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Physico-chemical qualities of water in high altitude rice fish farming system of Ziro valley, Arunachal Pradesh, India

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Abstract

Water in rice fields of mountain valley of Ziro, Arunachal Pradesh was investigated for physico-chemical characterization during rice fish farming season (*Kharif*) of 2013. Water temperature, dissolved oxygen, biological oxygen demand, free carbon dioxide, nitrate-nitrogen, phosphate-phosphorus, chloride, total hardness, calcium hardness, alkalinity, pH, total dissolved solids, specific conductivity and water depth were studied. This study revealed that the physical parameters of water in rice fields like water temperature, pH, total dissolved solids, specific conductivity and water depth were 23.5–31.3°C, 5.9–6.9, 250.34-370.5 mgl^{-1}, 437.75-660.33 μScm^{-1} and 3.72-16.9 cm respectively. The chemical features like dissolved oxygen, biological oxygen demand, free CO_2, nitrate–nitrogen, phosphate–phosphorus, chloride, total hardness ,Ca hardness, alkalinity were 2.4-12.9 mgl^{-1}, 1.5-11.1mgl^{-1}, 9.7-23.35 mgl^{-1}, 1.28-3.9 mgl^{-1}, 0.005-0.539 mgl^{-1}, 16.6-46.8 mgl^{-1}, 13.9-34.5 mgl^{-1}, 9.6-13.53mgl^{-1} and 23.16-43.34 mgl^{-1} respectively. On the other hand, investigation on planktonic life forms indicated the presence of 13.5×10^3-84.9×10^3 $indl^{-1}$ and 1.23×10^3-4.86×10^3 $indl^{-1}$ phytoplankton and zooplankton respectively during the *Kharif* season. The above physio-chemical parameters were found to be conducive for raising fish as companion crop of rice due to occurrence of diversified planktonic life forms in underneath water.

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Fishery, Plankton, Rice field, Water quality, Ziro valley.

Introduction

The 'Apatani' tribes in Ziro valley, Arunachal Pradesh, are known for their unique and intensive rice fish cultivation in hill agro-ecosystem (Saikia and Das, 2008) which is a low input and eco-friendly system (Noorhosseini and Bagherzadeh, 2013). It is also free from agrochemicals as excreta of domesticated animals, agricultural and household wastes are used as organic input in these fields. The source of water in these high altitude rice fields are the diverted mountain streams and trickle down rain water of the monsoon season. Bamboo pipes are used to distribute water from the networks of earthen irrigation channels using inlet and outlet pipes. One outlet is fitted angularly at upper level through dyke to maintain water level and another outlet fitted at bottom of the dyke, to the exterior, is used for dewatering field at harvest (Saikia and Das, 2004). Practically, rice fields are man made temporary aquatic ecosystem (Al-Shami *et al.,* 2009; Bahaar and Bhatt, 2011), its hydrologic regime plays a crucial role in production of both rice and fish (Bambaradeniya *et al.,* 2004; Saikia and Das, 2008). The practice of rice fish culture is in vogue in many countries of the world (Halwart and Gupta, 2004) as research endeavors mainly concentrated on the yield components of integrated agriculture- aquaculture (IAA) system. However, there exists a wide habitat specific information gap in relation to underneath water qualities of the Apatani rice fish system. To frame a judicious management and better resource utilization in the system, characterization of field water is a primary requisite which has hardly been documented earlier. In the context of unit land productivity, employment opportunity, better farm income, sustainable rural development and food security (Ahmed and Garnett, 2011; Noorhosseini and Bagherzadeh, 2013), the water quality parameters of such system play intricate role and become the essential determiner (Ali *et al.,* 2005) for its sustainability. In view of the above the present study was carried out to generate basic information along with critical appraisal towards better productivity of unique mountain IAA of Apatani plateau during rice growing season in 2013.

Materials and Methods

Study area: Study sites were selected in the wet rice areas of Ziro valley, lower Subansiri district, located at an altitude of 1500 m above mean sea level and situated within $26^{\circ}50^{'}$- $98^{\circ}21^{'}$ N latitude and $92^{\circ}40^{'}$ - $94^{\circ}21^{'}$ E longitude of Arunachal Pradesh, India (Fig.1). In total, 15 rice fields were randomly selected from five sites under villages namely, Mudang tage, Dutta, Nenchalya, Pine Grobe and Tajang.

All sampling activities were performed from April to September during the rice growing season of 2013 at fortnightly in morning hours (6:00-10:00 hrs.). Dissolved oxygen (DO), biological oxygen demand (BOD), alkalinity, free carbon dioxide (FCO_2), total hardness and calcium hardness, chloride, nitrate–nitrogen and phosphate–phosphorus were estimated by standard protocols of APHA (2005). Water temperature (WT), water depth (except refuge trenches), pH, specific conductivity (SC) and total dissolved solid (TDS) were measured using standard equipments like thermometer (ZPHI-9100 Zico, India Ltd.), centimeter scale, digital water analyzer (Systronics 371) respectively on the spot, during each field visit. For sampling of plankton, 25 l of randomly sampled water from each field was filtered through plankton net (60 µm) to make 15 ml concentrate in a labeled vial. The concentrated sample was then preserved in 4% formalin and kept for further qualitative and quantitative analysis in laboratory. Analyses of plankton samples were done using binocular light microscope having 10X & 40X objectives for necessary identification (Belcher and Swale, 1976; Turner, 1978; Tonapi, 1980; Penticost ,1984; Desikachary, 1989; Edmonson, 1992). Quantitative estimation of plankton population was performed following 'drop count' method (Lackey, 1938). The yield records of rice and fish from each of selected study fields were obtained from the farmers. Essential weather information of the study areas were obtained from nearby meteorological research station in Hapoli, Ziro. Statistical analyses wherever required, were done using MS excel software based on the standard procedure (Khan and Khanum, 1994).

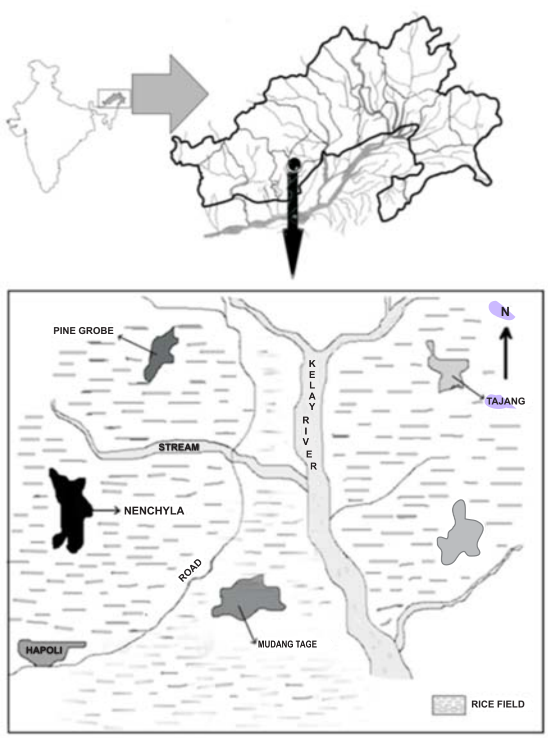

Fig. 1. Map showing the sampling sites in Ziro valley, Arunachal Pradesh.

Results and Discussion

The mean value of water temperature in rice fields varied from $23.5^{\circ}C$ (lowest) in May to $31.3^{\circ}C$ (highest) in August (Table 1). Higher temperature was perhaps due to shallow water level into which summer sunlight penetrated through erect canopy cover of rice. Fig. 2 depicts the location specific average rainfall pattern during the last ten years (2002-12) and actual rainfall pattern in 2013 which might be one of the causes of rapid variation of water temperature during the season. Moreover, incident sunlight and other climatic factors also influenced water temperature (Das *et al.,* 2011). It is to mention that $18.3^{\circ}C$ to $37.9^{\circ}C$ temperature was suitable for growth of planktonic organisms in water (Hossain *et al.,* 2013). Similarly, water temperature ranging from $18.6^{\circ}C$ – $32.0^{\circ}C$ was also reported appropriate for growth of carps and other stocked fishes in such rice fish system (Jha *et al.,* 2007; Santhosh and Singh, 2007). Water temperature of the entire site also matched with the view of judicious abundances of planktonic primary and secondary producers in wet rice field. The pH of field water also played a vital role in growth of fish in rice fish culture system (Das *et al.,* 2011). In the present study, the mean pH range was 5.9 (April) - 6.9 (September) indicating mild acidic nature, confirming the acceptable production possibilities in such rice fish system (Saikia and Das, 2010). Further, Ndebele *et al.,* (2013) reported that pH show frequent decrease with increasing depth and high amount of detritus load in water. Low pH value in April might have occurred due to high amount of free CO_2 in water for sudden submergence and decomposition of dry land weeds and left over rice stalks of the previous seasons and addition of metabolic residues of the stocked fishes (Chowdhary *et al.,* 2000; Siddhartha *et al.,* 2012). The mean value of TDS, in the present investigation, showed peak value of 370.5 mgl^{-1} in April and dip value of 250.3 mgl^{-1} in September indicating sufficient fluctuation

Table 1: Variation (Mean ±SD) of physical qualities of field water in rice fish system, Ziro valley, Arunachal Pradesh (*Kharif*, 2013)

Parameters	April		May		June		July		August		September	
Fortnight	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
WT (°C)	28.1 ±2.20	24.0 ±0.96	23.9 ±3.90	23.5 ±1.90	26.5 ±1.90	27.9 ±1.10	28.0 ±1.20	27.8 ±1.40	31.3 ±0.40	30.9 ±0.40	28.7 ±2.80	27.6 ±0.94
pH	5.9 ±0.558	6.2 ±0.578	6.6 ±0.17	6.8 ±0.36	6.7 ±0.56	6.3 ±0.14	6.5 ±0.25	6.3 ±0.74	6.5 ±0.25	6.7 ±0.31	6.4 ±0.53	6.9 ±0.35
TDS (mgl^{-1})	370.5 ±87.3	344.9 ±84.1	339.4 ±84.8	356.9 ±86.5	325.9 ±122.6	278.4 ±70.9	287.6 ±92.5	276.6 ±85.3	314.2 ±126.2	327.2 ±80.3	250.3 ±40.9	291.2 ±54.9
SC (µS/cm)	660.3 ±131.2	607.8 ±157.2	517.8 ±164.5	547.2 ±158.8	580.7 ±118.7	476.7 ±138.1	571.9 ±237.7	601.8 ±179.3	584.5 ±278.5	609.7 ±194.9	448.4 ±109.06	437.8 ±93.2
Water Depth (cm)	3.7 ±1.7	3.8 ±1.6	10.2 ±1.1	12.1 ±2.3	13.3 ±2.0	16.2 ±0.3	16.9 ±2.2	15.7 ±2.0	15.9 ±1.8	14.3 ±1.6	5.7 ±1.6	7.1 ±2.1

Table 2: Variation (Mean ± SD) of chemical qualities of field water in rice fish system, Ziro valley, Arunachal Pradesh (*Kharif*, 2013)

Parameters	April		May		June		July		August		September	
Fortnight	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
DO (mgl^{-1})	12.9 ±2.4	11.8 ±1.4	11.3 ±2.8	10.2 ±3.5	6.3 ±1.4	7.0 ±6.2	3.9 ±1.7	4.0 ±1.2	2.5 ±0.3	2.4 ±0.2	6.0 ±1.9	6.3 ±0.9
BOD (mgl^{-1})	11.1 ±2.4	10.7 ±1.8	10.1 ±2.1	9.0 ±1.8	4.1 ±1.5	3.9 ±0.9	2.25 ±1.5	3.2 ±0.9	1.5 ±1.5	3.2 ±1.8	5.0 ±0.3	4.0 ±1.8
FCO_2 (mgl^{-1})	23.3 ±8.1	23.0 ±9.1	19.9 ±7.8	20.2 ±7.6	16.0 ±2.8	15.6 ±4.2	11.3 ±1.5	11.2 ±2.5	9.7 ±3.6	10.5 ±2.2	12.9 ±3.2	13.6 ±1.2
Nitrate – N (mgl^{-1})	2.8 ±0.87	2.0 ±0.99	3.5 ±1.86	2.3 ±0.78	1.2 ±0.23	1.9 ±0.88	1.9 ±1.2	3.9 ±1.1	2.9 ±2.01	1.6 ±0.47	1.3 ±0.55	2.3 ±0.57
Phosphate –P (mgl^{-1})	0.024 ±0.015	0.056 ±0.041	0.032 ±0.010	0.015 ±0.081	0.539 ±0.670	0.040 ±0.018	0.024 ±0.016	0.034 ±0.010	0.005 ±0.001	0.020 ±0.020	0.460 ±0.567	0.352 ±0.39
Chloride (mgl^{-1})	33.3 ±16.2	33.9 ±14.4	21.2 ±9.8	19.2 ±8.5	16.6 ±8.6	22.0 ±3.5	46.8 ±40.1	41.1 ±32.9	32.3 ±8.6	34.7 ±7.5	36.1 ±26.1	43.9 ±23.0
TH (mgl^{-1})	29.4 ±36.9	24.1 ±26.0	15.3 ±5.3	16.6 ±5.8	13.9 ±5.8	17.5 ±3.8	17.8 ±13.1	14.2 ±9.3	23.8 ±16.9	27.1 ±19.0	30.6 ±19.1	34.5 ±17.2
Ca hardness (mgl^{-1})	13.0 ±6.2	12.5 ±5.6	10.7 ±3.7	10.6 ±4.3	9.8 ±3.7	9.6 ±2.9	9.8 ±3.8	10.3 ±3.7	13.3 ±9.02	13.5 ±9.2	11.1 ±5.2	10.2 ±5.0
Alkalinity (mgl^{-1})	24.9 ±1.1	24.4 ±2.3	25.3 ±2.5	24.7 ±1.1	23.1 ±5. 1	25.9 ±2.2	35.9 ±3.5	37.8 ±4.2	36.4 ±6. 1	43.3 ±0.791	39.1 ±5.5	40.3 ±7.1

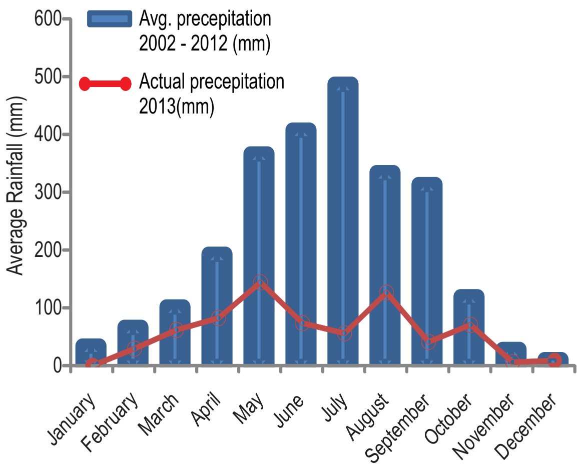

Fig. 2. Average rainfall pattern in last ten years (2002-12) and actual rainfall pattern in rice fish system,*(Kharif, 2013)*

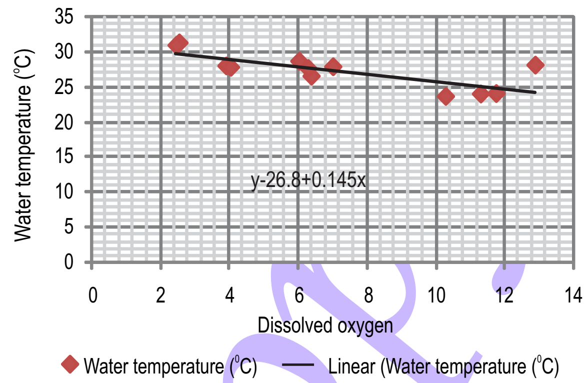

Fig. 3. Correlation and regression equation between WT and DO in rice fish system,*(Khariff, 2013); Ziro Vally, Arunachal Pradesh*

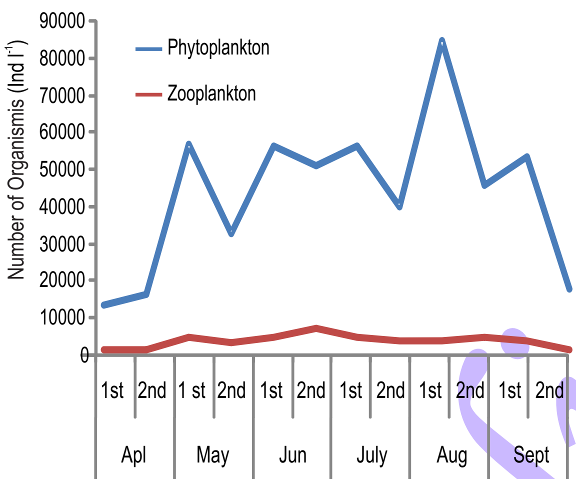

Fig. 4 Variations of plankton (Ind l^{-1}) in rice fish system, Ziro valley, Arunachal Pradesh *(Khariff, 2013)*

of all anions and cations in field water (Phyllis and Lawrence, 2007). This trend might have occurred probably due to dilution effect by frequent monsoon precipitation (Nweze and Ude, 2013). Specific conductivity indicates total ionic concentration of field water (Allison *et al.,* 2007). It showed highest mean value in April (660.3 μScm^{-1}) and lowest in September (437.8 μScm^{-1}), probably playing a crucial regulatory role as indicator for production of plankton and fish. SC in rice field and other freshwater ecosystems probably rises due to input of various decayed organic and inorganic matters through runoff of water from nearby households, hilly catchments (Helliwell and Stevens, 2000; Stevens *et al.,* 2006). WD acted on most of the physico-chemical parameters in rice fish system. (Ali *et al.,* 2005; Nweze and Ude, 2013; Ndebele *et al.,* 2013) and varied widely depending on growth stages of rice cultivation (Al-shami *et al.*, 2009). Water depth (WD) of fields ranged from 3.7 cm in April to 16.9 cm in July indicating the impact of special water regulatory techniques of the farmers for preventing crop submergence and fish escape (Saikia and Das, 2004) as well as maintenance of shallowness and terracing of mountain valley rice wetlands. It was also reported that low field water level (<20.0 cm) was adequate for rice fish culture system (Saikia and Das, 2010) if maintained uniformly above critical level. Apatani farmers, however, used to dig up 50-60 cm deep perpendicularly arranged trenches into their rice fields as fish refuge to combat with solar influx. These refuge trenches provide safe shelter to the stocked fishes when field water become warmer in summer and are often used for harvesting of fishes by dewatering the field (Saikia and Das, 2004).

DO level in rice field water play a vital role in life processes of aquatic organisms under rice fish system (Chowdhary *et al.,* 2000; Narasimha and Jaya, 2001). It was observed that DO content in Apatani rice fields fluctuated considerably and was recorded as low as 2.4 mgl^{-1} in August and reached as high as 12.9 mgl^{-1} in April (Table 2). However, it is evident that DO level less than 1.0 mgl^{-1} and higher than 15.0 mgl^{-1} is harmful for fish in rice fish culture system (Kumar *et al.,* 2014). Low water temperature, high metabolic rate of aquatic organisms and algal photosynthesis might have caused higher level of DO in field water (Al-Shami *et al.,* 2009; Thirumala *et al.,* 2011). On the contrary, lower DO probably occurred either due to monsoon cloud cover preventing incident sunlight or clear sky of summer allowing scorching solar heat into field water. A strong negative correlation (r = -0.758) between DO and water temperature (Fig. 3) was found significant ($p<0.05$). BOD of rice field water having maximum value of 11.1 mgl^{-1} in April and minimum of 1.5 mgl^{-1} in August ultimately influenced the growth of various

Table 3: Yields of rice & fish in rice fish system, Ziro valley, Arunachal Pradesh (*Kharif*, 2013)

Village	Rice yield(kg ha^{-1})	Fish yield(kg ha^{-1})
Pine grobe	2000.0-4000.0	350.0-500.0
Tajang	2000.0-3000.0	270.0-480.0
Nenchalya	2000.0-3000.0	260.0-430.0
Dutta	3000.0-4000.0	420.0-500.0
Mudang tage	3000.0-4000.0	390.0-500.0

microorganisms. Higher value of BOD probably due to decomposition of input of organic manures at field preparation as well as entry of derbies from surface run off into field water during heavy rains (Fuad *et al.,* 2012). Accordingly, maximum level (23.3 mgl^{-1}) of free CO_2 was also observed in April may be due to organic matter decomposition, density of stocked fish fingerlings and respiratory activities of various aquatic organisms (Saikia and Das, 2010). While in August it showed minimum value (9.7 mgl^{-1}) indicating its utilization either in algal photosynthesis or formation of carbonates (Manjare *et al.,* 2010). Growth of Chlorophyceae and Diatoms is supported by high water temperature, phosphate, nitrate, low DO and free CO_2 which might also be correlated with water quality criteria of Apatani rice fields (Kumar *et al.,* 2014). The result further depicted that nitrate–N content of rice field water ranged from 1.2-3.9 mgl^{-1}, showing minimum in June and maximum in July that was also within the acceptable range for productivity of fish (Stone and Thomforde, 2004). The reason behind the fluctuating levels of nitrate–N was probably the effects of agricultural activities, bacterial nitrification, high plankton production, decomposed macrophytes and concentration of various nutrients owing to evaporation of field water (Parikh *and* Mankodi, 2012). Phosphate-P is also an essential nutrient for the growth of aquatic organisms and can limit primary productivity (Wetzel, 2001). In the present study it ranged from 0.005 - 0.539 mgl^{-1} showing lower level in August and higher level in June. Such fluctuating levels was probably due to subsequent utilization of nutrient by rice plants itself and influx of flood water containing nutrients from the surrounding agricultural fields (Manjare *et al.,* 2010; Venkateshwarlu *et al. 2011).* It was also reported that a small level of phosphate-P is most important nutrient for the production of phytoplankton (Bhavimani and Puttaiah, 2014). Chloride content of rice fish system was higher (46.8 mgl^{-1}) in July and lower (16.6mgl^{-1}) in June. Actually, low water depth increased temperature and mixing of sewage cause high value of chloride (Pathak and Mankodi, 2013). Hardness of water indicates concentration of calcium and magnesium ions along with the capacity to react with soap (Kumar and Kakrani, 2000). In Apatani rice fish system, higher value of total hardness (34.5 mgl^{-1}) was seen in September and lower value (13.9 mgl^{-1}) in June, where Ca hardness contributed more (13.5 mgl^{-1}) in August with concurrently less amount (9.6 mgl^{-1}) in June like total hardness. Input of domestic and other sewages into field water, using calcium ion by rice field mollusc and other shell fishes, rapid oxidation and decomposition of organic substances probably caused soaring of total hardness as well as Ca hardness (Hazarika, 2010; Pathak and Mankodi, 2013). Alkalinity of field water indicates acid neutralizing capacity and average ranged between 23.1-43.3 mgl^{-1}in the study fields. At least 20.0 mgl^{-1} alkalinity is suitable for fish culture (Ekubo and Abowei, 2011). Further, variability in alkalinity level might also be possible due to the presence of carbonates, bicarbonates and respiration of living organisms (Solanki and Pandit, 2006; Tiseer *et al.,* 2008) in the flooded rice fish system.

Rice field water harbours diverse communities of plankton, which act as important primary and secondary producer towards productivity of fishes as well as indicator of water quality (Pradhan *et al.,* 2008) of rice fish system. Phytoplankton occupied diversified spatial niche (Fonge *et al.,* 2012) in rice fields showing attached forms (periphyton) on submerged rice stems and suspended form (true plankton) in rice field's water. Besides, many of these organisms also showed benthic habit on the bottom soil of rice field (Das *et al.*, 2007; Saikia and Das, 2009) particularly due to shallow field water. Qualitatively 64 taxa of phytoplankton were identified either at species or genus level. Among these, thirty five taxa of chlorophyceae, twenty three taxa of Bacilllariophyceae and six taxa of Cyanophyceae showed more or less uniform abundance in all the study fields. *Scenedesmus*, *Closterium*, *Euastrum*, *Micrasterias* within Chlrophyceae, *Navicula*, *Penium*, *Pinnularia*, *Cymbella* within Bacillariophyceae, *Anabaena*, *Nostoc* within Cyanophyceae were the most dominant genera. Among 32 taxa of zooplankton, fourteen within Cladocera, fifhteen within Copepoda, two within Rotifera and one taxon of Ostracoda were also identified. However *Bosmina*, *Moina*, *Macrothrix* among Cladocera, *Cyclop*, *Diaptomus* among Copepoda, *Keratella* among Rotifera were very dominant. Monthly total population density of zooplankton (44.06×10^3 $indl^{-1}$) was significantly ($p<0.01$) lower than phytoplankton (5.25×10^5 $indl^{-1}$) and was in conformity with the findings of Mondal *et al.,* (2005) and Singh (2011). Monthly variation of phytoplankton population ($84.90\times10^3 indl^{-1}$) was high in August (Fig. 4) which may be because of the fact that rainfall brings extra phytoplankton from water bodies of upper reaches (Verma, 2014) or upper rice terraces of Apatani rice fish system. Low population of phytoplankton in September (13.50×10^3 $indl^{-1}$) might be due to grazing activities by zooplankton and fish (Sadguru *et al.;* 2002; Verma, 2014). Probably heavy rainfall triggered the growth of certain genera specific high population (7.2×10^3 ind l^{-1}) of zooplankton (e.g. *Bosmina*, *Cyclop*, *Cypris*) in summer that later in water recession period showed lower population (1.23×10^3 ind l^{-1}) with the onset of winter. Similar observation was also reported by Tripathi *et al.,* (2006).

Apatani farmers use four cultivars of rice namely, Amo, Ambo, Mypia and Pyapee concurrently along with the fish species *Cyprinus carp* L (common carp) having three strains viz. *Cyprinus* *carpio speularis*, *C. carpio communis* and *C. carpio nudus*. Total productivity of rice fish farming system in Ziro valley ranged from 300-500 $kgha^{-1}season^{-1}$ for fish and 3000-4000 kg of rice $ha^{-1}season^{-1}$ (Table 3). Fish enhanced rice productivity (10-15%) by controlling the growth of algae, weeds and injurious insects, input of additional organic fertilizer by fish excreta and better tillering of rice seedlings through the activity of fish. Further, mineralization process of organic matter, puddling of mud and soil aeration by benthos cause better yield of rice (Mondal *et al.,* 2005).

From the above discussion it may be assumed that physico-chemical parameters of underneath water in high altitude rice fields were sufficiently conducive for the growth of fish food organisms' like plankton, benthos, periphyton, aquatic insects and other invertebrates which actually exerted great bearing on fish yield. In context of plankton and other fish food organisms, rice fish system is still data deficient and requires special attention for having better productivity and improved management protocol for such unique IAA in mountain wet rice agro ecosystem.

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