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Inventory of the Aquatic Macrophytes in Lake Kharungpat, India

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Abstract
The present study has been undertaken in Lake Kharungpat situated in Manipur state, India. The focal objective of the study is to evaluate the quantitative characters of the aquatic macrophytes viz., frequency, density, abundance, abundance by frequency (A/F) ratios and importance value index (IVI). During the whole study period, a total of 54 macrophytic plant species belonging to 28 families were found distributed in the lake. The aquatic plant species recorded were grouped into different categories viz., submerged (7 species), rooted with floating leaves (6 species), free floating (8 species) and emergent (33 species) respectively. *Alternanthera philoxeroides, Azolla pinnata, Brachiaria mutica, Ceratophyllum demersum, Echinochloa stagnina, Eichhornia crassipes, Enhydra fluctuans, Hygroryza aristata, Ludwigia adscendens, Pistia stratiotes, Salvinia cucullata* and *Zizania latifolia* were the dominant species found to occur in all the study sites during the entire study period. The maximum frequency was exhibited by *Echinochloa stagnina* (85%), whereas the maximum density value was shown by *Ceratophyllum demersum* (213.60 plants m^{-2}). The highest abundance value was exhibited by *Echinochloa stagnina* (506.67 plants m^{-2}). The higher ranges of A/F ratios were reported in some species viz., *Alternanthera philoxeroides* (0.44), *Echinochloa stagnina* (0.42), *Azolla pinnata* (0.38) etc. *Alternanthera philoxeroides* (42.41) recorded peak value of importance value index (IVI). The analysis of variance (ANOVA) for all the aquatic macrophytes reported from the lake indicates that there is no significant variation within the four study sites in terms of distribution. However, F-test result indicates significant variation in the quantitative characters between the different macrophytic plant species of the lake.
Keywords: inventory, aquatic macrophytes, quantitative, Lake Kharungpat, India.

1. Introduction

Macrophytes usually includes any plants which are observable by the naked eye and always identifiable when observed (Homes & Whitton, 1977). Macrophytes are an important component of the aquatic ecosystem and major changes in the abundance of individual species and community composition usually provide valuable information on the reason on how and why an ecosystem might be changing. Macrophytes are also valued as an important means for indirectly monitoring the water quality for instance, eutrophication can bring about change in the species composition and a loss of species diversity. At the same time, macrophytes also affect the physical, chemical and biological characters of the lake, and are affected by a group of factors such as lake Morphometry, water chemistry and biological characters of the lake (Lacoul & Freeman, 2006).

The state of Manipur has been included under the Indo-Burma Biodiversity hotspot region of the world along with Loktak Lake, India (a Ramsar site). The assessments of the Physico-chemical characteristics of the freshwater environment are essential to understand the distribution and productivity of aquatic macrophytes in the freshwater ecosystems. Some of the earlier studies on Phytosociology, Biomass and Primary Productivity, Physico-chemical characteristics of water are not adequate enough to compile a composite ecological database of the freshwater ecosystems of the country. Some of the relevant earlier works which have been carried out by a number of researchers at national and global levels are Devi, (1993), Melzer, (1999), Hanlon, et al., (2000), Devi, (2007), Devi, (2008), Usha & Sharma (2008), Cheruvelil & Soranno, (2008), Nurminen & Horppila, (2009), Mormul, et al., (2010), Usha, et.al., (2010a, 2010b), Singh, et. al., (2010a, 2010b, 2010c), Singh, et. al., (2011), Singh & Sharma, (2012), Singh, K.K. et. al., (2012), Soranno, et. al., (2011), Usha, et. al., (2012), Kanninen, et al., (2012), Singh & Sharma, (2013) etc.

In consonance with the efforts taken up by the International Biological Programme (IBP) and Man and the Biosphere Programme (MAB), Convention on Biological Diversity (CBD), Ramsar Convention, National Programme for Wetland Conservation (NPWC) of the Ministry of Environment and Forest (MoEF), Goverment of India (GoI), Inventory of the aquatic macrophytes in Lake Kharungpat has been undertaken. This study would serve as an important prerequisite for assessment of the distribution of the aquatic macrophytes of the lake. In the light of the above reasons, the present study has been carried out with the main objectives to evaluate the

quantitative characters like frequency, density, abundance, abundance by frequency (A/F) ratios and importance value index (IVI) of the aquatic macrophytes found in the lake at regular intervals during the study periods.

2. Methods

For the present investigation, the lake was divided into four study sites representing as Site I, II, III and IV which are locally named as *Panchao, Pangalpat, Kambong Leiram and Kharungpat Khong* respectively. The aquatic macrophytic plant samples were collected at regular monthly intervals during the period January, 2008 to December, 2009 from the different study sites. The sampling technique used for inventory of the aquatic macrophytes was the standard method as described by Curtis (1959) and Misra (1968). The quantitative analysis comprises frequency, density, abundance, abundance to frequency ratio, relative frequency, relative density, relative abundance and importance value index (IVI). Assessing of the different quantitative characters were done by using a square quadrat of 25 cm × 25 cm in dimension and in each study site not less than 20 quadrats were sampled randomly (Ambasht, 1970).

2.1. Description of the Study Sites

Lake Kharungpat is situated in Thoubal district of Manipur state, India. The lake is located in south western portion of the district at a distance of about 30 km. from Imphal (capital city of Manipur). The 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 49.98 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. The study site map of the lake has been presented in Fig.1.

2.2. Calculation of Quantitative Characters

$$\text{Frequency (\%)} = \frac{\text{No. of quadrats in which the species occurs}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Density/quadrat} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats studied}}$$

$$\text{Abundance/quadrat} = \frac{\text{Total number of individuals of a species in all the quadrats}}{\text{Total number of quadrats in which the species occurs.}}$$

$$\text{A/F Ratio} = \frac{\text{Abundance of a species}}{\text{Frequency of the same species}}$$

$$\text{Importance Value Index (IVI)/300} = \text{Relative Frequency (\%)} + \text{Relative Density (\%)} + \text{Relative Abundance (\%)}.$$

2.3. Statistical and Data Analysis

The statistical analysis is carried out by using SPSS Ver-20 and the statistical tools like ANOVA (Analysis of Variance) and Box Plot techniques are used for interpretation of the findings. ANOVA is done for quantitative characters viz., frequency, density, abundance, A/F ratio and IVI of the aquatic macrophytes between different study sites of the lake and also within different species of the lake. Box Plot is used to represent the distribution of the different macrophytic species recorded from the lake.

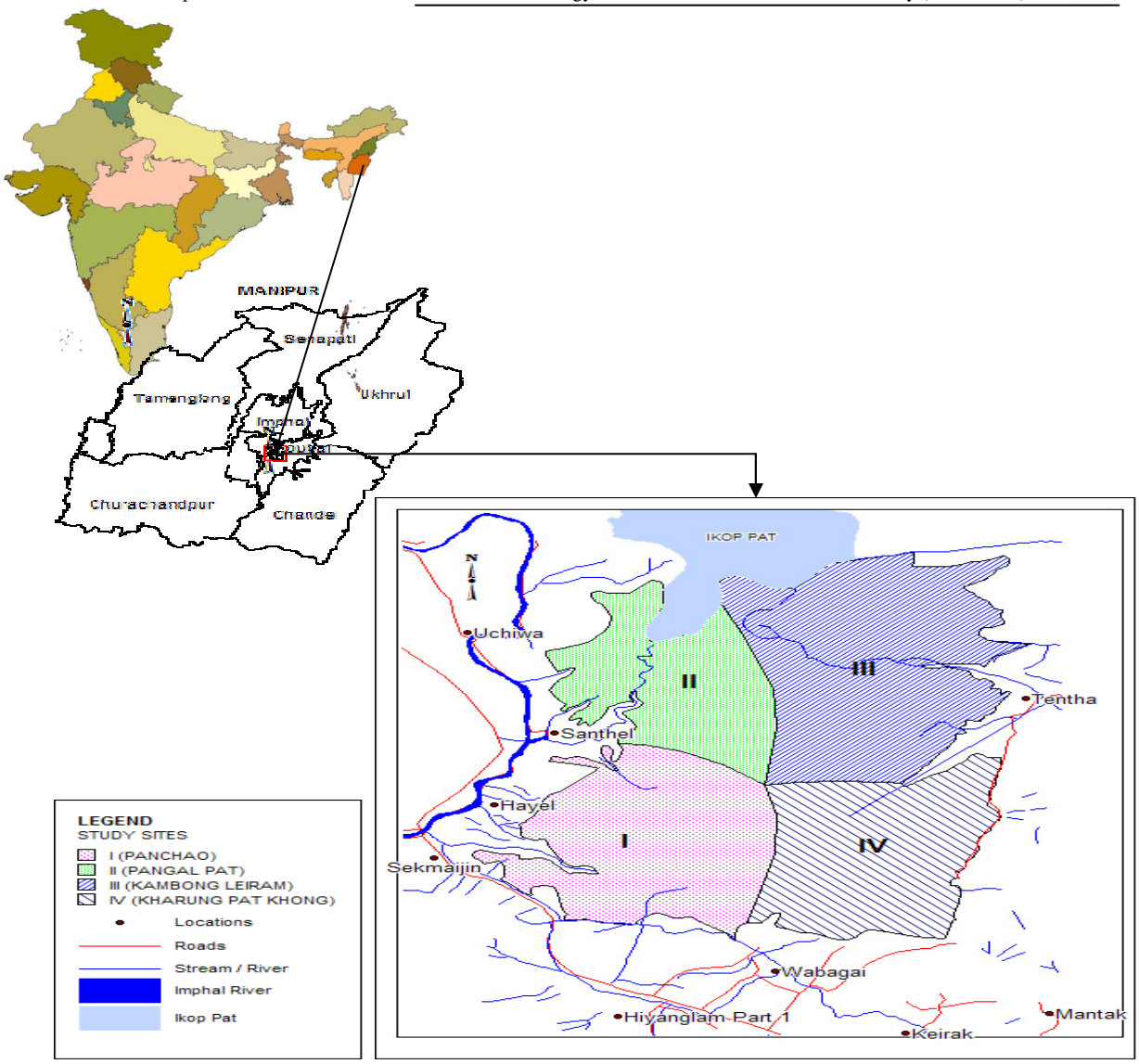

Figure 1. Map of Lake Kharungpat, India showing the different study sites.

3. Results

A total of 54 aquatic macrophytes belonging to 28 families were found distributed in the lake. Out of total 54 species recorded, Poaceae family has shown the presence of maximum number of species i.e. 14 species contributing to 25.92% which was then followed by families like Cyperaceae, Nymphaceae and Polygonaceae with 3 species each contributing to 5.55%. Other families like Alismataceae, Amaranthaceae, Convolvulaceae, Hydrocharitaceae, Lentibulariaceae, Pontederiaceae and Salvinaceae had 2 species each contributing to 3.70%. The remaining families viz., Apiaceae, Araceae, Asteraceae, Azollaceae, Ceratophyllaceae, Ceratopteridaceae, Characeae, Commelinaceae, Lemnaceae, Marsileaceae, Menyanthaceae, Mimosaceae, Nelumbonaceae, Onagraceae, Potamogetonaceae, Ranunculaceae, and Trapaceae comprised 1 species each constituting 1.85% (Fig. 2A). The list of aquatic macrophytes found in Lake Kharungpat are furnished in Appendix-1.

The aquatic macrophytes found in the lake were categorized into four main sub-categories viz., (a) submerged (b) rooted with floating leaves (c) free-floating (d) emergent groups. Under submerged group 7 species (12.96%) were reported. *Ceratophyllum demersum, Hydrilla verticillata, Potamogeton crispus, Utricularia exoleta, Utricularia flexuosa* were restricted to shallow areas where light is abundantly available upto the bottom and such plants usually have long stems with dissected leaves. Altogether 6 species belonging to rooted with floating leaves were reported viz., *Euryale ferox, Nymphoides cristatum, Nymphaea stellata, Trapa bispinosa* etc. In the free-floating category 8 species were recorded viz., *Azolla pinnata, Ceratopteris thalictroides, Eicchornia crassipes, Neptunia prostrata, Pistia stratiotes, Salvinia cucullata* etc. The maximum numbers of 33 species

were recorded under the emergent group viz., *Echinochloa stagnina, Enhydra fluctuans, Ludwigia adscendens, Hygroryza aristata, Ipomoea aquatica. Zizania latifolia, Phragmites karka, Pseudoraphis minuta* etc. The percentage compositions of the different macrophytic species were found maximum in the emergent group (61.11%), which was then followed, by the free-floating species (14.81%) and submerged species (12.96%). The lowest percentage (11.11%) was contributed by rooted and floating leaved species (Fig.2B).

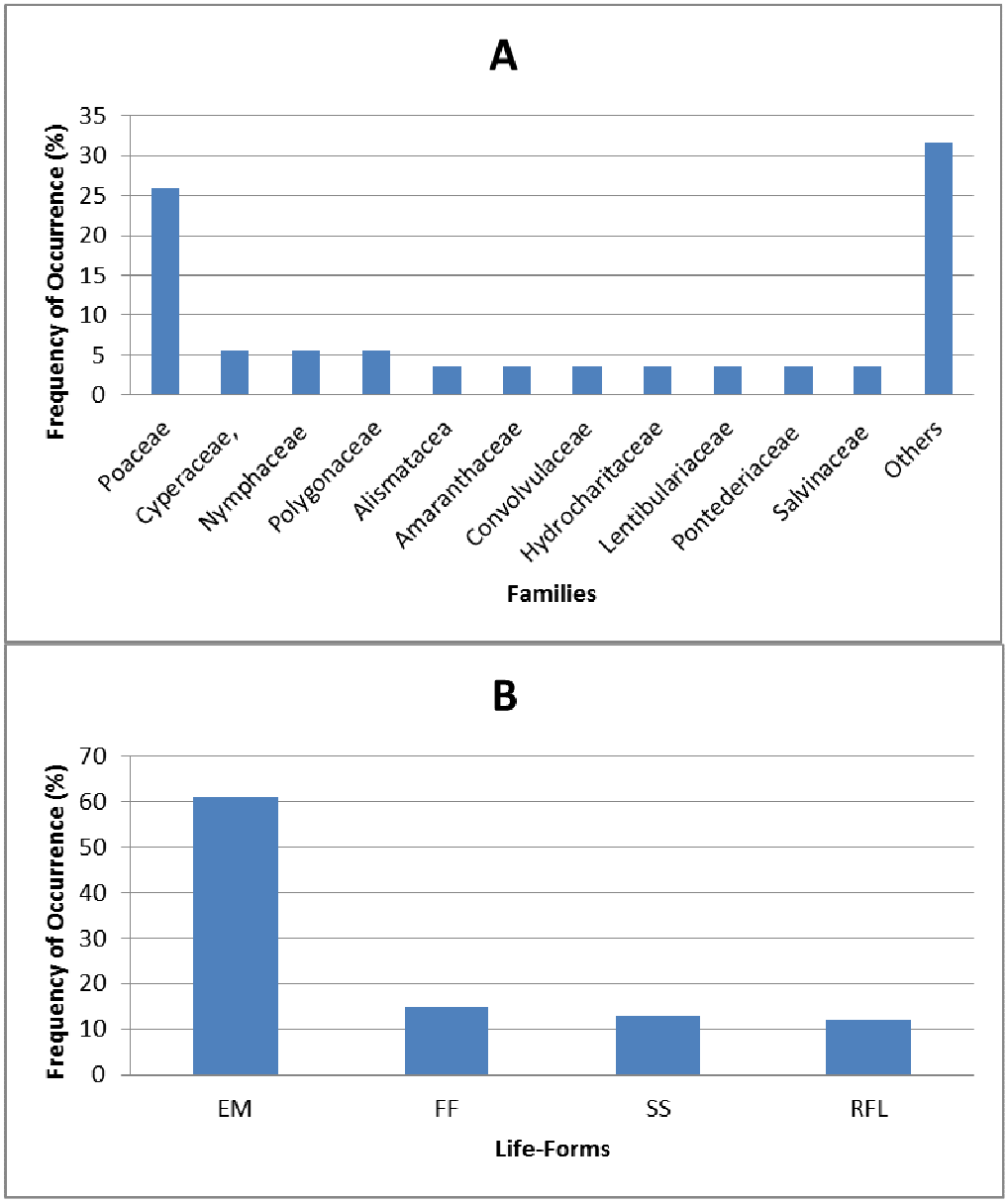

Figure 2 (A). Frequency of Family Occurrence recorded from Lake Kharangpat, India; Others families were included in the column "Others".
Figure 2 (B). Life-forms recorded from Lake Kharangpat, India; Emergent (Em), Free floating (FF), Submerged Species (SS), Rooted with floating leaves (RFL);

Table 1. ANOVA of Aquatic Macrophytes in the different study sites of Lake Kharungpat, India

Parameter	Study Sites	N	Mean ± S.E.	95% Confidence Interval		Minimum	Maximum	F	P-value
				Lower Bound	Upper Bound				
Frequency	1	54	13 ± 2	9	17	0	55	0.222	0.877
	2	54	12 ± 2	8	16	0	50		
	3	54	14 ± 2	10	18	0	55		
	4	54	12 ± 2	8	17	0	63		
	Total	216	13 ± 1	11	15	0	63		
Density	1	54	15.26 ± 3.15	8.94	21.58	0	111	0.087	0.967
	2	54	16.00 ± 3.28	9.42	22.59	0	89		
	3	53	17.00 ± 3.41	10.17	23.84	0	122		
	4	54	14.78 ± 3.26	8.24	21.33	0	114		
	Total	215	15.76 ± 1.63	12.55	18.96	0	122		
Abundance	1	54	49.53 ± 8.74	31.99	67.06	0	324	0.233	0.873
	2	54	50.05 ± 9.25	31.50	68.60	0	251		
	3	54	55.13 ± 8.89	37.29	72.97	0	325		
	4	54	44.54 ± 8.97	26.54	62.53	0	318		
	Total	216	49.81 ± 4.46	41.02	58.60	0	325		
A/F ratio	1	54	0.09 ± 0.011	0.07	0.11	0	0.26	0.504	0.68
	2	54	0.08 ± 0.012	0.05	0.10	0	0.27		
	3	54	0.10 ± 0.012	0.07	0.12	0	0.34		
	4	54	0.08 ± 0.013	0.05	0.11	0	0.39		
	Total	216	0.09 ± 0.006	0.07	0.10	0	0.39		
IVI	1	54	4.60 ± 0.78	3.08	6.12	0	25	0.022	0.995
	2	54	4.87 ± 0.86	3.15	6.59	0	22		
	3	54	4.80 ± 0.72	3.35	6.25	0	24		
	4	54	4.67 ± 0.90	2.87	6.47	0	29		
	Total	216	4.74 ± 0.40	3.94	5.53	0	29		

Note: S.E. = standard error; C.I. = Confidence Interval; Units-(Frequency - %; Density and Abundance- Plants m/sq)

During the present investigation the maximum values of frequency ranges were exhibited by *Echinochloa stagnina* (15 to 85%) followed by *Alternanthera philoxeroides* (10 to 80%), *Ceratophyllum demersum* (10 to 75%) respectively. The maximum value of density was shown by *Ceratophyllum demersum* with values ranging from 13.60 to 213.60 plants m^{-2}. The maximum abundance value was shown by *Echinochloa stagnina* (96.0 to 506.67 plants m^{-2}). The peak value of IVI varied from 16.10 to 42.41 in *Alternanthera philoxeroides.*

The mean frequency of any one of the species found in one quadrat is 13 with standard deviation 1 and 95% C.I. (11, 15). The density of a particular species concentrated in one quadrat is found to be 15.76 plants m^{-2} with standard error (S.E.) 1.63 and 95% C.I. (12.55, 18.96). Further, it is found that the mean abundance of any species in a study area is 49.81 plants m^{-2} with standard error of 4.46 and 95% C.I. (41.02, 58.60) and thus the ratio of abundance to frequency (A/F) is 0.09 and S.E. 0.006 and 95% C.I. (0.07, 0.10). The mean IVI of the study area for all species is 4.74 with S.E. 0.40 and 95% C.I. (3.94, 5.53). The analysis of variance for all the aquatic macrophytic plant species reported from the different study sites of the lake are presented in Table 1. The F-test result indicates that there is no variation on the availability of the different aquatic macrophytes in the four study sites with respect to the various quantitative parameters.

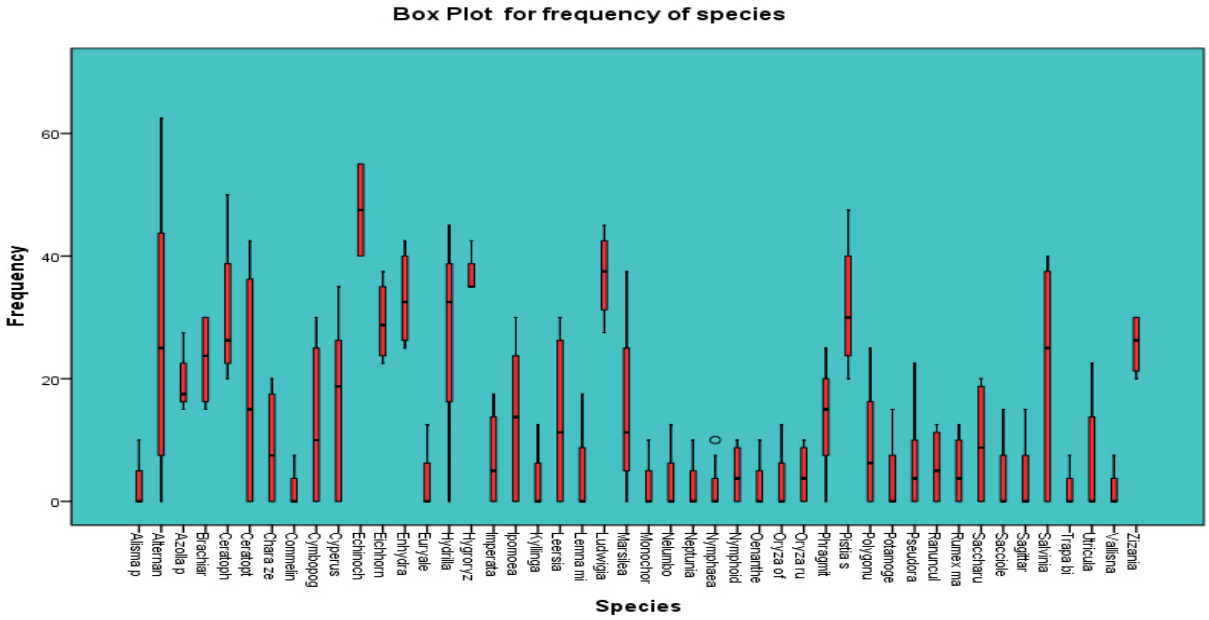

Figure 3. Box Plot for Frequency (%) of the Aquatic Macrophytes in Lake Kharungpat, India

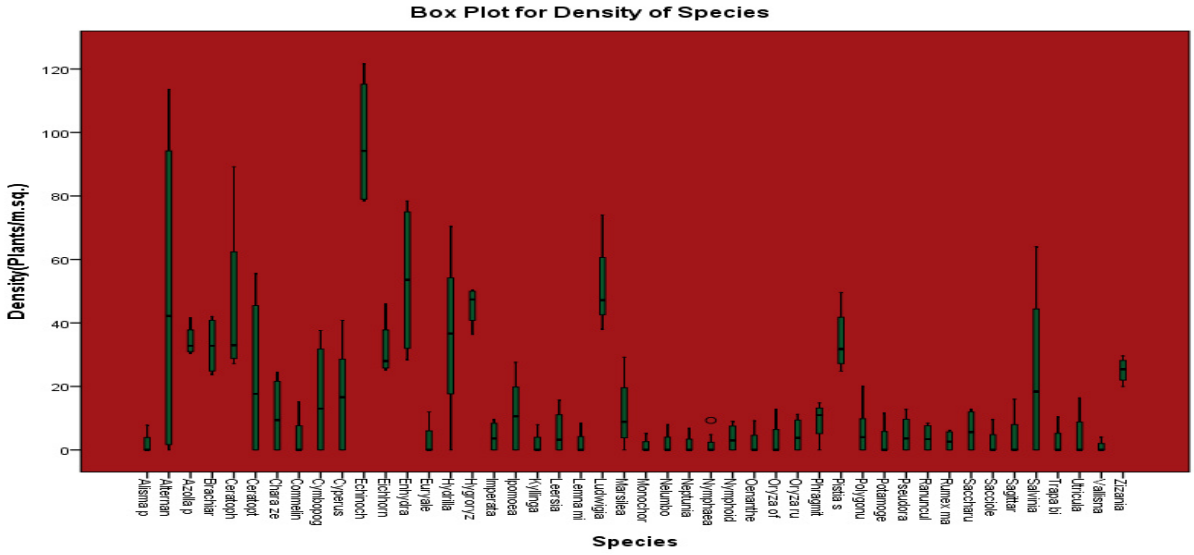

Figure 4. Box Plot for Density (Plants/m.Sq) of the Aquatic Macrophytes in Lake Kharungpat, India

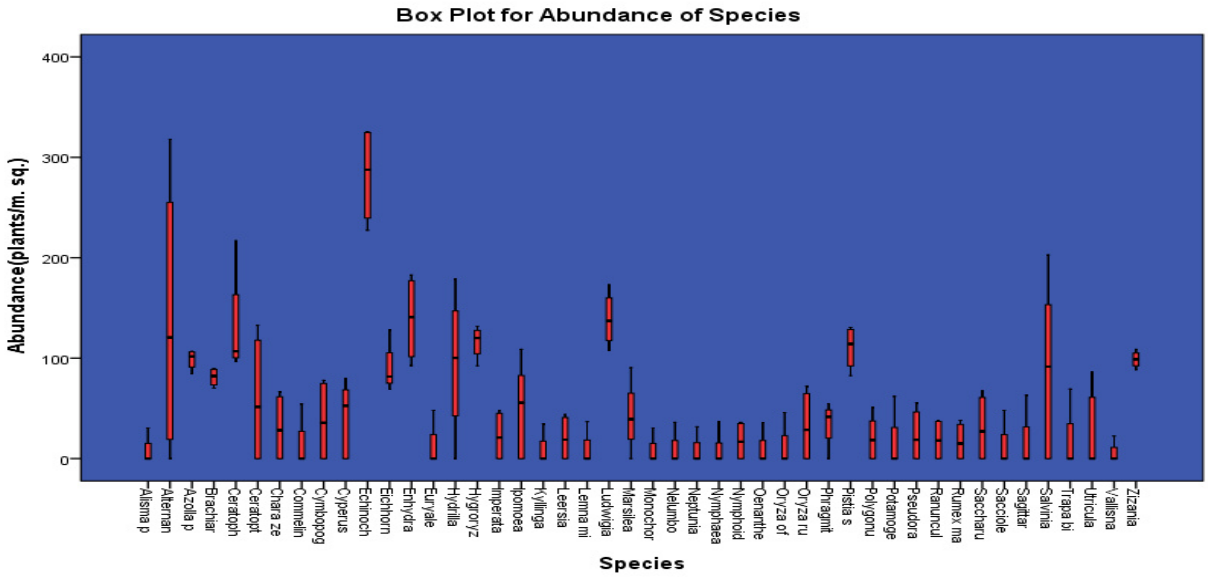

Figure 5. Box Plot for Abundance (Plants/m.Sq) of the Aquatic Macrophytes in Lake Kharungpat, India

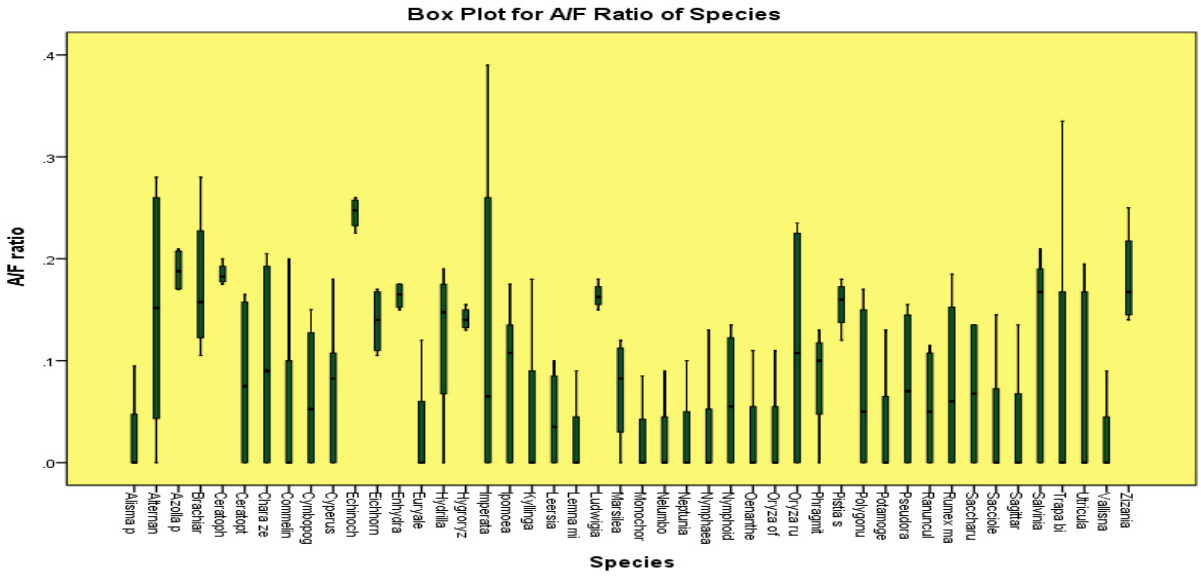

Figure 6. Box Plot for A/F Ratios of the Aquatic Macrophytes in Lake Kharungpat, India

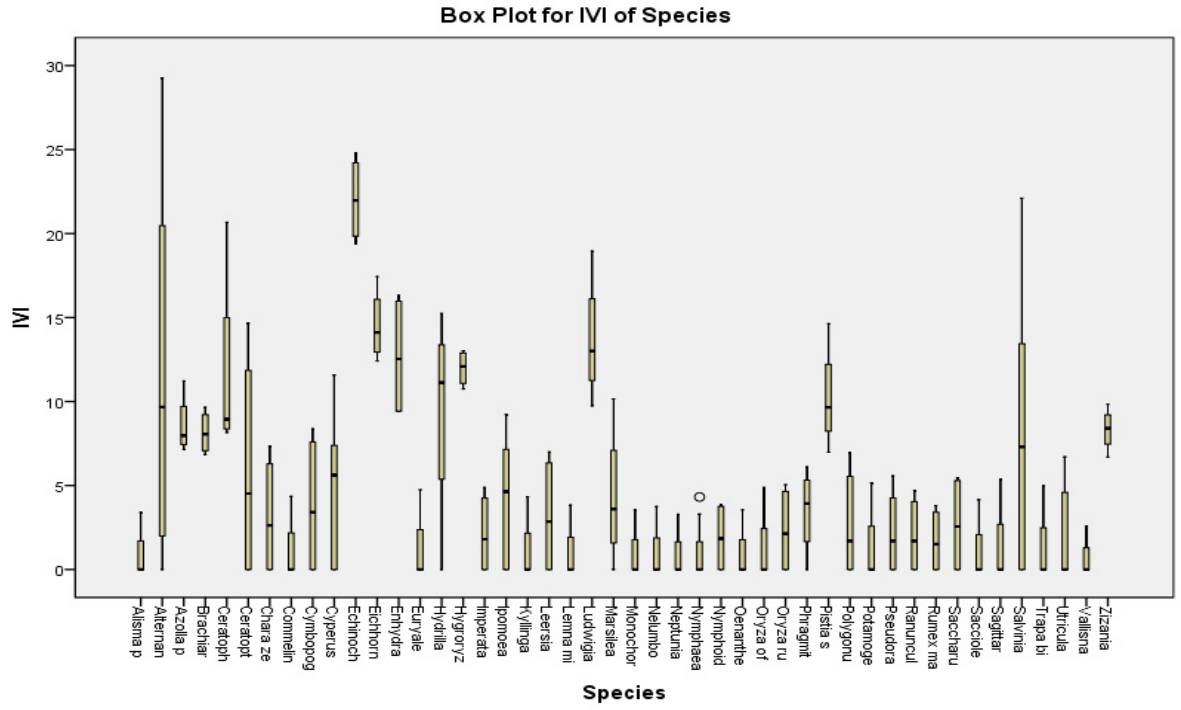

Figure 7. Box Plot for IVI of the Aquatic Macrophytes in Lake Kharungpat, India

Table 2. ANOVA for the different Aquatic Macrophytes of Lake Kharungpat, India

Parameters	Source of variation	Sum of Squares	d.f.	Mean Sum Squares	F	P-value
Frequency	Between species	33773.06	53	637.23	6.914	<0.01
	Within species	14929.69	162	92.16		
	Total	48702.75	215			
Density	Between species	100239.80	53	1891.32	14.078	<0.01
	Within species	21629.59	161	134.35		
	Total	121869.39	214			
Abundance	Between species	755975.03	53	14263.68	13.803	<0.01
	Within species	167408.16	162	1033.38		
	Total	923383.18	215			
A/F ratio	Between species	0.76	53	0.01	2.631	<0.01
	Within species	0.89	162	0.01		
	Total	1.65	215			
IVI	Between species	5827.31	53	109.95	10.342	<0.01
	Within species	1722.30	162	10.63		
	Total	7549.61	215			

Note: d.f. =degrees of freedom; Units-(Frequency - %; Density and Abundance- Plants m/sq)

The analyses of variance between species available in whole study site are presented in Table 2. . The variability of species available with respect to frequency, density, abundance, A/F ratio and IVI is tested by applying statistical tools. It is observed that the variation of among species with respect to these measures viz., frequency, density, abundance, A/F ratio and IVI are highly significant as evident by F-test result. This finding reveals that

the inventory of species within the study area is also significantly different in terms of quantitative parameters due to heterogeneities of basic features like temperature, pH etc.

4. Discussion

The quantitative characters which comprises the estimation of frequency, density, abundance, abundance by frequency (A/F) ratio and importance value index (IVI) of the different macrophytic species in the different study sites of the lake, recorded higher values during rainy season which influenced the growth of the macrophytes and favouring good climatic conditions. The rainy season seems to be most favourable season for the germination of buried seeds of the perennial emergents like *Cyperus* species and other mud-growing species like *Eclipta, Enhydra, Ipomoea, Caesula* species etc (Rai & Munshi, 1982). Similarly, high values during the rainy season were recorded from a number of lakes and wetlands viz., Hokarsar wetland, India (Kumar & Pandit, 2005), Manasbal Lake, India (Rather & Pandit, 2006), Awangsoipat Lake, India (Devi, 2007), Oksoipat Lake India (Devi, 2008), Poiroupat Lake, India (Usha, et. al., 2010b) etc.

It was observed that the maximum numbers of aquatic macrophytic plant species were recorded at the onset of the summer season and the rainy season due to the favourable warm temperature while the lowest numbers of species were recorded during the winter season. Hogeweg & Brenkert (1969) and Verma *et al.,* (1982) earlier recorded luxuriant growth of the aquatic macrophytes, in the tropics during the rainy season. It is evident from the survey of the aquatic macrophytes distributions in the different lakes and wetlands in record that the Lake Kharungpat is comparatively richer in Macrophytic species as compared to the other lakes of the state and other regions of India. The emergent, submerged and other groups of aquatic macrophytes were found in intermixed mats representing heterogeneous composition and distribution. Such heterogeneous compositions of species were also recorded earlier by Swindale & Curtis (1957) and Schmid (1965) in the submerged vegetations of U.S.A. and Seshavatharam & Venu (1982) in the Kolleru Lake, India. Such intermixed distribution of the plant communities have also been found rampant in the different lakes in Manipur recorded by number of earlier researcher.

According to Curtis and Cottam (1956) and Curtis (1959) if A/F ratios of the different species are less than 0.025, the species are found distributed homogeneously, while the ratio within 0.025 to 0.05 indicate random distribution. When the ratios are higher than 0.05, they indicate the aggregate nature of distribution of the species. In the present study the A/F ratios is higher than 0.05 indicating aggregate pattern of species distribution. There is luxuriant growth of the aquatic plants with maximum number from emergent group. The growth of the macrophytes is more in shallow sloping basins, while it is less in the deep ones. The contributions of the aquatic plants have been found correlated to the ratio of the mean depth to maximum depth (Moss, 1989). In the present study, the ratio of mean depth and maximum depth has been found to be 0.45. A very high surface area to volume ratio of 540.91 has been found in the lake under study which indirectly indicates the occurrence of luxuriant growth of the macrophytes, with high efficient ratios of production.

The statistical analysis reveals that there is no significant variation with respect to frequency, density, abundance, A/F ratio and IVI of the different aquatic macrophytes recorded from the lake in the four study sites of the lake. The analysis of variance within the different species of the aquatic macrophytes indicated significant variation with respect to the quantitative characters. Comparable findings were reported from Manasbal Lake, Kashmir Himalaya, India (Rather & Pandit, 2006), Itaipu reservoir, Brazil (Mormul, et al., 2010) and Poiroupat Lake, India (Usha, et.al., 2012).

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Appendix 1: List of Aquatic Macrophytes in Lake Kharungpat, India

Sl. No.	Name of species	Family
1.	*Alisma plantago aquatica* Linn.	Alismataceae
2.	*Alternanthera philoxeroides* (Mart) Griseb.	Amaranthaceae
3.	*Alternanthera sessiles* (Linn.) R.Br.	Amaranthaceae
4.	*Azolla pinnata* R.Br.	Azollaceae
5.	*Brachiaria mutica* (Forsk). Stapf.	Poaceae
6.	*Ceratophyllum demersum* Linn.	Ceratophyllaceae
7.	*Ceratopteris thalictroides* (Linn.)	Ceratophyllaceae
8.	*Chara zeylanica* Willd.	Characeae
9.	*Commelina bengalensis* Linn.	Commelinaceae
10.	*Cymbopogon nardus* ((Linn.) Rendle.	Poaceae
11.	*Cyperus corymbosus* Rottb.	Cyperaceae
12.	*Cyperus distans* Linn.f.	Cyperaceae
13.	*Echinochloa stagnina* (Retz.) P. Beauv.	Poaceae
14.	*Eicchornia crassipes* (Mart.) Solms.	Pontederiaceae
15.	*Enhydra fluctuans* Lour.	Lemnaceae
16.	*Euryale ferox* Salisb.	Asteraceae
17.	*Hydrilla verticillata* (Linn. F.). Royle.	Nymphaeaceae
18.	*Hygroryza aristata* (Retz.) Nees.	Hydrocharitaceae
19.	*Imperata cyllindrica* (Linn.)	Poaceae
20.	*Ipomoea aquatica* Forsk.	Convolvulaceae
21.	*Ipomoea fistulosa* Mart.	Convolvulaceae
22.	*Kyllinga tenuifolia* Steud.	Cyperaceae
23.	*Lemna minor* Linn.	Lemnaceae
24.	*Leersia hexandra* Swartz.	Poaceae
25.	*Ludwigia adscendens* (Linn.) Hara	Onagraceae
26.	*Marsilea quadrifoliata* Linn.	Marsileaceae
27.	*Monochoria hastata* (Linn.) Solms.	Pontederiaceae
28.	*Nelumbo nucifera* Gaertn.	Nelumbonaceae
29.	*Neptunia prostrata* Bail.	Mimosaceae
30.	*Nymphoides cristatum* (Roxb.) O. Kuntze	Menyanthaceae
31.	*Nymphaea pubescens* Willd.	Nymphaeaceae
32.	*Nymphaea stellata* Willd.	Nymphaeaceae
33.	*Oenanthe javanica* (Bl) D.C.	Apiaceae
34.	*Oryza officinalis* Wall en Watt.	Poaceae
35.	*Oryza rufipogon* Griff.	Poaceae
36.	*Polygonum glabrum* Willd	Polygonaceae
37.	*Polygonum hydropiper* Linn.	Polygonaceae
38.	*Pistia stratiotes* Linn.	Araceae
39.	*Phragmites karka* (Retz.) Trin. Ex Stand.	Poaceae
40.	*Potamogeton crispus* Linn.	Potamogetonaceae
41.	*Pseudoraphis minuta* (Mez) Pilger	Poaceae
42.	*Pseudoraphis spinescens* (R.Br.) Vickery	Poaceae
43.	*Ranunculus scleratus* Linn.	Ranunculaceae
44.	*Rumex maritimus* Linn.	Polygonaceae
45.	*Sacciolepsis myosuroides* (R.Br.) A. Camus	Poaceae
46.	*Saccharum procerum* Roxb.	Poaceae
47.	*Sagittaria sinensis* Linn..	Alismataceae
48.	*Salvinia cucullata* Roxb.	Salvinaceae
49.	*Salvinia natans* Hoffm	Salvinaceae
50.	*Trapa bispinosa* Roxb.	Trapaceae
51.	*Utricularia flexuosa* Vahl.	Lentibulariaceae
52.	*Utricularia exoletaR.Br.*	Lentibulariaceae
53.	*Vallisnaria spiralis* Linn.	Hydrocharitaceae
54.	*Zizania latifolia* (Griseb.) Stapf.	Poaceae
	Total number of species	54