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Research Article

ECOLOGICAL PRODUCTIVITY STUDIES OF THE MACROPHYTES IN KHARUNGPAT LAKE, MANIPUR NORTHEAST INDIA

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ABSTRACT
The present investigation has been carried out in Kharungpat Lake located in Thoubal District, Manipur. The lake is located in South Western Portion of Thoubal District at a distance of about 30 km. from Imphal City. Net Primary Productivity is the rate of storage of organic matter in plant tissues in excess of the respiratory utilization by plants during the measurement period. Daily and annual net primary productivity of the dominant macrophytic vegetation were determined for a period of two years. *Alternanthera philoxeroides* exhibited the highest daily net primary productivity with values ranging from 0.15 to 2.12 gm^{-2} day^{-1} in the first year and 0.08 to 2.17 gm^{-2} day^{-1} in the second year. *Echinochloa stagnina* recorded daily net productivity values ranging from 0.15 to 2.03 gm^{-2} day^{-1} in the first year and 0.06 to 1.76 gm^{-2} day^{-1} in the second year. *Ceratophyllum demersum*, the present values varied from 0.11 to 1.54 gm^{-2} day^{-1} in the first year and 0.04 to 1.84 gm^{-2} day^{-1} in the second year. The daily net production of all species (combined) varied from 0.03 to 6.10 gm^{-2} day^{-1} and 0.15 to 8.42 gm^{-2} day^{-1} in the first and second year respectively. The total annual net production of all species (combined) varied from 682.64 to 891.13 gm^{-2} yr^{-1} and 702.49 to 840.45 gm^{-2} yr^{-1} in the first and second year respectively.

Keywords: *Primary Productivity, Biomass, Macrophytes, Kharungpat Lake, Manipur*

INTRODUCTION
Net Primary Productivity (NPP) is the rate of storage of organic matter in plant tissues in excess of respiratory utilization (R) by the plants during the measurement period (Odum, 1971). Jordan (1985) reported that productivity of an ecosystem is vital and indispensable for ecosystem analysis as the same integrates the cumulative effects of the various physiological processes and interactions occurring simultaneously within the ecosystem. Long and Hutchinson (1991) have also defined it as the net rate of gain of organic carbon by the vegetation over a given time interval. Primary productivity is the measure of the rate at which biomass or organic matter is produced by the primary producers per unit area (Mackenzie *et al.,* 2001). According to Odum and Barrett (2008) the primary productivity of an ecological system is the rate at which radiant energy is converted to organic substances by the photosynthetic and chemosynthetic activity of the producer organisms. The aquatic resources have been till date the potential source of organic production for the entire living organisms. Many ecologists of the world have laid emphasis on the importance of the primary productivity as an important functional attribute of the biosphere because of its controlling effects on the rate of multiplication and growth of the living organisms of the ecosystem (Westlake, 1963). The International Biological Programme (IBP) of the UNESCO has paid due attention on the assessment of Primary Production of the diverse freshwater ecosystems of the Biosphere under the section on Productivity of freshwater communities (PF). Thus, the study of the net primary productivity of the freshwater macrophytes has become necessary to assess the functioning as well as dynamics of the aquatic bodies.
In the present study, primary productivity of the aquatic macrophytes of Kharungpat Lake was assessed for the dominant species in all the different study sites on daily, monthly and annual basis for two consecutive years. The various findings for the entire study period are presented herewith along with the discussion in the light of the numerous works done in the various wetlands within and outside India.

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Description of study sites

Kharungpat Lake is situated in Thoubal District, Manipur. The lake is located in South Western Portion of Thoubal District at a distance of about 30 km. from Imphal City. Kharungpat Lake is surrounded by Ikoppat on the Northern portion, Wangjing Tentha on Eastern side, Uchiwa, Santhel and Sekmaijin on the Western side and Wabagai on the southern side. The lake is located at the intersection of 24°32′14″ N – 24°36′46″ N Latitude and 93°54′46″ E – 93°58′42″ E Longitude. The lake has an area of about 33.52 sq. km during rainy season and is located at about 781 m above the mean sea level. The lake is naturally aging and it is under heavy environmental stress due to human encroachments, conversion of low lying areas into piscicultural farms, disposal of untreated domestic sewage, leaching of synthetic chemical fertilizers etc.

MATERIALS AND METHODS

The present investigation was carried out in Kharungpat Lake located in Thoubal District, Manipur. The Net Primary Productivity of the different dominant macrophytes has been assessed both on monthly and daily for a period of two years from January, 2008 to December, 2009. The annual primary productions of the individual species as well as total species were also assessed for each site during the study period. For the present study, the lake was divided into four study sites representing as Site I, II, III and IV which are named as Panchao, Pangalpat, Kambong Leiram and Kharungpat Khong (Shamu Lanpham) respectively. Collections of macrophytic plants samples were done on monthly regular intervals from the four study sites (Fig. 1).

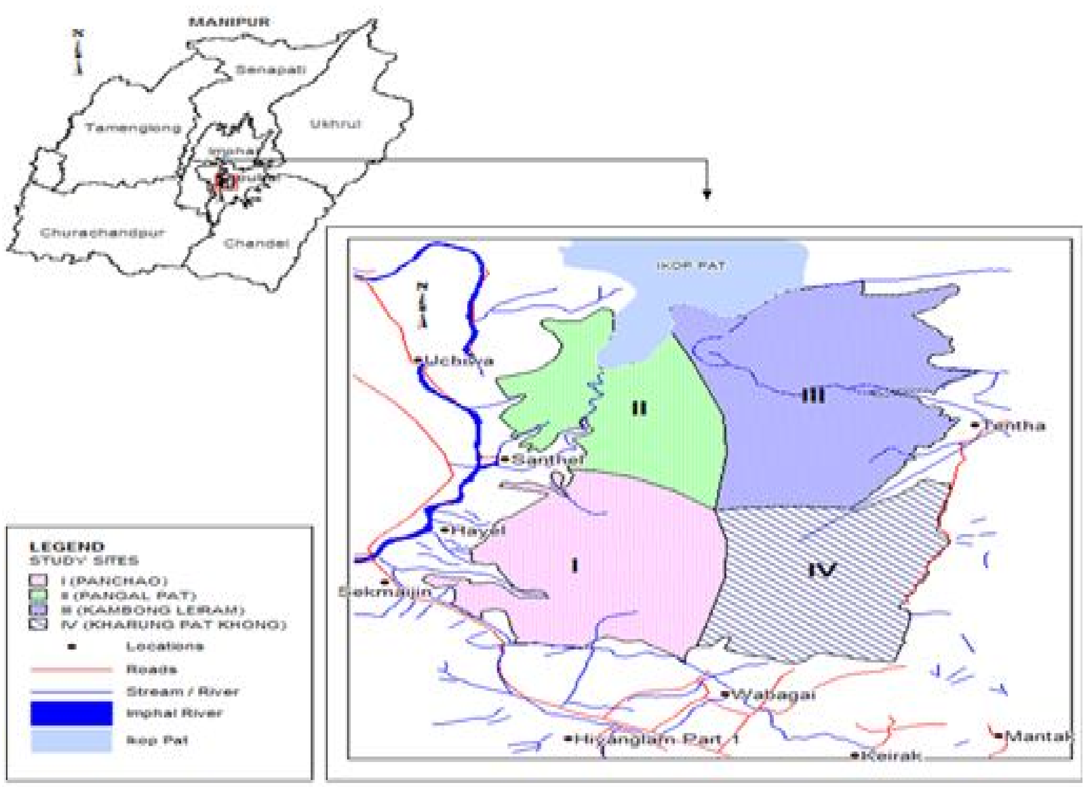

Figure 1: Map of KHARUNGPAT LAKE (THOUBAL) MANIPUR

Standing crop biomass was estimated by Harvest method (Odum, 1956). Plant samples were collected using Quadrats of 25 cm × 25 cm in dimension from the vertical core sampling sites and the cumulative data were analyzed. However for the sampling of some submerged species methods described by Ekman Dredge were used (Welch, 1948). After collection each sample was kept in polythene bags marked with wax pencil and brought to the laboratory. Plant materials were washed to remove the adhering silt, soil, mud, other plants and animal debris etc. Then the plants were sorted out as dominant species and remaining as 'other species'. Excess of water was drained using blotting papers. Fresh weights of the different species were taken by differentiating into shoot and root Net Primary Production was estimated by adding all the positive values of changes in biomass when values for successive intervals were compared (Vollenweider, 1974). The values of the Net Primary Productivity were assessed both at the individual species level as well as at the community level. The Net Primary Productivity on monthly basis has been expressed in terms of grams per square metre per month (gm^{-2} $month^{-1}$) and the values of daily net primary productivity were expressed as grams per square metre per day (gm^{-2} day^{-1}). The annual net primary productivity values were expressed in terms of grams per square metre per annum (gm^{-2} yr^{-1}). For obtaining the annual Production, all positive monthly changes of standing crop biomass of a species for each month were added.

RESULTS AND DISCUSSION

The variations in net primary production of the different study sites in the first and second year of the study period are furnished in Table 3 and Table 4 respectively. The variation in the daily net primary productivity of the macrophytes in different freshwater ecosystems is presented in Table 3 and the annual net primary productivity of the macrophytes in different freshwater ecosystems is presented in Table 4.

Monthly Net Primary Productivity

The maximum monthly net primary production was recorded by *Alternanthera philoxeroides* with values ranging from 4.56 (site II) to 63.48 gm^{-2} $month^{-1}$ (site IV) in the first year and 2.64 (site III) to 65.07 gm^{-2} $month^{-1}$ in the second year. This was followed by *Echinochloa stagnina* with values ranging from 1.73 to 61.00 gm^{-2} $month^{-1}$ and 1.09 to 52.81 gm^{-2} $month^{-1}$ in the first and second year respectively. This was successively followed by *Ceratophyllum demersum* with values ranging from 3.57 to 46.36 gm^{-2} $month^{-1}$ and 0.95 to 55.32 gm^{-2} $month^{-1}$ in the first and second year respectively. The monthly net primary production values for *Ceratopteris thalictroides* varied from (0.00 to 33.13gm^{-2} $month^{-1}$). *Zizania latifolia* recorded the monthly netprimary production values ranging from 2.04 to 31.37 gm^{-2} $month^{-1}$ in the first year and 1.27 to 24.95 gm^{-2} $month^{-1}$ in the second year. For, *Eichhornia crassipes*, the monthly net primary production values varied from 2.05 to 24.30 gm^{-2} $month^{-1}$ in the first year and 0.76 to 30.07 gm^{-2} $month^{-1}$ in the second year. This was followed by *Pistia stratiotes* (1.38 to 24.02 gm^{-2} $month^{-1}$). This was successively followed by *Salvinia cucullata* (0.96 to 22.82 gm^{-2} $month^{-1}$). The monthly net primary production values for *Hydrilla verticillata* varied from 0.77 to 20.59 gm^{-2} $month^{-1}$ in the first year and 0.63 to 22.38 gm^{-2} $month^{-1}$ in the second year. This was followed by *Nymphoides cristatum* (1.18 to 10.86 gm^{-2} $month^{-1}$); *Marsilea quadrifoliata* (0.85 to 14.60 gm^{-2} $month^{-1}$); *Ipomoea aquatica* (0.84 to 9.30 gm^{-2} $month^{-1}$). The monthly net production of 'other species' ranged from 1.39 to 55.39 gm^{-2} $month^{-1}$in the first year and 1.25 to 36.22 gm^{-2} $month^{-1}$in the second year. The monthly net production of all species (combined) varied from 0.96 to 183.09 gm^{-2} $month^{-1}$ and 4.60 to 252.67 gm^{-2} $month^{-1}$ in the first and second year respectively (Fig. 2 and Fig 3).

Daily Net Primary Productivity

During the whole study period, *Alternanthera philoxeroides* exhibited the highest daily Net Primary Productivity with values ranging from 0.15 to 2.12 gm^{-2} day^{-1} in the first year and 0.08 to 2.17 gm^{-2} day^{-1} in the second year. The observed values are found to be in agreement with the findings of Devi, L.G. (1993) and Devi, L.G. and Sharma (2002) in the different Freshwater bodies of Canchipur, Manipur (0.01 to 2.27 gm^{-2} day^{-1}) and Bebika and Sharma (2002) in Sanapat lake, Manipur (0.01 to 2.27 gm^{-2} day^{-1}). The present values are also comparable with those values reported by Devi, S.U. (2008) in Oksoipat Lake, Manipur (0.02 to 2.38 gm^{-2} day–1. The values in the present study are found to be higher than those reported by Devi, O.I. (1993) in Waithou lake, Manipur (0.0 to 0.91 gm^{-2} day^{-1}), Devi, K.I. (1998) in Utrapat lake, Manipur (0.11 to 0.79 gm^{-2} day^{-1}), Devi, Ch. N. (2002) in Ikop lake, Manipur (0.01 to 0.28

gm^{-2} day^{-1}), Usha, Kh. 2002) in Poiroupat lake, Manipur (0.03 to 0.89 gm^{-2} day^{-1}), Devi, L.G. (2007) in Awangsoipat lake, Manipur (0.07 to 1.82 gm^{-2} day^{-1}).

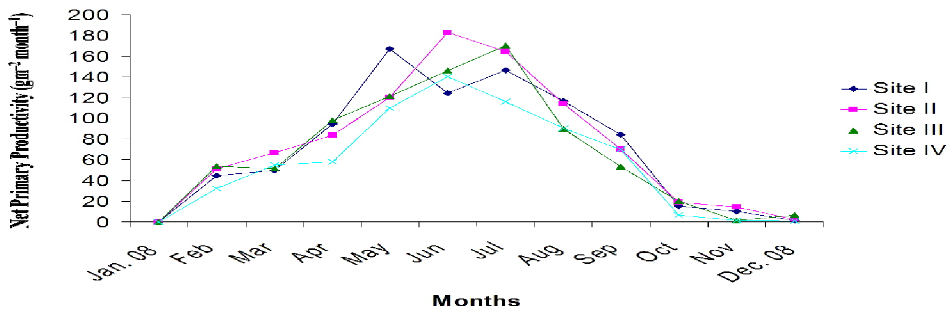

Fig. 2: Variations in Net Primary Productivity (gm^{-2} month^{-1}) of All Species (Combined) in the First Year.

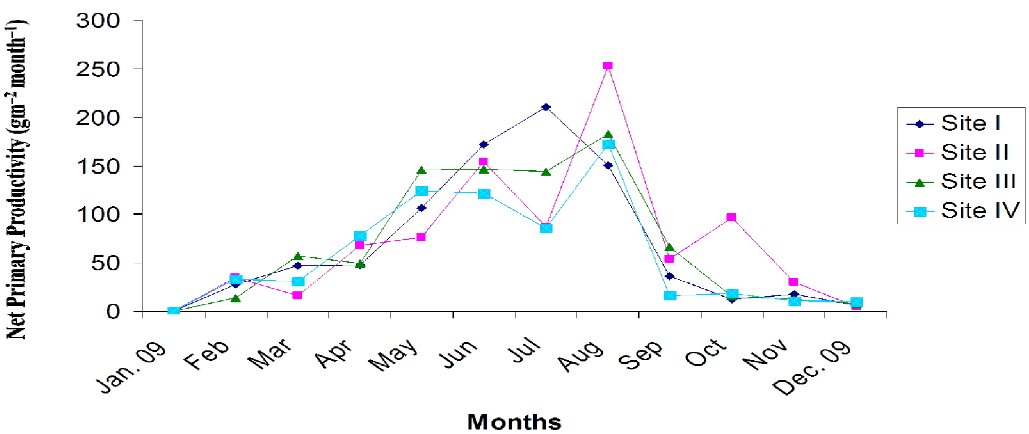

Fig. 3: Variations in Net Primary Productivity (gm^{-2} month^{-1}) of All Species (Combined) in the Second Year.

Echinochloa stagnina recorded daily net productivity values ranging from 0.15 to 2.03 gm^{-2} day^{-1} in the first year and 0.06 to 1.76 gm^{-2} day^{-1} in the second year. The present estimated values are found to be higher than those reported by Devi, O.I. (1993) in Waithou lake, Manipur (0.08 to 0.81 gm^{-2} day^{-1}); Devi, Ch. N. (2002) in Ikop lake, Manipur with values ranging from 0.01 to 1.25 gm^{-2} day^{-1} in the first year and 0.02 to o.40 gm^{-2} day^{-1} in the second year, Devi, L.G. (2007) in Awangsoipat lake, Manipur with values ranging from 0.10 to 0.91 gm^{-2} day^{-1} in the first year and 0.32 to 0.84 gm^{-2} day^{-1} in the second year. The present findings are lower than those reported by Devi, N.B. (1993), in Phumdi area of Loktak lake, Manipur (0.02 to 5.22 gm^{-2} day^{-1}). The present recorded values are comparable with those reported by Devi, S.U. (2008) in Oksoipat Lake, Manipur with values ranging from 0.02 to 1.36 gm^{-2} day^{-1} and 0.06 to 1.54 gm^{-2} day^{-1} in the first and second year respectively.

For, *Ceratophyllum demersum*, the present values varied from 0.11 to 1.54 gm^{-2} day^{-1} in the first year and 0.04 to 1.84 gm^{-2} day^{-1} in the second year. The present values are found comparable with those reported by Devi, K.I. (1998) in Utrapat lake, Manipur (0.17 to 2.0 gm^{-2} day^{-1}), Devi, Ch. N. (2002) in Ikop lake, Manipur (0.01 to 2.85 gm^{-2} day^{-1}), Usha, Kh. (2002) in Poiroupat lake, Manipur (0.06 to 2.86 gm^{-2} day^{-1} and 0.02 to 2.19 gm^{-2} day^{-1} in the first and second year respectively) and Devi, L.G. (2007) in Awangsoipat lake, Manipur (0.16 to 1.63 gm^{-2} day^{-1}). In Oksoipat lake, Manipur Devi, S.U. (2008) reported similarly comparable values ranging from 0.19 to 2.06 gm^{-2} day^{-1} and 0.01 to 1.84 gm^{-2} day^{-1} in the first and second year respectively. However the present values are found to be higher than those reported by Devi, N.B. (1993) from the Loktak lake, Manipur where the values varied from 0.01 to 0.78 gm^{-2} day^{-1}.

Table 1: Variation In The Monthly Values Of Net Primary Productivity (Gm^{-2} $Month^{-1}$) Of The Macrophytes For The First Year (Daily Npp Values In Gm^{-2} Day^{-1} Are Given In Parenthesis)

S. No.	Name of Species	Site I	Site II	Site III	Site IV
1.	*Alternanthera philoxeroides*	5.35-16.70 (0.17-0.55)	4.56-31.20 (0.15-1.04)	4.60-17.54 (0.15-0.58)	5.43-63.48 (0.18-2.12)
2.	*Brachiaria mutica*	1.09-12.74 (0.03-0.42)	_	_	_
3.	*Ceratophyllum demersum*	5.03-46.36 (0.16-1.54)	3.57-39.46 (0.11-1.31)	3.59-35.01 (0.12-1.17)	_
4.	*Ceratopteris thalictroides*	_	0.00-30.43 (0.00-1.01)	0.00-28.91 (0.00-0.96)	_
5.	*Cyperus distans*	_	_	_	2.76-6.09 (0.09-0.20)
6.	*Echinochloa stagnina*	5.09-59.31 (0.16-1.97)	4.54-57.27 (0.15-1.90)	5.84-61.00 (0.19-2.03)	1.73-51.49 (0.06-1.72)
7.	*Eichhornia crassipes*	4.53-23.19 (0.15-0.77)	3.24-23.54 (0.10-0.78)	2.06-24.30 (0.07-0.81)	2.05-23.41 (0.07-0.78)
8.	*Enhydra fluctuans*	1.05-12.27 (0.03-0.40)	4.96-12.27 (0.16-0.40)	0.92-17.68 (0.03-0.59)	_
9.	*Hydrilla verticillata*	_	0.77-18.84 (0.02-0.62)	1.83-20.59 (0.06-0.69)	1.74-15.94 (0.06-0.53)
10.	*Hygroryza aristata*	1.73-14.09 (0.05-0.46)	1.98-9.95 (0.06-0.33)	4.35-13.88 (0.15-0.46)	3.29-14.96 (0.11-0.49)
11.	*Ipomoea aquatica*	_	_	2.58-6.75 (0.09-0.22)	_
12.	*Leersia hexandra*	1.10-5.47 (0.03-0.18)	_	_	_
13.	*Ludwigia adscendens*	2.15-37.94 (0.07-1.26)	3.85-14.25 (0.12-0.47)	2.56-11.27 (0.09-0.38)	2.18-12.53 (0.07-0.42)
14.	*Marsilea quadrifoliata*	_	_	_	1.72-7.96 (0.06-0.26)
15.	*Nymphoides cristatum*	_	_	1.18-10.86 (0.04-0.36)	_
16.	*Nymphaea pubescens*	_	0.92-18.80 (0.03-0.61)	_	_
17.	*Phragmites karka*	0.70-5.04 (0.02-0.16)	_	_	_
18.	*Pistia stratiotes*	_	4.35-20.94 (0.14-0.69)	2.22-21.85 (0.07-0.73)	5.40-24.02 (0.18-0.80)
19.	*Pseudoraphis minuta*	4.81-9.82 (0.16-0.32)	_	_	_
20.	*Salvinia cucullata*	1.48-17.58 (0.04-0.58)	1.92-22.82 (0.06-0.76)	_	0.96-19.70 (0.03-0.66)
21.	*Zizania latifolia*	2.04-31.37 (0.06-1.04)	4.05-23.98 (0.13-0.79)	2.28-20.03 (0.08-0.67)	2.30-22.08 (0.08-0.74)
22.	*Other Species*	1.39-55.39 (0.04-1.84)	5.93-52.10 (0.19-1.73)	1.73-50.16 (0.06-1.67)	2.13-38.77 (0.07-1.29)
All Species (Combined)		1.60-167.29 (0.05-5.57)	2.44-183.19 (0.08-6.10)	1.76-170.03 (0.06-5.65)	0.96-140.36 (0.03-4.67)

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Table 2: variation in the monthly values of net primary productivity (gm^{-2} month^{-1}) of the macrophytes for the second year (Daily npp values in gm– 2 day– 1 are given in parenthesis.)

S. No.	Name of Species	Site I	Site II	Site III	Site IV
1.	*Alternanthera philoxeroides*	4.60-61.45 (0.15-2.05)	4.37-47.54 (0.14-1.58)	2.64-44.69 (0.08-1.48)	4.66-65.07 (0.16-2.17)
2.	*Brachiaria mutica*	4.66-11.69 (0.16-0.38)	_	_	_
3.	*Ceratophyllum demersum*	2.97-55.32 (0.09-1.84)	0.95-38.06 (0.03-1.26)	3.77-42.51 (0.12-1.41)	_
4.	*Ceratopteris thalictroides*	_	2.29-33.13 (0.07-1.10)	3.01-31.29 (0.10-1.04)	_
5.	*Cyperus distans*	_	_	_	2.06-7.01 (0.07-0.23)
6.	*Echinochloa stagnina*	5.19-44.64 (0.17-1.48)	2.0-43.28 (0.06-1.44)	2.10-52.81 (0.07-1.76)	1.09-51.38 (0.04-1.73)
7.	*Eichhornia crassipes*	2.62-23.94 (0.08-0.79)	2.01-30.07 (0.06-1.00)	2.72-10.98 (0.09-0.36)	0.76-28.85 (0.03-0.96)
8.	*Enhydra fluctuans*	4.12-14.97 (0.14-0.49)	3.25-18.92 (0.10-0.63)	1.51-32.17 (0.05-1.07)	_
9.	*Hydrilla verticillata*	_	1.13-17.71 (0.03-0.59)	2.65-22.38 (0.08-0.74)	0.63-10.97 (0.02-0.37)
10.	*Hygroryza aristata*	7.49-12.49 (0.25-0.42)	1.59-12.92 (0.05-0.43)	9.62-16.38 (0.32-0.54)	3.03-10.41 (0.10-0.35)
11.	*Ipomoea aquatica*	_	_	0.84-9.30 (0.03-0.31)	_
12.	*Leersia hexandra*	1.20-7.01 (0.04-0.23)	_	_	_
13.	*Ludwigia adscendens*	2.28-15.91 (0.07-0.53)	1.78-15.29 (0.05-0.50)	3.50-12.65 (0.11-0.42)	2.02-14.65 (0.07-0.49)
14.	*Marsilea quadrifoliata*	_	_	_	0.85-14.60 (0.03-0.49)
15.	*Nymphoides cristatum*	_	_	1.19-9.48 (0.04-0.32)	_
16.	*Nymphaea pubescens*	_	1.71-8.10 (0.05-0.27)	_	_
17.	*Phragmites karka*	1.78-8.96 (0.06-0.29)	_	_	_
18.	*Pistia stratiotes*	_	1.38-10.52 (0.04-0.35)	1.61-18.00 (0.05-0.60)	7.63-16.38 (0.25-0.55)
19.	*Pseudoraphis minuta*	2.91-5.68 (0.09-0.19)	_	_	_
20.	*Salvinia cucullata*	1.42-14.39 (0.05-0.48)	2.06-22.72 (0.06-0.75)	_	1.01-18.43 (0.03-0.61)
21.	*Zizania latifolia*	5.93-24.95 (0.19-0.82)	4.56-18.23 (0.15-0.60)	7.82-21.18 (0.26-0.71)	1.27-23.99 (0.04-0.80)
22.	*Other Species*	1.25-21.97 (0.04-0.73)	2.06-19.26 (0.06-0.64)	1.65-26.54 (0.06-0.88)	2.19-36.22 (0.07-1.21)
	All Species (Combined)	5.93-210.75 (0.19-7.02)	4.60-252.67 (0.15-8.42)	7.82-182.55 (0.26-6.09)	10.27-172.72 (0.34-5.76)

Table 3: Daily Net Primary Productivity Of The Macrophytes In Different Freshwater Ecosystems.

S. No.	***Ecosystem***	***Productivity (gm^{-2} day^{-1})***	***Authors***
1.	Kharungpat Lake, Manipur	0.03 – 6.10 (1st year) 0.15 – 8.42 (2nd year)	Present Study
2.	Pond Ecosystem, Bhagalpur	4.30	Nasar and Munshi, 1974
3.	Tropical Lakes	0.20 – 15.20	Likens, 1973
	Temperate Lakes	0.01–7.2	
	Alpine Lakes	0.002–0.9	
	Arctic Lakes	0.002–0.34	
4.	Eutrophic Lakes	1.20 – 16.00 >1.32	Wetzel, 1975,Colinvaux, 1986, Dodds (2002)
5.	Ramgarh Lake, Gorakhpur	2.50	Sinha, 1969
6.	Lekoda Lake, Ujjain	0.50	Vyas, 1973
7.	Manasbal Lake, Srinagar	2.70	Kaul, 1977
8.	Hazratbal Lake, Kashmir	0.80 – 1.86	Kaul *et.al.*, 1978
9.	Indrasagar tank, Udaipur	1.50	Dhakar, 1979
10.	Baghela tank, Udaipur	2.20	Sankhla, 1981
11.	Pichhola Lake, Udaipur	2.00	Billore and Vyas, 1982
12.	Gujar Lake, Jaunpur	4.00 – 31.90	Verma *et.al.,* 1982
13.	Dal Lake, Kashmir	5.26	Vass and Zutshi, 1983
14.	Fatehsagar tank, Udaipur	2.10	Paliwal, 1984
15.	Dal Lake, Kashmir	1.85 – 11.80	Kaul and Handoo, 1989
16.	Tropical Wetlands (B.H.U.), Varanasi	0.50	Shardendu and Ambasht, 1991
17.	Loktak Lake, Manipur	0.03 – 9.79 (Phumdi) 0.01 – 5.04 (Non-phumdi)	Devi, N.B., 1993
18.	Waithou Lake, Manipur	3.70 – 4.39	Devi, O.I., 1993
19.	Freshwater Lake, East Antarctica	0.0013-0.014	Ingole and Dhargalkar, 1998
20.	Utrapat Lake, Manipur	0.05 – 2.88	Devi, K.I., 1998
21.	Freshwater ecosystems, Canchipur, Manipur	0.07 – 4.38	Devi, Ch. U., 2000
22.	Temple tank, Kerala	0.16 – 2.61	Harikrishnan and Azis, 2000
23.	Mariut Lake, Egypt	1.98 – 6.38	Khalil, 2000
24.	Sanapat Lake, Manipur	1.58 – 3.22	Devi, Ch. B., 2001
25.	Ikop Lake, Manipur	0.06 – 4.93	Devi, Ch. N., 2002
26.	Poiroupat Lake, Manipur	0.01 – 4.00	Usha, Kh. 2002
27.	Awangsoipat Lake, Manipur	0.02 – 5.21	Devi, L.G. 2007
28.	Oksoipat Lake, Manipur	0.08 – 5.21	Devi, S.U., 2008

Table 4: Annual Net Primary Productivity of The Macrophytes In Different Freshwater Ecosystems.

Sl. No.	*Ecosystem*	*Productivity (gm^{-2} yr^{-1})*	*Authors*
1.	Kharungpat Lake, Manipur	682.64 – 891.13 (1st year) 702.49 – 840.45 (2nd year)	Present Study
2.	Silver Springs, Florida	621.00	Odum, 1957
3.	Swamp Vegetations, Assam	850.00	Bellamy, 1967
4.	BENCO pond (B.H.U.), Varanasi	345.00	Jha, 1968
5.	Ramgarh Lake, Varanasi	930.00 340.00	Sinha, 1969 Ambasht, 1971
6.	Tropical fresh waters	2000.00	Whittaker, 1970
7.	Temperate fresh water	80.00 500.00 – 800.00	Wassink, 1975 Westlake, 1975
8.	Dal Lake, Kashmir	3000.00 3,000.000 – 15,000.00 4,100.00	Kaul, 1977 Vass, 1980 Zutshi and Vass, 1982
9.	Manasbal Lake, Srinagar	9700.00 8,000 – 10,000.00	Kaul, 1977 Vass, 1980
10.	Gordhan Vilas tank, Udaipur	1265.21	Jain, 1978
11.	Indrasagar tank, Udaipur	504.32	Dhakar, 1979
12.	Gujar Lake, Jaunpur	628.00	Verma, 1979
13.	Baghela tank, Udaipur	748.31	Sankhla, 1981
14.	Pichhola Lake, Udaipur	691.00	Billore and Vyas, 1982
15.	Kolleru Lake, Andhra Pradesh	30.00 – 1,320.00	Seshavatharam and Venu, 1982
16.	Nainital Lake, Kumaun	666.00	Singh *et.al.*, 1982
17.	Naukuchiatal Lake, Kumaun	1226.00	Singh *et.al.*, 1982
18.	Udaipur Lakes, Udaipur	205.94 – 788.67	Vyas *et.al.*, 1989
19.	Tropical Lagoon De Rio Lake, Costa Rica	326.00	Goeke *et.al.*, 1991
20.	Mikolajskie lake, Poland	130.66	Hillbricht Illkowska, 1993
21.	Freshwater marsh Riparian wetlands Cold Temperate wetlands	2000–12000 1200–2600 480–3000	Mitsch and Gosselink, 1993
22.	Loktak Lake, Manipur	737.65 – 1240.64 (Phumdi) 181.37 – 358.92 (Non-Phumdi)	Devi, N.B. 1993
23.	Waithou Lake, Manipur	1350.51 – 1601.04	Devi, O.I., 1993
24.	Utrapat Lake, Manipur	2.97 – 265.46	Devi, K.I., 1998
25.	Fresh water ecosystems of Canchipur, Manipur	2.88.68 – 678.16	Devi, Ch. U., 2000
26.	Sanapat Lake, Manipur	242.64 – 316.88	Devi, Ch. B., 2001
27.	Lotic and Lentic Fresh water Ecosystems, Jharkhand	4.52 – 54.11	Kumari and Kumar, 2002
28.	Ikop Lake, Manipur	2.07 – 137.13	Devi, Ch. N. 2002, Devi, Ch. N. and Sharma, 2006
28.	Poiroupat Lake, Manipur	214.47 – 384.02	Usha, Kh., 2002
30.	Awangsoipat Lake, Manipur	486.59 – 850.28	Devi, L.G. 2007
31.	Oksoipat Lake, Manipur	196.85 – 756.33	Devi, S.U. 2008

Zizania latifolia recorded the daily net productivity values ranging from 0.04 to 0.82 gm^{-2} day^{-1} in the first year and 0.06 to 1.29 gm^{-2} day^{-1} in the second year. The present recorded values are found comparable with those reported by Devi, L.G. (2007) in Awangsoipat Lake, Manipur, with values ranging from 0.05 to 1.19 gm^{-2} day^{-1} and 0.45 to 0.94 gm^{-2} day^{-1} in the two consecutive years of study. *Ludwigia adscendens,* had daily net production ranging from 0.07 to 1.26 gm^{-2} day^{-1} in the first year and 0.05 to

0.53 gm^{-2} day^{-1} in the second year. The present recorded values are comparable with the values reported by various workers viz., Devi, O.I. (1993) in Waithou lake, Manipur (0.09 to 0.91 gm^{-2} day^{-1}, first year and 0.01 to 0.64 gm^{-2} day^{-1}, second year), Devi, Ch. U. (2000) in Freshwater Ecosystems of Canchipur, Manipur (0.09 to 0.91 gm^{-2} day^{-1}, first year and 0.01 to 0.64 gm^{-2} day^{-1}, second year), Devi, Ch. N. (2002) in Ikop lake, Manipur (0.01 to 0.97 gm^{-2} day^{-1}), Usha, Kh. (2002) in Poiroupat lake, Manipur (0.03 to 0.66 gm^{-2} day^{-1} in the first year and 0.02 to 0.67 gm^{-2} day^{-1} in the second year), Devi, L.G. (2007) in Awangsoipat lake, Manipur (0.16 to 0.78 gm^{-2} day^{-1}) and Devi, S.U. (2008) in Oksoipat lake, Manipur (0.06 to 0.72 gm^{-2} day^{-1} in the first year and 0.03 to 0.66 gm^{-2} day^{-1} in the second year).

For *Eichhornia crassipes*, the daily net production values varied from 0.07 to 0.78 gm^{-2} day^{-1} in the first year and 0.06 to 0.79 gm^{-2} day^{-1} in the second year. The present findings are found to be higher when compared to those reported by Usha, Kh. (2002) in Poiroupat Lake, Manipur (0.04 to 0.27 gm^{-2} day^{-1}. The present values are comparable to those reported by Devi, L.G. (2007) in Awangsoipat lake, Manipur (0.05 to 0.46 gm^{-2} day^{-1} in the first year and 0.02 to 0.93 gm^{-2} day^{-1} in the second year) and Devi, Ch. B. (2001) in Sanapat lake, Manipur (0.81 gm^{-2} day^{-1}).

The daily net productivity values for *Hydrilla verticillata* varied from 0.02 to 0.69 gm^{-2} day^{-1} in the first year and 0.03 to 0.59 gm^{-2} day^{-1} in the second year. The present observed values are comparable to those reported by Usha, Kh. (2002) in Poiroupat lake, Manipur (0.06 to 0.78 gm^{-2} day^{-1} in the first year and 0.06 to 0.75 gm^{-2} day^{-1} in the second year), Devi, Ch. U. (2000) in Freshwater Ecosystems of Canchipur, Manipur (0.02 to 0.53 gm^{-2} day^{-1}), Devi K.I. (198) in Utrapat lake, Manipur, (0.08 to 0.73 gm^{-2} day^{-1}). Lower values were recorded by Shardendu and Ambasht (1991) in Varanasi (0.13 gm^{-2} day^{-1}), Devi, O.I. (1993) in Waithou lake, Manipur (0.02 to 0.17 gm^{-2} day^{-1} and 0.01 to 0.42 gm^{-2} day^{-1} in the first and second year respectively). Higher values were reported by Devi, N.B. (1993) in Loktak lake, Manipur (0.02 to 6.58 gm^{-2} day^{-1}), Devi, L.G. (2007) in Awangsoipat lake, Manipur (0.10 to gm^{-2} day^{-1} in the first year and 0.20 to 1.13 gm^{-2} day^{-1} in the second year), Devi, S.U. (2008) in Oksoipat lake, Manipur (0.02 to 1.78 gm^{-2} day^{-1} in the first year and 0.03 to 1.70 gm^{-2} day^{-1} in the second year).

Salvinia cucullata recorded the daily net production values ranging from 0.03 to 0.78 gm^{-2} day^{-1} in the first year and 0.05 to 0.75 gm^{-2} day^{-1} in the second year. The present observed values are in conformity with the values reported by Devi, Ch. U. (2000) in Freshwater Ecosystems of Canchipur, Manipur (0.16 to 0.55 gm^{-2} day^{-1} in the first year and 0.19 to 0.49 gm^{-2} day^{-1} in the second year). Devi, S.U. (2008) in Oksoipat lake, Manipur reported comparable values in the range of 0.04 to 0.64 gm^{-2} day^{-1} (first year) and 0.06 to 0.94 gm^{-2} day^{-1} (second year) for *Salvinia natans*. Lower values were observed in Sanapat lake, Manipur (0.01 to 0.03 gm^{-2} day^{-1}) by Devi, Ch. B. (2001) and Poiroupat lake, Manipur by Usha, Kh. (2002) with values of 0.01 to 0.18 gm^{-2} day^{-1} in the first year and 0.03 to 0.32 gm^{-2} day^{-1} in the second year. Higher values were reported by Devi, N.B. (1993) in Loktak lake, Manipur (0.06 to 2.49 gm^{-2} day^{-1}), Devi, L.G. (2007) in Awangsoipat lake, Manipur with values of 0.02 to 1.28 gm^{-2} day^{-1} in the first year and 0.10 to 0.89 gm^{-2} day^{-1} in the second year.

The daily net production of *Nymphoides cristatum* varied from 0.04 to 0.36 gm^{-2} day^{-1} in the first year and 0.04 to 0.32 gm^{-2} day^{-1} in the second year. Higher values are reported by Devi, L.G. (2007) in Awangsoipat lake, Manipur (0.01 to 0.91 gm^{-2} day^{-1}), Devi, S.U. (2008) in Oksoipat lake, Manipur (0.01 to 0.64 gm^{-2} day^{-1} and 0.04 to 0.96 gm^{-2} day^{-1} in the first and second year respectively). Comparable values were reported by Devi, K.I. (1998) in Utrapat Lake, Manipur (0.10 to 0.48 gm^{-2} day^{-1}. Devi, Ch. U. (2000) observed very low values of 0.03 to 0.62 gm^{-2} day^{-1} for *Nymphaea pubescens* in the Freshwater Ecosystems of Canchipur, Manipur while Devi, Ch. B. (2001) in Sanapat Lake, Manipur also reported a very low value of 0.05 gm^{-2} day^{-1}.

The daily net production of *Pistia stratiotes* ranged from 0.07 to 0.80 gm^{-2} day^{-1} in the first year and 0.04 to 0.60 gm^{-2} day^{-1} in the second year. For *Enhydra fluctuans*, the daily net production varied from 0.03 to 0.40 gm^{-2} day^{-1} in the first year and 0.05 to 0.49 gm^{-2} day^{-1} in the second year. The present findings are comparable with those reported by Devi, L.G. (2007) in Awangsoipat lake, Manipur (0.10 to 0.46 gm^{-2} day^{-1} in the first year and 0.03 to 0.21 gm^{-2} day^{-1} in the second year). The net production of *Hygroryza* *aristata* varied from 0.06 to 0.46 gm^{-2} day^{-1} in the first year and 0.05 to 0.43 gm^{-2} day^{-1} in the second year. The present findings are slightly lower than those reported by Devi, S.U. (2008) in Oksoipat lake, Manipur (0.03 to 0.79 gm^{-2} day^{-1} in the first year and 0.08 to 0.68 gm^{-2} day^{-1} in the second year). However the present values are comparable to those reported by Devi, L.G. (2007) in Awangsoipat lake, Manipur (0.02 to 0.32 gm^{-2} day^{-1} in the first year and 0.04 to 0.51 gm^{-2} day^{-1} in the second year) and Usha, Kh. (2002) in Poiroupat lake, Manipur (0.06 to 0.35 gm^{-2} day^{-1} in the first year and 0.11 to 0.46 gm^{-2} day^{-1} in the second year).

For *Ceratopteris thalictroides* the daily net primary production ranged from 0.96 to 1.01 gm^{-2} day^{-1} in the first year and 0.07 to 1.10 gm^{-2} day^{-1} in the second year. The daily net production of *Marsilea quadrifoliata* varied from 0.06 to 0.22 gm^{-2} day^{-1} in the first year and 0.03 to 0.49 gm^{-2} day^{-1} in the second year. The present findings are comparable to those reported by Devi, S.U. (2008) in Oksoipat lake, Manipur (0.03 to 0.49 gm^{-2} day^{-1} in the first year and 0.01 to 0.95 gm^{-2} day^{-1} in the second year).

The daily net production of *Ipomoea aquatica* ranged from 0.09 to 0.22 gm^{-2} day^{-1} in the first year and 0.03 to 0.31 gm^{-2} day^{-1} in the second year. The present findings are comparable with the values reported by Usha, Kh. (2002) in Poiroupat lake, Manipur (0.06 to 0.34 gm^{-2} day^{-1} in the first year and 0.02 to 0.50 gm^{-2} day^{-1} in the second year). Devi, L.G. (2007) in Awangsoipat lake, Manipur also reported similarly comparable values ranging from 0.02 to 0.44 gm^{-2} day^{-1} in the first year and 0.08 to 0.42 gm^{-2} day^{-1} in the second year. The daily net production of 'other species' ranged from 0.04 to 1.84 gm^{-2} day^{-1} in the first year and 0.04 to 0.88 gm^{-2} day^{-1} in the second year. The present findings are higher than those reported by Devi, S.U. (2008) in Oksoipat lake, Manipur (0.03 to 0.60 gm^{-2} day^{-1} in the first year and 0.02 to 0.43 gm^{-2} day^{-1} in the second year).

The daily net production of all species (combined) varied from 0.03 to 6.10 gm^{-2} day^{-1} and 0.15 to 8.42 gm^{-2} day^{-1} in the first and second year respectively. The present values are found to be in conformity with those of Devi, N.B. (1993) in Loktak lake, Manipur with values ranging from 0.03 to 9.79 gm^{-2} day^{-1}. The present values are found to be lower when compared with those of Likens, (1973) in Tropical lakes (0.2 – 15.20 gm^{-2} day^{-1}), Wetzel (1975) and Colinvaux (1986) in Eutrophic lake (1.2 to 16.0 gm^{-2} day^{-1}), Verma *et.al.,* (1982) in Gujar lake, Jaunpur (4.0 to 31.90 gm^{-2} day^{-1}), Kaul and Handoo (1989) in Dal lake Kashmir (1.85 to 11.80 gm^{-2} day^{-1}) etc. It is observed that the values in the present study agree with those of temperate lakes but they are superior to those in the Alpine and Arctic lakes reported earlier by Likens (1973). However, the present findings are found to be higher when compared with those of Devi, O.I. (1993) in Waithou lake, Manipur (3.70 to 4.39 gm^{-2} day^{-1}), Devi, K.I. (1998) in Utrapat lake, Manipur (0.05 to 2.88 gm^{-2} day^{-1}), Devi, Ch. U. (2000) in Freshwater Ecosystems of Canchipur, Manipur (0.07 to 4.38 gm^{-2} day^{-1}), Khalil (2000) in Mariut lake, Egypt (1.98 to 6.38 gm^{-2} day^{-1}), Devi, Ch. B. (2001) in Sanapat lake, Manipur (1.58 to 3.22 $gm^{-2}day^{-1}$), Devi, Ch. N. (2002) in Ikop lake Manipur (0.06 to 4.93 gm^{-2} day^{-1}), Usha Kh. (2002) in Poiroupat lake, Manipur (0.01 to 4.00 gm^{-2} day^{-1}), Devi, L.G. (2007) in Awangsoipat lake, Manipur (0.02 to 5.21 gm^{-2} day^{-1}), Devi, S.U. (2008) in Oksoipat lake, Manipur (0.08 to 5.21 gm^{-2} day^{-1}) etc. A comparative account of the Daily net primary productivity of the macrophytes in the different wetlands has been furnished in Table 3.

Annual Net Primary Productivity

In the present investigation, the total annual net production of all species (combined) varied from 682.64 to 891.13 gm^{-2} yr^{-1} and 702.49 to 840.45 gm^{-2} yr^{-1} in the first and second year respectively. The values in the present study are found within the range of annual productivity for the cold temperate wetlands observed by Mitsch and Gosselink (1993). The present values are also found to be in conformity to those reported by Westlake (1975) in Temperate fresh waters (500 to 800 gm^{-2} yr^{-1}), Devi, L.G. (2007) in Awangsoipat lake, Manipur (486.59 to 850.28 gm^{-2} yr^{-1}), Vyas *et.al,* (1989) in Udaipur lakes with total annual net production of 205.94 to 788.67 gm^{-2} yr^{-1}, Devi, S.U. (2008) in Oksoipat lake, Manipur (196.85 to 744.33 gm^{-2} yr^{-1} in the first year and 228.82 to 756.33 gm^{-2} yr^{-1} in the second year).

The present findings are found to be lower than those reported by Zutshi and Vass, (1982) in Dal lake, Kashmir (4100.00 gm^{-2} yr^{-1}), Singh *et.al.,* (1982) in Naukuchiatal lake, Kumaun (1226 gm^{-2} yr^{-1}), Vass

(1980) in Manashbal lake, Srinagar (9700.00 gm^{-2} yr^{-1}), Devi, O.I. (1993) in Waithou lake, Manipur (1350.51 to 1601.04 gm^{-2} yr^{-1}), Devi, N.B. (1993) in Loktak lake, Manipur (737.64 to 1240.64 gm^{-2} day^{-1}).

The present findings are found to be higher than those reported by Jha (1968) and Ambasht (1971) in the ponds of Varanasi (345.00 to 350.00 gm^{-2} yr^{-1}), Verma (1979) in Gujar Lake, Jaunpur (628.00 gm^{-2} yr^{-1}), Singh *et.al.*, (1982) in Nainital lake, Kumaon (666.00 gm^{-2} yr^{-1}). Similarly, lower values of annual net production were reported by a number of workers viz., Shardendu and Ambasht (1991) in tropical wetlands (179.00 gm^{-2} yr^{-1}), Hillbricht Illkowsha (1993) in Kikolajskie Lake, Poland (130.66 gm–2 yr–1. Kumari and Kumar (2002) in the different ponds of Jharkhand reported low annual productivity values ranging from 4.52 gm^{-2} yr^{-1} in Hizlaghat to 54.11 gm^{-2} yr^{-1} at Singhaara pond.

Lower values of annual net production were also reported by number of workers in various lakes in Manipur viz., Devi, K.I. (1998) in Utrapat lake (2.97 to 265.46 $gm^{-2}yr^{-1}$), Devi, Ch. U. (2000) in Freshwater Ecosystems of Canchipur, Manipur (288.68 to 678.16 gm^{-2} yr^{-1}), Devi, Ch. B. (2001) in Sanapat lake, Manipur (242.64 to 316.88 gm^{-2} day^{-1}), Devi, Ch. N. (2002) in Ikop lake, Manipur (2.07 to 137.13 gm^{-2} day^{-1}), Usha, Kh. (2002) in Poiroupat lake, Manipur (214.47 to 384.02 gm^{-2} yr^{-1}). Comparable values of Annual Net Productivity of the macrophytes in different Freshwater Ecosystems have been presented in Table 4.

Conclusion

In the light of the discussions made the present lake having annual net primary productivity of 682.64 to 891.13 gm^{-2} yr^{-1} is found to be markedly polluted and hence it may be inferred that the lake in the present study is in Eutrophic state. According to the observations of some leading ecologists, the magnitudes of primary productivity of the freshwater ecosystems exhibit close relationships with the degree of eutrophication. Rodhe (1969) had quite earlier opined that lakes having gross productivity over 75 g Cm^{-2} yr^{-1} are naturally eutrophic whereas those lakes which have gross productivity values above 350 g Cm^{-2} yr^{-1} (equivalent to 700 g dry matter m^{-2} yr^{-1}) are indicative of artificial or cultural eutrophication with high degree of pollution. Likens (1973) viewed that a freshwater body may become culturally eutrophic when the rate of net primary production exceeds 150 g Cm^{-2} yr^{-1} or 300 g dry matter m^{-2} yr^{-1}. Wetzel (1975) also reported that a lake becomes eutrophic when the daily production ranges from 600 to 8000 mg $Cm^{-2}day^{-1}$ equivalent to 1.2 to 16.0 g dry matter m^{-2} day^{-1}. According to Moss (1989), high production rates have close relationships with the degree of cultural eutrophication which is mainly caused by additional input of sewage-borne phosphates and run-off nitrates from catchment areas. According to Dodds (2002) different levels of productivity signify different Eutrophic status viz., Oligotrophic with productivity upto 300 mg Cm^{-2} day^{-1}, Mesotrophic, 300 to 600 mg cm^{-2} day^{-1} and over 660 mg cm^{-2} day^{-1} for Eutrophic lakes.

The lake is naturally aging and it is under heavy environmental stress due to human encroachments, conversion of low lying areas into piscicultural farms, disposal of untreated domestic sewage, leaching of synthetic chemical fertilizers etc. Hence, the trophic status of the lake has been assigned to Eutrophic state, steadily approaching towards Hypertrophy. This calls for the necessity of proper planning and processing of requisite remedial activity to protect and conserve the Kharungpat Lake from further deterioration.

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