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Comparative Studies of Macrophytes Productivity in Three Urban Traditional Water Reservoirs of Imphal (Manipur), North East India

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ABSTRACT

The traditionally followed community ponds ("Leikai pukhri") in Manipur have much significance on the fact that they are purely rain water harvest structures, but continued to have water all through the year. These traditional water reservoirs (TWRs) provide a suitable habitat for the growth of macrophytes. Macrophytes play a crucial role in the functionality of aquatic ecosystems. Given the ecological significance of Macrophytes in in treatment of traditional water reserviors, this current study was conducted by selecting three urban sites for a comparative analysis. A detailed investigation of net primary productivity was carried out on monthly intervals throughout the period of one year. The monthly net primary productivity in site I varied from minimum of 0.1 g m^{-2} $month^{-1}$ (*Salvinia cucculata*) to maximum of 101 g m^{-2} $month^{-1}$ in *Alternanthera philoxeroide*. The annual NPP of the different species varied from 2.6 g m^{-2} yr^{-1}(*Azolla pinnata*) to 278 g m^{-2} yr^{-1} in *Alternanthera philoxeroides*. It was found that the values of monthly NPP ranged from minimum (0.1 g m^{-2} $month^{-1}$) in *Lemna perpusilla* to maximum (323.2 g m^{-2} $month^{-1}$ in *Eichhornia crassipes* in site II. But the annual NPP of different species varied from 0.7gm^{-2} yr^{1} in *Lemna perpusilla* to 425.2 g m^{-2} yr^{-1} in *Eichhornia crassipes*. The site III exhibit monthly NPP ranged from minimum (0.2 g m^{-2} $month^{-1}$) in *Salvinia cucculata* to maximum (33.1 g m^{-2} $month^{-1}$) in *Eichhornia crassipes* in site III. The annual NPP values of different species varied from minimum (0.3 g m^{-2} yr^{-1} in *Lemna perpusilla* to (69.7 g m^{-2} yr^{-1}) in *Pistia stratiotes*. The total annual NPP of all species was recorded 224. g m^{-2} yr^{-1} which is far less than that of site-I (408.8 g m^{-2} yr^{-1}) and site-II (580.2 g m^{-2} yr^{-1}). It is clear from the result that the maximum NPP were observed during monsoon in both site-II and site-III. But in site-I, the maximum productivity was found in retreating monsoon. The minimum NPP was observed during winter season in all the study sites.

Key words: *Pukhri, TWRs, Macrophytes, Primary productivity, Manipur*

Introduction

In recent times, there has been a notable increase in interest regarding wetland ecosystems due to the recognition and demonstration of their substantial contribution to biological productivity (Leith and Whittaker, 1975), recharge of aquifers (Carter *et al*., 1979), erosion control (Dean, 1979), regulation of water quality (Larson, 1982).

North-Eastern India harbours dense forest cover owing to high annual rainfall (over 1500-2000mm). The rain water drains off the hills and reaches the water bodies in the valley. Nevertheless, the fresh water reservoirs and ponds are the most exploited water bodies in the region and hence are amongst the most threatened habitats on the earth's surface. The increasing human population has dramatically changed the fate of the lentic system for settlements.

On the other hand, the human's requirement for portable water increases day-by-day. In this regards, the traditionally followed community ponds ("Leikai pukhri") in Manipur have much significance on the fact that they are purely rain water harvest structures, but continued to have water all through the year. Especially, in the city range, these traditional water reservoirs (TWR) are serving a variety of needs of the humans like drinking water, bathing and washing place. Influx of wastes entering from municipal and urban areas contain high concentration of nitrogen, phosphorous and their higher concentration supports luxurious growth of microbial flora in water bodies. Yet, an excess of nitrogen and phosphorus, crucial nutrients for the growth of aquatic plants, leads to pronounced eutrophication, algal blooms, and the proliferation of aquatic macrophytes (Lander, 1975). A greater paucity of information on urban traditional water reservoirs is much concern and warrants the need of detailed investigation to generate scientific database for vegetational composition and productivity of macrophytes.

Macrophytes are pivotal for the operation of aquatic ecosystems (Pandit, 2010). They impact different aspects of the aquatic system, playing a role in biotopes by facilitating primary production (Adams and Mc-Craken, 1974), contributing to detritus formation, serving as a source of nutrients (Carignan and Kalff, 1980), and acting as a food source for fish (Yousuf and Firdous, 1997). Conversely, they function as nutrient pumps by absorbing nutrients from deeper layers and releasing them at the surface through decomposition after death. Numerous investigations on the distribution and diversity of macrophytes have been conducted by different researchers (Pandit, 2010; Ali and Pandit, 2009; Birk et al., 2006; Kumar and Pandit, 2006; Rather and Pandit, 2005; Lee and McNaughton, 2004).

Primary productivity refers to the overall quantity of organic matter gathered by producers. According to Odum (1971), net primary productivity (NPP) is characterized as the process of storing organic matter in plant tissues beyond the respiratory utilization by plants during the measurement period.

Ecologists have been estimating to comprehend the status of primary productivity of the fresh water ecosystems as there is increasing demands on the aquatic resources. Therefore, examining the net primary productivity of freshwater macrophytes is crucial for evaluating the functionality and dynamics of the aquatic ecosystem. Given the ecological significance of macrophytes in (TWR) systems, the current study was conducted at monthly intervals over the course of one year.

Study area

Imphal is located at an elevation of 800 m. above the mean sea level, between 93º 012 483 E and 94º 462 043 E longitude and 23º 492 483 N and 25º 402 483 N latitude. The average temperature in the region fluctuates between 5.3ºC and 29.5ºC, while the annual precipitation averages between 1250 mm and 2700 mm. The climate in the western section of the state is tropical, while the remaining areas experience a subtropical climate characterized by distinct summer, winter, and rainy seasons.

Geologically, Manipur belong to the recent formation with the loose and soft surface rock in nature and therefore vulnerable to the weathering process. These peculiar characteristics also accelerate erosion, silting and sedimentations. The state experiences four seasons, which are pre-monsoon (March-May), monsoon (June-September), retreating monsoon (October-November), and winter (December–February). There has been no record of particular land use history of the reservoirs such as for pisciculture purposes. However, these TWRs have been serving as a major source of domestic water including for drinking purposes of the community in the Imphal area since long time before the establishment of the municipal water supply systems.

Materials and Methods

The three study sites were (1) Kanglapat (Moat), (2) Bijoy Govinda Thangapat, and (3) Wangkhei Thangapat. These sites were selected because of their presence close to the proximity to human habitation and public places and the local population depend on these reservoirs for various purposes. The sites have also been selected based on the following criteria.

i) Location of TWRs in Imphal city
ii) As a source of water for domestic and drinking purposes
iii) Size of TWRs for comparative study.

The three selected study sites have been mapped and these are situated at the heart of Imphal city (Fig.1.)

Plant samples particularly macrophytes were col-

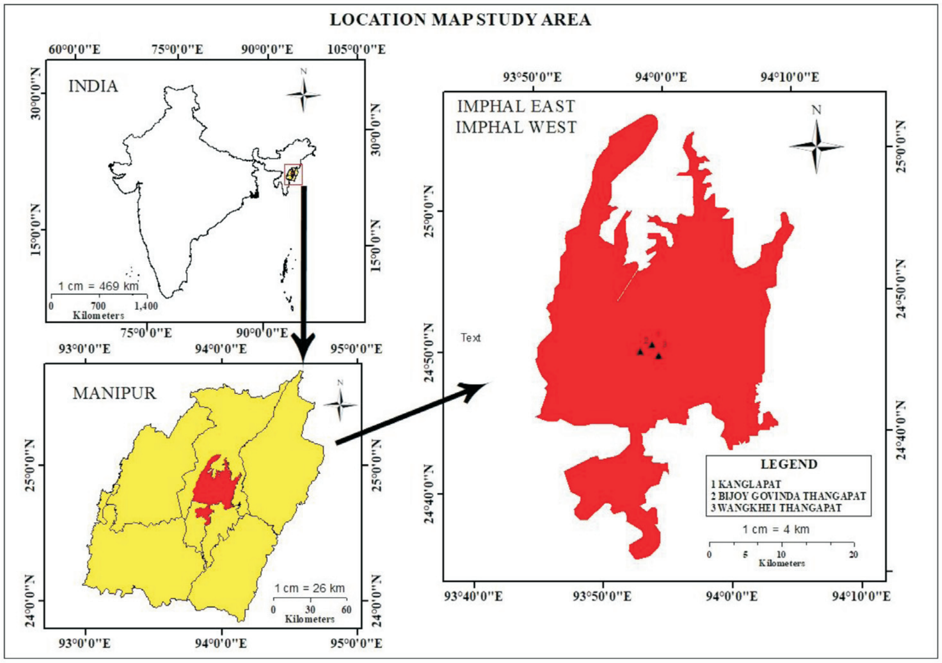

Fig. 1. Map of the study sites

lected for one year using quadrates of 25×25 cm^2. The standing biomass which is expressed as (gm^{-2}) on dry weight basis were determined by harvest method (Odum, 1956 and Trivedy and Goel, 1986). In each site, vertical core sampling was done at five different areas and the cumulative data were analysed. The collection of macrophytes was done on monthly basis. These were thoroughly washed for removal of silt, mud etc. and excess water was allowed to absorb on a cloth. These were brought to the laboratory in polyethylene bags. After sorting out each species wise, fresh weight was measured. Then the plant material was dried at 80°C for 48 hours in an oven. Therefore, the biomass was determined based on dry weight and quantified in gram per square meter, following the methods outlined by Misra in 1968 and 1989. Net primary productivity (NPP) denotes the pace at which organic matter is stored in plant tissues beyond the respiratory consumption by plants throughout the measurement period. The estimation involved summing all positive changes in biomass values when comparing successive intervals (Vollen Weider, 1973). NPP values were computed for individual species and the entire community over twelve months. The annual net primary productivity is expressed as $gm^{-2}\ yr^{-1}$, while the monthly values are denoted as $gm^{-2}\ month^{-1}$. To determine annual production, all positive monthly changes in standing crop biomass for each species were aggregated.

Results and Discussion

In the present investigation, there were 12 species belonging to various plant groups have been recorded. The Dicotyledonous species were maximum (7) whereas Monocotyledonous species were only 3. Two species of Pteridophytes (*Azolla, and Salvinia*) have also been recorded. But, all the three sites were different in number of species. Site-I of TWRs possessed 8 species, Site-II recorded 5 species and Site-III possessed 7 species. Out of the total 12 macrophytic species recorded in all the three study sites, family Salviniaceae and Poaceae contributed 2 species each while family Amaranthaceae, Pontenderiaceae, Hydrocharitaceae, Onagraceae, Nymphaeceae, Utriculariaceae, Araceae and Lemnaceae contributed 1(one) species each. A total of 12 (twelve) species were identified across the three study sites.

Variation in the net primary productivity in site-I

The variations in net primary productivity (NPP) of different species have been furnished in Figure 2 &

3 and it contains the monthly values of NPP in site-I where 8 macrophytic species were recorded and assessed for NPP. The monthly net primary productivity in this site varied from minimum of 0.1 g.m^{-2} month^{-1} (*Salvinia cucculata*) to maximum of 101 g m^{-2} month^{-1} in *Alternanthera philoxeroide*. Thus, the monthly maximum production was recorded in *Alternanthera philoxeroides* (101 g m^{-2} month^{-1}), followed successively by *Eichinochloa stagnina* (19.2 g m^{-2}) and *Jussiae repens* (13.7 g m^{-2} month^{-1}) and the least productivity was found in *Salvinia cucculata* (0.1 g m^{-2} month^{-1}). The monthly net primary productivity (NPP) of all species together varied from 3.1 g m^{-2} month^{-1} (June 2015) to 121.1 g m^{-2} month^{-1} (May 2014). The observed values of all species together during the study period did not exhibit any definite trend. However, the values showed a deceasing pattern from September 2014 to January 2015.

The annual NPP of the different species varied from 2.6 g m^{-2} yr^{-1} (*Azolla pinnata*) to 278 g m^{-2} year^{-1} in *Alternanthera philoxeroides* which is shown in Fig. 4. The maximum value of annual production after *Alternanthera philoxeroides* was successively followed by the values of *Eichinochloa stagnina* (50.1 g m^{-2} yr^{-1}) and *Jussiae repens* (47 g m^{-2} yr^{-1}). The total NPP of all available species was 408.8 g m^{-2} yr^{-1}. The highest percentage contribution of the individual species to the total productivity in site site-I was found in *Eichhornia crassipes* (68.0%) while the minimum was contributed by *Azolla pinnata* (0.65%) which is shown in Fig. 5.

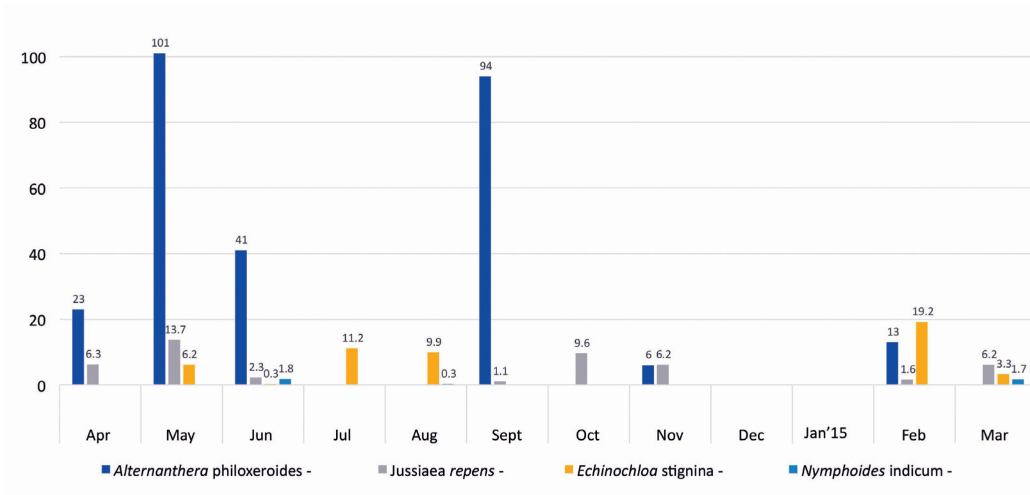

Fig. 2. Net primary productivity (NPP) (g m^{-2} month^{-1}) of the macrophytes in site -1

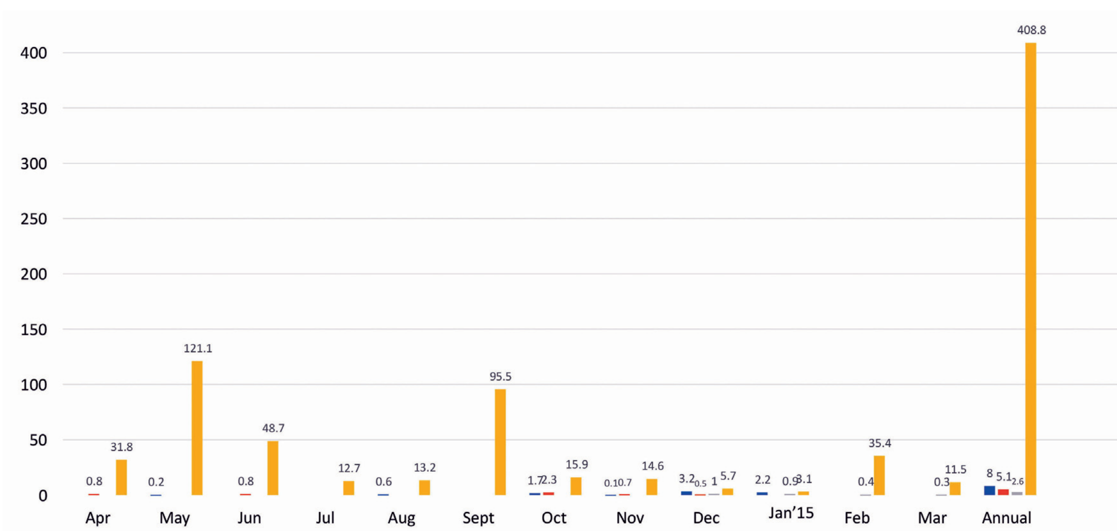

Fig.3. Net primary productivity (NPP) (g m^{-2} month^{-1}) of the macrophytes in site -1

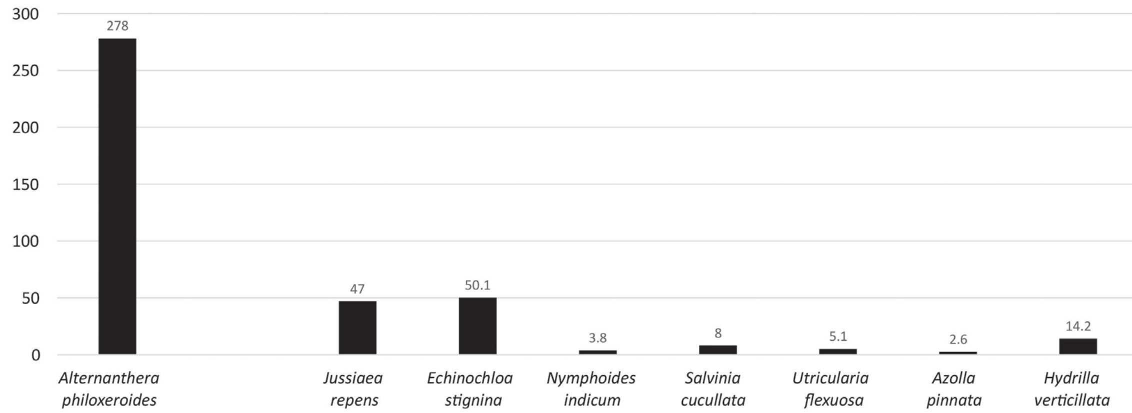

Fig.4. Annual net primary productivity (g m^{-2} year^{-1}) of the macrophytes in site-1

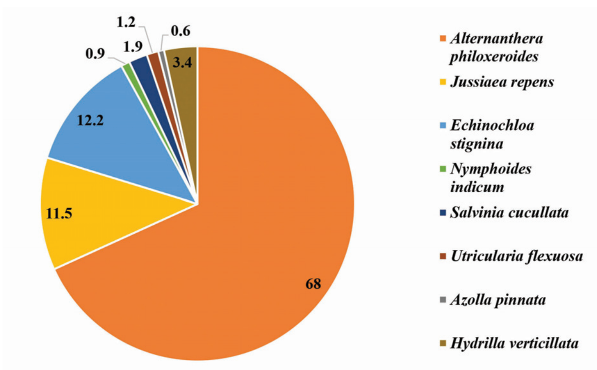

Fig. 5. Percentage variations in the monthly NPP (g m^{-2}) of the macrophytes in site–I.

Variation in the net primary productivity in site-II

Monthly and annual values of NPP of different species in site-II have been presented in Figure 6, 7 & 8. Five macrophytic species were recorded and contributed to the NPP in this site. The values of monthly NPP ranged from minimum (0.1 g m^{-2} month^{-1}) in *Lemna perpusilla* to maximum (323.2 g m^{-2} month^{-1} in *Eichhornia crassipes.* Thus, the highest of NPP was observed in *Eichhornia crassipes* and followed successively by *Alternanthera philoxeroides* (62.5 g m^{-2} month^{-1}) and *Pistia stratiotes* (20.8 g m^{-2} month^{-1}) respectively. The minimum NPP was observed in *Lemna perpusilla* (0.1 g m-2 month^{-1}). The monthly NPP of all species together were ranged from 1.4 g m^{-2} month^{-1} (August 2014) to 406.5 g m^{-2} month^{-1} (July 2014). The observed values of NPP for all species (combined) during the study period did not show any significant trend of increase or decrease. The annual NPP of different species varied from 0.7 g.m^{-2} yr^{-1} in *Lemna perpusilla* to 425.2 g m^{-2}

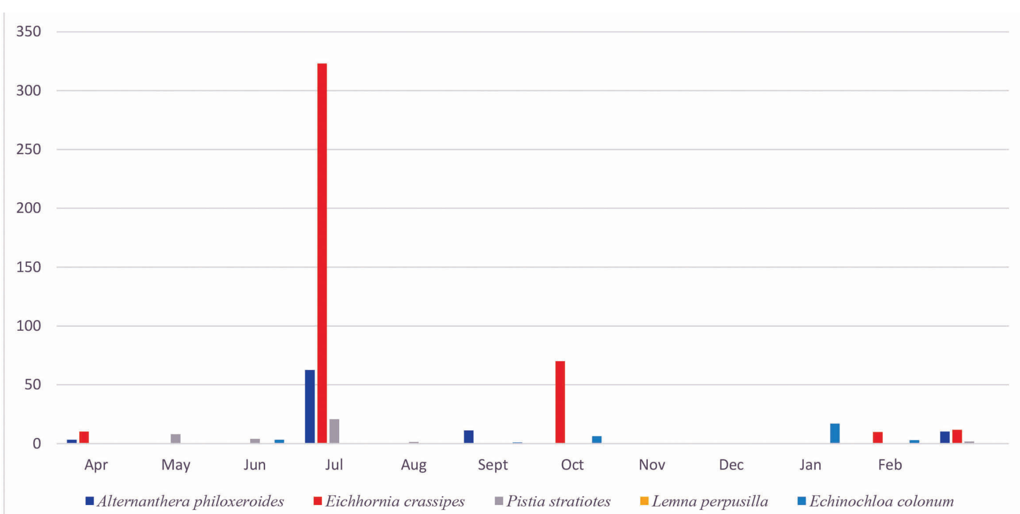

Fig. 6. Net primary productivity (NPP) (g m^{-2} month^{-1}) of the macrophytes in site –II

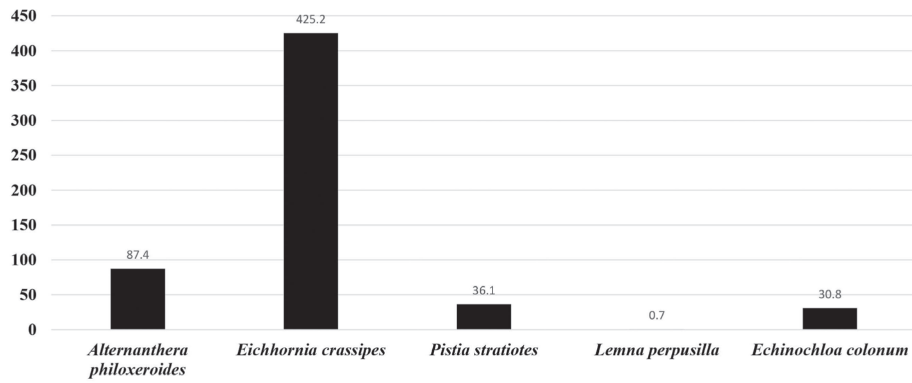

Fig. 7. Net primary productivity (NPP) (g m^{-2} month^{-1}) of the macrophytes in site -II

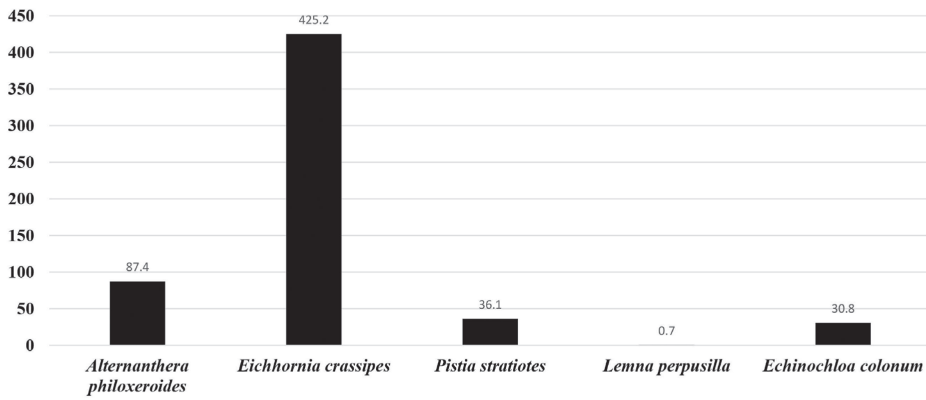

Fig. 8. Annual net primary productivity (g m^{-2} yr^{-1}) of the macrophytes in site-II

yr^{-1} in *Eichhornia crassipes*. The maximum value of annual NPP was found in *Eichhornia crassipes* and was successively followed by the value of *Alternanthera philoxeroides* (87.3 g m^{-2} yr^{-1}) and *Pistia stratiotes* (36.1 g m^{-2} yr^{-1}). Total NPP of all available species was 580.2 g m^{-2} yr^{-1}. The highest percentage contribution of individual species to the total productivity was observed in *Eichhornia crassipes* (73.2%), followed by *Alternanthera philoxeroides* (15.0%) which is shown in Fig. 10. The minimum percentage contribution to the total productivity was recorded in *Lemna perpusilla* (0.12%). The present observed values of annual NPP are similar to the values reported by Khelchandra and Usha at khumanpat lake (Manipur), 2019. However, the values are close with the findings of various workers viz. Verma (1979) in Gujar Lake, Jaunpur (628 g m^{-2} yr^{-1}). Singh *et al*. (1982) in Nainital lake, Kumaun reported the production of 666 g m^{-2} yr^{-1} and Billore and Vyas (1982) in Pichhola lake, Udaipur (690 g m^{-2} yr^{-1}). Some other workers have also reported lower values than those of the present investigations, viz. Hillbricht Illkowska (1993) in lake Mikolajakie, Poland (130.6 g m^{-2} yr^{-1}); Jha (1968) for BENCO pond, Varanasi; Ramgarh shallow pond, Varanasi (Ambasht, 1971); Kumari and Arvind Kumar (2002) in Singhara pond, Dhumka, Jharkhand (54.11 g m^{-2} yr^{-1}) and Nivanonee (2003) in Ikop lake, Manipur

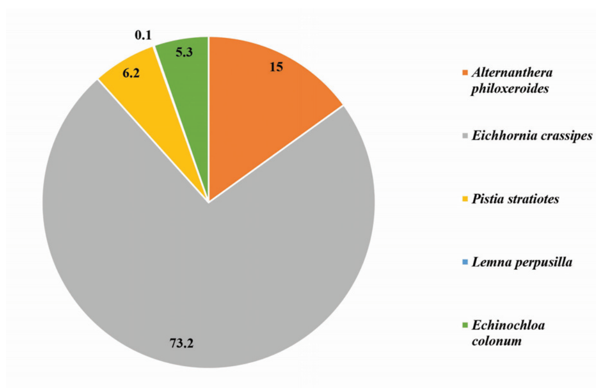

Fig. 9. Percentage variations in the monthly NPP (g m^{-2}) of the macrophytes in site-II

(137.1 g m^{-2} yr^{-1}) which are recorded in Table 1. Such variations in the values of NPP occur due to several factors like species diversity, age of the plants, nutrient content of water and human activities on cleansing the water body etc.

Variation in the net primary productivity in site-III

The variation of the values of NPP both on monthly and annually in the different species have been presented in Figure 10 & 11**.** In this site seven macrophytic species were recorded and assessed for the NPP. The values of monthly NPP ranged from minimum (0.2 gm^{-2} month^{-1}) in *Salvinia cucculata* to maximum (33.1 g m^{-2} month^{-1}) in *Eichhornia crassipes*. The maximum value of NPP after *Eichhornia crassipes* was followed successively by the values of NPP observed both in *Pistia stratiotes* and *Eichinochloa stagnina* (27.2 g m^{-2} month^{-1}) and *Alternanthera philoxeroides* (14.8 g m^{-2} month^{-1}). The minimum NPP was observed in *Salvinia cucculata* (0.2 g m^{-2} month^{-1}). The monthly variations in the value of NPP of all the species together were varied from 0.9 g m^{-2} month^{-1} (September 2014) to 56.5 g m^{-2} month^{-1} (July 2014). The observed values of NPP for all species (combined) during the study period did not show any significant pattern of increase or decrease.

The annual NPP values of different species varied from minimum (0.3 g m^{-2} yr^{-1} in *Lemna perpusilla* to (69.7 g m^{-2} yr^{-1}) in *Pistia stratiotes*. The maximum value of annual NPP was found in *Pistia stratiotes* (69.7 g m^{-2} yr^{-1}) which was followed successively by the value of *Eichhornia crassipes* (64.9 g m^{-2} yr^{-1}) and *Alternanthera philoxeroides* (40.0 g m^{-2} yr^{-1}) etc. The

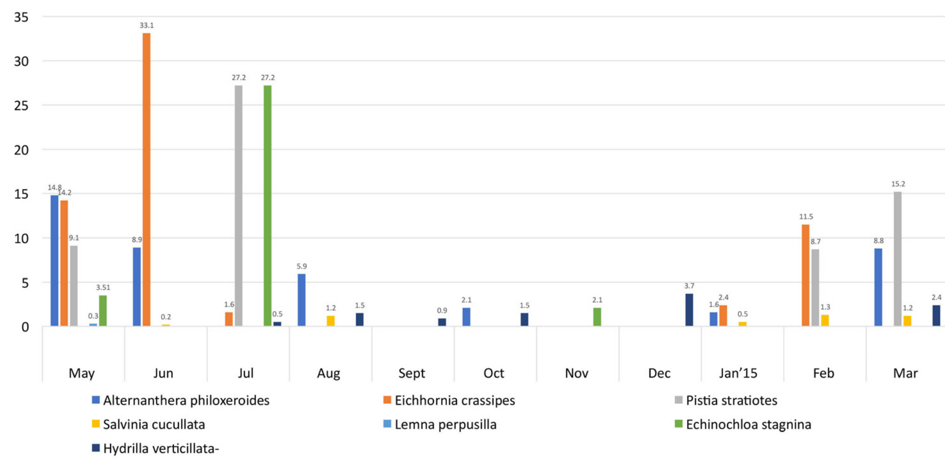

Fig. 10. Net primary productivity (NPP) (g m^{-2} month^{-1}) of the macrophytes in site-III

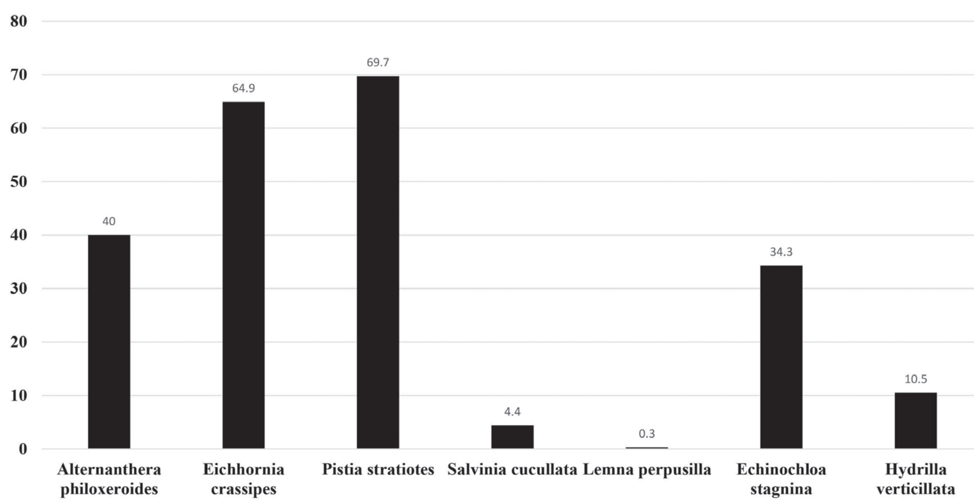

Fig. 11. Annual net primary productivity (g m^{-2} yr^{-1}) of the macrophytes in site-III

total annual NPP of all species was recorded 224. g m^{-2} yr^{-1} which is far less than that of site-I (408.8 g m^{-2} yr^{-1}) and site-II (580.2 g m^{-2} yr^{-1}). The highest percentage contribution of individual species to the total productivity was observed in *Pistia stratiotes* (31.1%) and followed by *Eichhornia crassipes* (28.9%) and *Alternanthera philoxeroides* (17.8%) etc. The minimum percentage contribution to the total productivity was observed in *Lemna perpusilla* (0.1%) which is shown in Fig. 12.

The present estimated values of annual NPP of all species (combined) were found to be 224.1 g m^{-2} yr^{-1} in site III (Figure 4). This observed values of NPP were

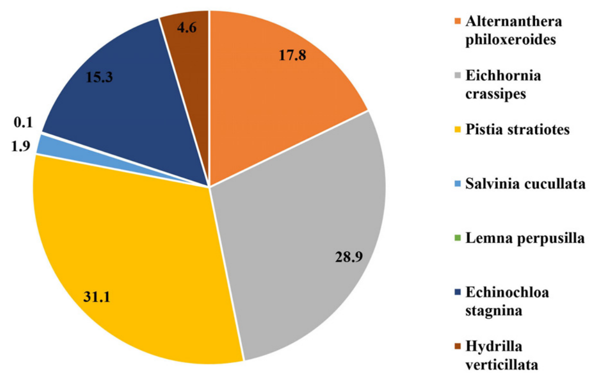

Fig. 12. Percentage variations in the monthly NPP (g m^{-2}) of the macrophytes in site-III

found similar to values reported by Wassink (1975) from tropical freshwaters (200 gm^{-2} yr^{-1}) and close agreement with Devi, I. K (1998) from Utrapat lake, Manipur (265.4 g m^{-2} yr^{-1}). Similar observation was also obtained in Poiroupat lake (Manipur), which was studied by Usha (2002). However, some other workers have also reported higher values than the present investigations, viz. Billore and Vyas (1982) in Pichhola Lake, Udaipur. But the present values were found to be higher when compare to the values reported by other workers viz. Kumari and Arvind Kumar (2002) in Singhara pond, Dhumka, Jharkhand, Nivanonee (2003) in Ikop lake, Manipur and Hillbricht Illkowska (1993) in lake Mikolajakie, Poland.

It is clear from the above discussions that the maximum NPP were observed during monsoon in both site-II and site-III. But in site-I, the maximum productivity was found in retreating monsoon. The lowest net primary productivity (NPP) was noted during the winter season across all the study sites. The most important factor in growth is the nutrient status of the TWRs and favourable temperature. These reservoirs get enriched during rainy seasons as a result of water inflow into the reservoirs bringing soluble nutrients from the surrounding area. Thus, there was gradual fall in production after monsoon and become least during winter in all the

Table 1. Annual Net Primary Productivity of Plants in Different Freshwater ecosystems

Ecosystem Type	Annual NPP (g $m^{-2}yr^{-1}$)	Authority
BENCO Pond (B.H.U), Varanasi	345.0	Jha, 1968
Mikolajakie Lake,Poland	54.11	Hillbricht Illkowska, 1993
Ramgarh shallowlake, Varanasi	350	Ambasht, 1971
Dal lake, Kashmir	3000	Kaul, 1977
Manasbal lake, Srinagar	9700	Kaul, 1977
Gujar lake, Jampur	628	Verma, 1979
Dal lake, Kashmir	3,000 – 15,000	Vass, 1973
Manasbal lake, Srinagar	8000 – 10,0000	Vass, 1973
Baghela tank, Udaipur	748.31	Sankhla, 1981
Pichhola lake, Udaipur	690	Billore and Vyas, 1982
Dal lake, Kashmir	4,100	Zutshi and Vass, 1982
Nainital lake, Kumaon	666	Singh *et al.*, 1982
Singhara pond	54.11	Kumari and Arvind Kumar, 2002
Loktak lake, Manipur (i) Phumdi zone	737.6-1240.6	Devi, N.B. 1993
(ii) Non-Phumdi zone	181.3 – 358.9	
Waithou lake, Manipur	1350.5 –1601.0	Devi, O.I., 1993
Utrapat lake, Manipur	2.97 – 265.46	Devi, K.I., 1998
Freshwater ecosystems, Canchipur, Manipur	288.68 – 678.16	Devi, Ch.U. 2000
Poiroupat Lake, Manipur	214.47 – 384.02	Usha, 2002
Ikop lake, Manipur	2.07 – 137.13	Nivanonee, 2002
Traditional Water Reservoirs, Imphal, Manipur	224.1 –580.2	Present study

study sites (Fig.2 - 4). The fresh water ecosystem, reaches the eutrophic stage when their gross primary productivity exceeds over the specific value. Rodhe (1969) suggested that lakes with a gross productivity surpassing 150 g m^{-2} yr^{-1} are inherently eutrophic, while those with a gross productivity exceeding 700 g m^{-2} yr^{-1} are considered severely polluted. Various work on NPP of macrophytes at different fresh water ecosystem of the world are placed at Table 1.

In the light of the above findings and considerations, the GPP of the TWRs varied between 224 g m^{-2} yr^{-1} and 580 g m^{-2} yr^{-1} which is within the range of naturally eutrophic condition. This is mainly caused by the following factors such as (i) inflow of nutrients into the reservoirs from the surroundings during monsoon. (ii) washing and bathing activities at the reservoirs and (iii) non-point sources of input of wastes.

The present study, therefore, represents a base line data on the ecology of the reservoirs in relation to various ecological attributes and accordingly suitable management practices can be prescribed from time to time.

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