reason for higher primary productivity may be due to higher values of desirable features temperature, total hardness, nutrients and higher phytoplankton count. Nauman [44],Yoshimura [45], Moyle [46], Rao[47], Zafar [48], Laksminarayana [49], and Islam et al, [50] pointed out that a body of water is highly productive if it is characterized by rich phosphates, total hardness, dissolved oxygen and desirable temperature.

In ponds under study higher productivity was recorded during non-rainy season. This was similar to the observation made by Khan and Siddique [51], Saltero and Wright [52], Singh and Desai [53] and Sharma and Sahai [54]. On the other hand Nair and Prabho [55] recorded decline in productivity during summer months. Higher productivity in the present study during non-rainy season might be due to comparatively higher nutrient concentration.

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