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Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing Escherichia coli in the Calgary Health Region: emergence of CTX-M-15-producing isolates. Antimicrob. Agents Chemother. 51: 1281-1286.

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Table of Contents: Volume 6 Number 4 April, 2014

ARTICLES

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Full Length Research Paper

Plant species diversity of homegarden agroforestry in Jabithenan District, North-Western Ethiopia

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Homegarden agroforestry is believed to be more diverse due to the combination of crops, trees and livestock. The aim of this study was to assess plant species composition and diversity of homegarden agroforestry in Jabithenan district, North-western Ethiopia. Two sites purposively and two villages randomly from each site were selected. Plant species diversity inventories were carried out for 48 homegardens. All woody species and herbaceous species were counted and recorded in 10 x 10 m and 2 x 2 m plots, respectively. A total of 69 plant species (44 woody and 25 herbaceous) belonging to 40 families were recorded in the study homegarden. About 6-8 different species of plants per plot were recorded. Plant species such as *Musa paradisiaca* and *Brassica integrifolia* among herbs and *Coffea arabica* and *Cordia africana* among woody were the most frequently recorded species in the study Kebele. Of all woody species, *C. arabica* and *C. africana* showed the highest importance value index. Generally, according to the calculated diversity indices, the studied homegarden was found to be diverse

Key word: Composition, diversity, importance value index.

INTRODUCTION

Background and justification

A large percentage of the Ethiopian population (80%) depends upon agriculture for its livelihoods, which contributes 42-45% of the total gross domestic product of the country (Zenebe et al., 2011). But currently, the agricultural production falls under a risk due to a number of factors, such as climate change, soil erosion, soil fertility loss and severe soil moisture stress which is partly the result of loss of trees and organic matter (Salvatore et al., 2011). The whole effect of the above problem is loss of biodiversity, financial insecurity, food insecurity, subsequent increases in rates of malnutrition, which are becoming the major tribulations of human well-being, so having plant diversity for this serious problem should be necessary. The loss of biodiversity in turn has a range of ecological and societal consequences. Loss of biodiversity can have significant impacts on ecosystem function and reduces opportunities to avert production related risks (World Bank, 2008).

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Despite this, one of the solutions to meet diverse people's requirement with fixed/plot of land is through the application of agroforestry which has more diverse species than monocropping (Mcneely and Schroth, 2006).

Homegarden is an agroforestry practice known to be ecologically sustainable. Homegarden agroforestry is commonly defined as a land use system involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and invariably livestock within the compounds of individual houses, the whole tree-crop, and animal unit is being intensively managed by family labour (Kumar and Nair, 2006).

Despite its vast coverage homegarden agroforestry practice in tropical country, in Ethiopia inventory and documentation of homegarden diversity and species composition are very few and focused in south and south-western parts of the country (Zemede and Zerihun, 1997; Zebene, 2003; Bekele, 2007; Mengistu, 2008). Therefore in the present study, we assess and quantify plant species diversity and composition in the homegarden agroforestry system of the Jabithenan district in Ethiopia.

MATERIALS AND METHODS

Study area

This study was conducted in the Jabithenan district, west Gojjam zone of Amhara National regional state, Ethiopia (10° 40′N; 37° 11′E). The topography of the district is generally characterized by flat gentle slope (65%), mountainous (15%), undulating terrain (15%) and valley (5%), with an altitudinal range from 1500 - 2300 m.a.s.l (JWARDO, 2012). The major soil types found in the district are Vertisol and Nitosol (JWARDO, 2012).

Climatically, the district falls within midland and lowland. The mean annual temperature is about 23°C, with maximum temperatures slightly above 32°C, and minimum of 14°C. The mean annual rainfall ranges between 800 - 1250 mm (JAWRDO, 2012).

The total human population of the district is 277,590, of whom 139,616 individuals are males and 137,974 are females. An estimated population density of the district is about 455.32 people per square kilometers (JAWRDO, 2012).

Agriculture is the principal source of livelihood for rural population. It is characterized by subsistence mixed farming of rain-fed, irrigated crops, and livestock. Besides crop plants, the common vegetation in the district includes tree species of *Croton macrostachys, Ficus sur, Albizia gummifera, Cordia africana, Acacia abyssinica, Rosa abyssinica* and *Erythrina abyssinica* which are found as scattered in most farm lands, whereas *Eucalyptus* spp. and *Gravillea robusta* are grown as boundaries, live fences and woodlots (JWARDO, 2012).

Sampling method

Site selection

Two Kebele Administrations (KA) namely, Mankusa Abdegoma and Jiga Yelmdar were selected purposefully based on the extensive presence of both homegarden agroforestry (HGAF). During preliminary surveys with the district agricultural office and development agent, Debohela and Waza villages from Mankusa Abdegoma KA and Atahagne and Tikurwuha villages from Jiga Yelmdar KA were randomly selected making a total of four villages for this study

Data collection

To assess the diversity and composition of plant species in the HGAF, two 10 x 10 m sample main plots were laid in 48 randomly selected homegardens (12 from each village). The first plot was selected randomly and the second plot was selected systematically in order to cover all species types occurring in the garden. Tree species with diameter at breast height (DBH) were measured (DBH>=5 cm while recording and counting those DBH<5 cm). Using ''X'' design within the main plot, either from the corners or at the middle one 2 x 2 m sub-plots were laid to catch herbs interspersed between woody plants. Since almost all herbaceous plants (spice, vegetable, tubers and roots) were concentrated near an individual house alone, another two sub-plots near/close to home were laid (randomly for the first plot and systematically for the second plot) to cover all herbaceous species in the garden and making a total of four sub-plots per garden/household. Plant species identification and data collection was carried out using knowledgeable persons from the local community, and the researcher himself.

In this study, plant species nomenclature follows flora of Ethiopia and Eritrea (Edwards et al., 1995; Hedberg et al., 2004, 2006) and a glossary of Ethiopian plant names (Kelecha, 1980). In order to show diversity across wealth category, the owner of the homegardens were classified according to local wealth category criteria.

Data analysis

HGAF plant diversity between villages was subjected to one-way ANOVA and mean differences between groups were considered significant at $p < 0.05$ using Turkey's test.

To estimate plant species diversity, several ecological indices were used: Shannon diversity index (H^1), equitability index (E), Simpson diversity index (D) and important value index (IVI) were used.

RESULTS

Plant species diversity in homegarden agroforestry

In the study villages, a total of 69 plant species (44 woody and 25 herbaceous), belonging to 40 families and different functional groups were recorded (Appendix 1 and 2). Among the woody species, families Euphorbiaceae, Myrtaceae, Mimosoideae and Rutaceae were the most diverse each having four species. The contribution of remaining families to species richness was in the order of: Rosaceae with three species > Moraceae and Anacardiaceae each of them contain two species, and the rest of families with one species each. Among herbs, the family Poaceae were the most diverse with four species, followed by Solanaceae with three species while others, Lamiaceae, Musaceae, Fabaceae, Brassicaceae and Alliaceae had two species. All the remaining families contained only one species. The

Table 1. Overall woody and herbaceous species richness of homegarden agroforestry at four villages, Jabithenan district, Ethiopia.

Village	Species richness		
	Woody	Herbaceous	Total
Waza	28	18	46
Debohela	28	15	43
Tikurwuha	31	15	46
Atahagne	34	17	51

Table 2. Mean woody species richness and abundance per plot in homegarden agroforestry at four villages, Jabithenan district, Ethiopia.

Village	Richness	Abundance
	Mean (± Std)	Mean (± Std)
Tikurwuha	7.87^{b} ± 0.50	32.31^{a} ± 3.96
Atahagne	8.37^{b} ± 0.35	34.83^{a} ± 4.45
Waza	6.69^{a} ± 0.21	31.66^{a} ± 3.38
Debohela	6.37^{a} ± 0.40	16.29^{b} ± 3.22
Overall mean	7.32 ± 0.37	28.77 ± 3.69

Single different small letters on mean values indicate significant difference at P < 0.05 between the four study villages.

Table 3. Mean woody species richness per plot in homegarden agroforestry belonging to three wealth classes at four villages, Jabithenan district, Ethiopia.

Village	Richness		
	Rich	Medium	Poor
Waza	6.37^{a} ± 0.15	7.57^{a} ± 0.25	6.13^{a} ± 0.22
Debohela	7.63^{a} ± 0.86	5.87^{ab} ± 0.58	5.62^{b} ± 0.41
Atahagne	5.92^{a} ± 0.32	8.21^{b} ± 0.40	10.97^{c} ± 0.32
Tikurwuha	5.45^{a} ± 0.73	8.92^{b} ± 0.62	9.25^{b} ± 0.81

Single different letters on mean values indicate significant difference at P < 0.05 between the four study villages.

Table 4. Mean abundance of woody species in homegarden agroforestry belonging to three wealth classes at four villages, Jabithenan district, Ethiopia.

Village	Abundance		
	Rich	Medium	Poor
Waza	32.63^{a} ± 3.21	31.49^{a} ± 5.20	30.85^{a} ± 1.75
Debohela	24.87^{a} ± 3.15	13.87^{ab} ± 3.28	10.13^{b} ± 3.21
Atahagne	49.75^{a} ± 5.43	32.62^{ab} ± 3.34	22.12^{b} ± 4.58
Tikurwuha	46.62^{a} ± 4.93	28.69b ± 3.87	21.62^{b} ± 3.10

Single different letters on mean values indicate significant difference at P < 0.05 between wealth classes with in a village in a row.

homegarden species of the study villages can be grouped into four life forms; herbs, shrubs, trees and climbers (Figure 1).

Plant species richness, abundance and frequency

Farmers in the study villages retain various tree components based on spaces available and their compatibility with agricultural crops and household objectives. Table 1 and 2 shows plant species richness at four villages. The highest and lowest number of species (woody and herbaceous) was recorded at Atahagne and Debohela village, respectively. Extent of species richness at village level was in order of: Atahagne > Tikurwuha and Waza > Debohela.

The abundance of woody species in the villages was variable. Except at Waza village, there was significant difference in species richness and abundance between wealth classes (rich households are different from the other) of the same village in the study site (Tables 3 and 4).

Species abundance is a function of either household preference or best fit to the given ecology/climate. In this study, the top abundant recorded species are presented in Table 5 and the village level in Appendix 7.

The frequency occurrence of each species across the study sites is presented in Figures 2 and 3. Of the total species recorded at Mankusa Abdegoma KA; *Coffea arabica* (94%), *Cordia africana* (81%), *Sesbania sesban* (80%), *Persea americana* (60%) and *Citrus sinensis* (50%) were the top five frequently appeared woody species (Appendix 3). Among herbaceous species *Musa paradisiacal* (85%), *Brassica integrifolia* (59%) and *Saccharum oficinarum* (38%) were top frequently appeared ones (Appendix 4).

In Jiga Yelmdar KA, *C. arabica* (96%), *C. africana* (94%), *S. sesban* (75%), *M. indica* (60%) and *P. americana* (56%) were the five most frequently recorded woody species (Appendix 5). In this KA *B. integrifolia* (84%), *M. paradisiacal* (75%), *Daucus carota* (64%) were the top frequent herbaceous species (Appendix 6). The overall frequency across all sites/villages shows that *C. arabica*, *C. africana* and *S. sesban* were the three most frequently recorded species (Figure 4).

Diversity Indices

In order to get a better picture of plant species diversity, various diversity indices (ecological models) were calculated for each village and wealth category within the village. For woody and herbaceous species, the highest values of diversity indices were recorded at Atahagne village (Tables 6 and 7). Diversity indices showed a variation among wealth categories in each village (Table 8).

Table 5. Top five most abundant woody and herbaceous species in homegarden agroforestry at two kebeles, Jabithenan district, Ethiopia.

Kebele	Top five abundant species in decreasing order	
	Woody	Herbaceous
Jiga Y.	*Coffea arabica, Rhamnus prinoides, Sesbania sesban, Catha edulis, Cordia africana*	*Brassica integrifolia* , *Capsicum frutescens* , *Brassica oleracea, Musa paradisiaca, Daucus carota*
Mankusa A.	*Coffea arabica, Rhamnus prinoides, Persea americana, Citrus reticulate, Catha edulis*	*Musa paradisiacal, Brassica integrifolia, Lycopersicon esculentum , Capsicum frutescens, Brassica oleracea*

Table 6. Overall Shannon, evenness and Simpson indices of woody species in homegarden agroforestry at four villages, Jabithenan district, Ethiopia.

Village	Shannon index	Evenness	Simpson index
Waza	2.26	0.65	0.79
Debohela	2.31	0.66	0.83
Atahagne	2.43	0.73	0.82
Tikurwuha	2.38	0.70	0.80

Table 7. Overall Shannon, evenness and Simpson indices of herbaceous species in homegarden agroforestry at four villages, Jabithenan district, Ethiopia.

Villages	Shannon index	Evenness	Simpson index
Waza	2.50	0.86	0.89
Debohela	2.28	0.84	0.85
Atahagne	2.55	0.90	0.90
Tikurwuha	2.30	0.83	0.87

Table 8. Mean per plot of Shannon, evenness and Simpson indices of woody species belonging to three wealth categories in homegarden agroforestry at four villages, Jabithenan district, Ethiopia.

Indices	Wealth	Village			
		Waza	Debohela	Atahagne	Tikurwuha
Shannon	Rich	1.50^{a}± 0.07	1.35^{a}± 0.09	1.26^{a}± 0.09	1.01^{a}± 0.09
	Medium	1.22^{ab}± 0.07	1.40^{a} ±0.08	1.47^{a}± 0.08	1.59^{b} ±0.07
	Poor	0.98^{b} ±0.10	1.36^{a}± 0.07	1.88^{b}± 0.08	1.92^{c} ±0.07
Overall mean		1.23±0.08	1.37±0.08	1.54±0.09	1.50±0.08
Evenness	Rich	0.78^{a} ±0.02	0.77^{a}± 0.03	0.61^{a}± 0.03	0.59^{a}± 0.05
	Medium	0.62^{b}± 0.05	0.75^{a}± 0.04	0.70^{b} ±0.04	0.74^{b} ±0.04
	Poor	0.48^{c}± 0.05	0.71^{a} ±0.07	0.87^{c}± 0.02	0.88^{c}± 0.02
Overall mean		0.63±0.04	0.74±0.05	0.73±0.03	0.74±0.04
Simpson	Rich	0.70^{a}± 0.03	0.68^{a}± 0.04	0.57^{a} ±0.04	0.48^{a}± 0.05
	Medium	0.55^{ab}± 0.07	0.60^{a} ±0.07	0.65^{a} ±0.04	0.67^{b}± 0.04
	Poor	0.46^{b} ±0.05	0.63^{a}± 0.04	0.79^{b} ±0.02	0.81^{c}± 0.02
Overall mean		0.57±0.06	0.64±0.06	0.67±0.03	0.65±0.03

Single different letters on mean values indicate significant difference at ($P < 0.05$) between wealth classes with in a village in a column.

Table 9. Importance value index of the top five woody species with their rank (in bracket) at four villages, Jabithenan district, Ethiopia.

Species	Village			
	Waza	Debohela	Atahagne	Tikurwuha
Cordia africana	31.48(2nd)	38.18(2nd)	38.28(2nd)	55.11(1st)
Coffea arabica	53.69(1st)	49.51(1st)	49.95(1st)	51.82(2nd)
Sesbania sesban	20.96(4th)	20.73(5th)	16.77(4th)	29.33(3rd)
Albizia gummifera	23.39(3rd)	25.53(3rd)	-	17.74(4th)
Persea americana	15.54(5th)	-	16.10(5th)	15.45(5th)
Mangifera indica	-	-	17.92(3rd)	-
Acacia abyssinica	-	21.16(4th)	-	-

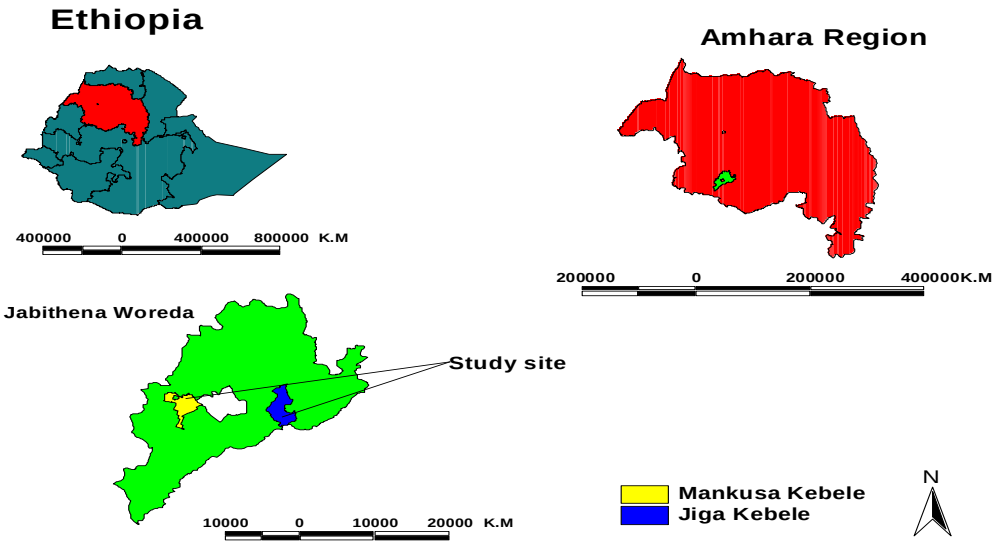

Figure 1. Location of study sites at Mankusa Abdegoma and Jiga Yelmdar Kebele, Jabithenan district, Ethiopia.

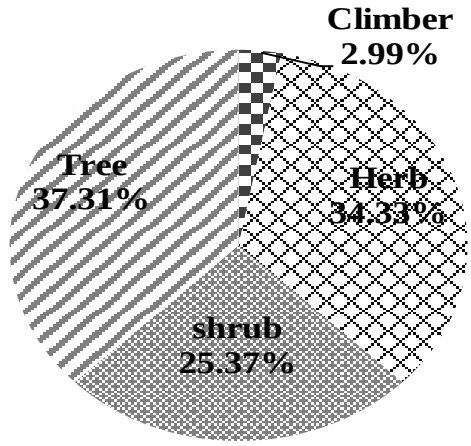

Figure 2. Proportion of life forms among homegarden plant species at four villages, Jabithenan district, Ethiopia.

Importance value index

To evaluate ecological and other benefit of each woody species recorded in the study site, their importance value index (IVI) was calculated and presented in Table 9; mainly for the top five while Appendix 7 shows the overall value for all species.

DISCUSSION

Most plant species found in the studied homegarden were frequently cited in other work, such as *Prunus persica*, *Dodonaea viscose*, *Zea mays*, *Curcurpita pepo* (Larato, 2011), *Citrus* species and *Psidium guajav* (Wezel and Bender, 2003); *Schnius molle* (Molebatsi et al., 2010); *Rhamnus prinoides*, *Otostegia integrifolia*, *Chata edulis, Brassica integrifolia, Lycopersicon esculant,*

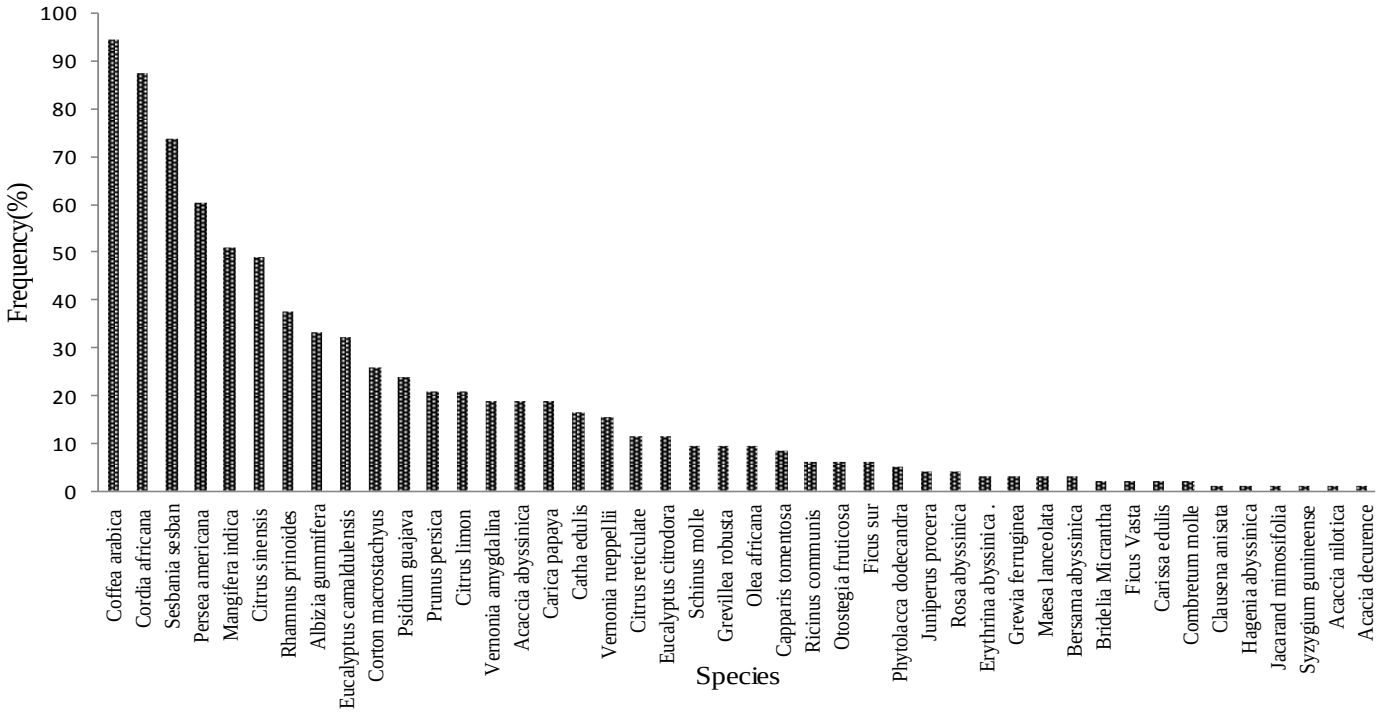

Figure 3. Overall frequent occurrence of woody species in homegarden agroforestry across four villages, Jabithenan district, Ethiopia.

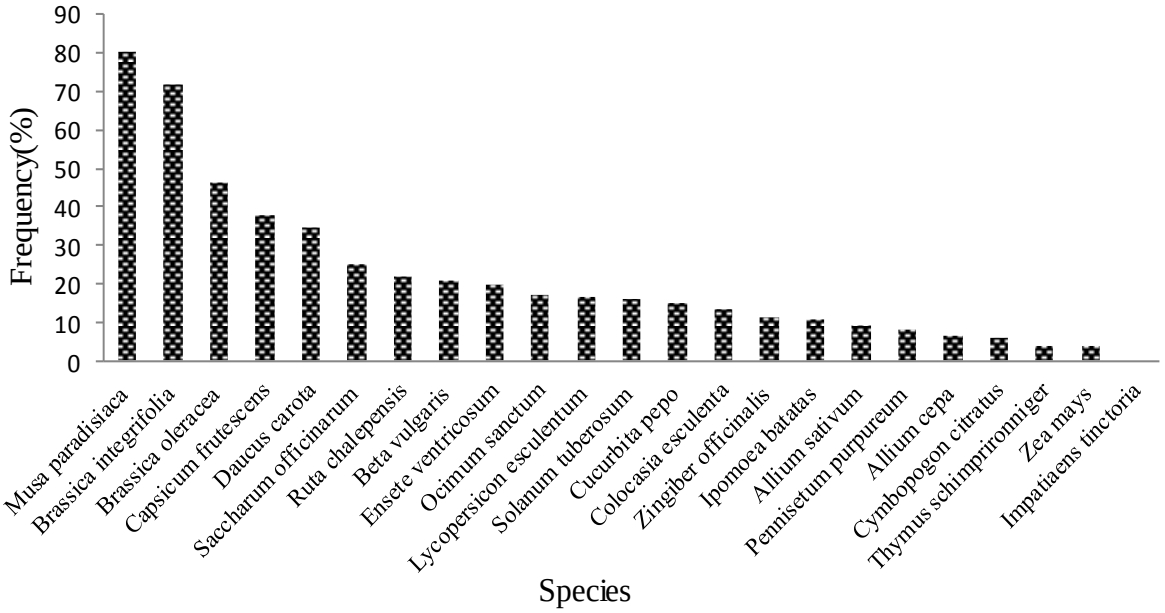

Figure 4. Overall frequency occurrence of herbaceous species in homegarden agroforestry across four villages, Jabithenan district, Ethiopia.

Allium cepa (Abebe et al., 2010). Wider global distribution of species shows their higher socio-economic and environmental role.

The 48 studied homegardens were composed of a total of 69 species. A study done in Sri Lanka, out of 106 homegarden, 289 plant species were recorded (Sandya et al., 2009); 84 plant species (n=420) from Nigeria (Udofia et al., 2012) and 32 plant species (n=81) from semiarid environment of central Sudan (Gebaur, 2005). Even in the study homegarden, there was a significant difference ($P < 0.05$) of plant species richness between two KA and more particularly the mean number of

species (species richness) per homegarden varied within a village.

The mean number of species (averaged across villages) per homegarden in this study (7) is lower than (11.0) that reported by Zemede and Ayele (1995) from 111 sample homegarden in Ethiopia and higher than the mean number of species (3.94) reported from Hintalo wajerat homegarden of Tigray (Hinsa, 2012). In general, the difference in species richness from place to place could be attributed to income difference, altitude, personal preference of species, soil type and homegarden size. Even in Debohela village, rich farmers had significantly higher number of species than poor farmers. This is may be due to the fact that farmers that experience income constraint tends to focus on few selected species which generate money to satisfy immediate needs, which is in line with research in homegarden of Arsi negele, Ethiopia (Motuma et al., 2008). In contrast, in Jiga Yelmdar Kebele; rich farmers had significantly lower number of species richness than poor households. This is may be due to the fact that richer household prefer to purchase species that are not much valued than poor farmers.

Jiga Yelmdar KA has higher species diversity than Mankusa Abdegoma kebeles in a plot base. This may be due to the higher species richness which leads to the higher species diversity In Jiga Yelmdar. This possible explanation was also forwarded to sidama homegarden (Abebe, 2005). The Shannon diversity index of the study area in village base was higher than that of the research done in northern Ethiopia of Tigray (H'=1.6 to 1.8) (Muruts, 2012); but the mean Shannon index was lower than homegarden of Meghalaya (2.37) (Tynsong and Tiwari, 2010). Mean Shannon indices vary widely in tropical homegardens and ranged from 0.93 to 3.00 (Tynsong and Tiwari, 2010).

In the study site, *C. arabica* and *Rhamnus prinoides* are the two most abundant species due to their higher socio-economic and social roles. *C. arabica* is the major source of cash income, whereas *R. prinoides* is primarily used to prepare local beer called ‘'Tela'' and is also another source of cash income. So, the studied homegarden is dominated by cash generating plant species instead of supplementary food crop.

The frequent occurrence of plant species was estimated to understand the extent of species distribution in each homegarden. *C. arabica, C. africana* and *S. sesban* were the top three most frequently appearing species. Farmers preferred the species due to their higher socio-economic and service benefit than the rest recorded species.

The importance of each individual woody species was estimated (importance value index). Accordingly, *C. arabica* scores the first and *C. africana* follows. This finding is also in line with the reports of Tynsong and Tiwari (2010) which shows that species with multiple uses showed higher IVI value.

Conclusion

High plant diversity was found in the studied homegardens. Homegarden agroforestry can also act as a refuge for threatened species like *C. africana* in Ethiopia. Vegetable crop (*Brassica integrifolia*), cash crop (*Coffea arabica*), fruit crop (*Persea americana, Musa paradisiaca*), timber tree (*Cordia africana*) and fodder tree (*Sesbania sesban*) are important species that were recorded.

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Biodiversity of the Bharathiar university campus, India: A floristic approach

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A total of 335 vascular plant species represented by 222 genera belonging to 67 different families were recorded, of which only one species was represented by gymnosperms. The Poaceae, Fabaceae, Mimosaceae, Caesalpiniaceae and Amaranthaceae were the dominant families of the vascular floristic composition of the study region. The occurrence of invasive alien species is detrimental as they have started invading the campus flora. Though the exotic species should be allowed to grow, introducing and adding new species should be avoided in the campus as they are affecting the survival of the native plant diversity.

Key words: Floristic diversity, exotic plants, habitat destruction, Bharathiar University, Tamil Nadu.

INTRODUCTION

Biodiversity is the total variety of life on earth. It includes all genes, species and ecosystems. In short it reflects the totality of genes, species and ecosystems in a region (FES, 2010). The studies of biodiversity have now assumed greater significance as ecologists try seriously to document global biodiversity in the face of unprecedented perturbations, habit loss and extinction rates.

To understand and assess richness of the biodiversity, a taxonomic study of the flora and forests is very much essential. Floristic surveys are the only means by which we can achieve this goal. The floristic studies are considered as the backbone of the assessment of phytodiversity, conservation management and sustainable utilization (Jayanthi and Rajendran, 2013).

The flora are helpful in providing clues of changing floristic patterns, new invasions, current status, rare, endemic and threatened taxa (RET) in a phytogeographical area. They also form a vital component of any resource management and planning activities at the local, regional and global levels. It is essential to prepare local floras of urban areas where there is severe threat to natural vegetation due to identification of species that are in different stages of vulnerability (Padalia et al., 2004) as well as the various factors that influence the existing vegetation in any region (Parthasarathy, 1999). Knowledge of vegetation and flora of any region is essential for the study of its biodiversity and environment. Today there is a pressing need for detailed surveys of plant resources, both exotic and indigenous for the development of rural as well as urban economy of a region. Preparation of the flora of smaller areas like districts, protected areas, unexplored areas, etc. is not only a pre-requisite for the revision of the flora of the vast country like India, but also for understating the ecosystem function and its conservation. Hence,

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floristic studies form a vital component of any natural resource management and planning activities at the local, regional and global levels.

Several studies have been conducted to analyze the floristic composition of the wall habitats in India and abroad (Brandes, 1995; Krigas et al., 1999; Altay et al., 2010; Bilge, 2001; Ocak and Ture, 2001; Ture and Bocuk, 2001; Turgut, 1996; Harshad, 2008). The Bharathiar University campus has rich and diverse ecological communities performing a variety of functions. This diversity has been modified at times and has tried to sustain itself in changing circumstances. Several academicians have found the campus a very informative and practical laboratory to study several floral aspects. However, the drawback is the lack of proper documentation of the several components of the natural history on the campus.

To understand the significance of the existing biodiversity it is necessary to understand what is valued of the place and what are the benefits it provides and its relevance for the future. Hence, the present study was conducted to examine the vascular plant diversity in the Bharathiar University Campus (Tamil Nadu), India. The outcome of the study can be used constructively in planning sustainability of both man and natural environment.

MATERIALS AND METHODS

Study area

The Bharathiar University Campus is situated at the foot hills of Maruthamalai Hiils, at an elevation of 410 m altitude above mean sea level (MSL). With a campus of over 1000 acres, the Bharathiar University is considered as one of the green educational institution in Coimbatore with a rich floral and faunal diversity. The campus is known for its excellence in education, in addition the entire campus has a fairly diverse ecological setting. It is geographically located at 76° 52' 44° 64' longitude and 11° 02' 24° 38' N latitude. The campus is located in habitats of scarce vegetation due to dry weather prevailing in it. According to Champion and Seth (1968), the vegetation of the Maruthamalai hills comes under the dry deciduous thorn forests.

Floristic analysis

This study was carried out between the periods 2008 - 2010. Periodical survey was made for the identification and collection of plant species followed by botanical name, family, habitat, uses and anthropogenic disturbances to the natural vegetation in campus. During the course of study, field visits were made to every nook and corner of the University Campus in search of vascular plant species occurring in the region. The plants were freshly collected and their digital photographs were also taken. The collected plant specimens have been identified using taxonomic literatures (Gamble and Fischer, 1915-1936; Matthew, 1983; Nair and Henry, 1983; Henry et al., 1987, 1989; Chandrabose and Nair, 1988). Further, their identification was confirmed by matching with authentic specimens in the Madras Herbarium (MH), Botanical Survey of India, Southern Circle, Coimbatore, India. The voucher specimens were deposited at the Herbarium of Department of Botany, Bharathiar University, Coimbatore for future reference.

RESULTS AND DISCUSSION

On the basis of field survey conducted in the campus area, 335 species belonging to 67 families were collected, identified and listed (Table 1) excluding the lichens, Pteridophytes, bryophytes and mycoflora which was not possible during the present study. Out of the identified plant species, 334 belong to the angiosperms which include 238 species of Dicotyledons and 96 species of Monocotyledons and the remaining one species belong to Gymnosperm (Figure 1). When floral elements were examined based on family, it was determined that Poaceae contained the most species with 72, Fabaceae were represented with 27 species, Mimosaceae were represented with 14 species, Caesalpiniaceae and Amaranthaceae were represented with 12 species each and Acanthaceae represented with 11 species (Figure 2).

The genera represented by the highest number of taxa in the study are as follows: *Eragrostis* is represented by 11 taxa, *Brachiaria* by 8 taxa, *Cyperus* by 7 taxa, *Accacia* and *Ficus* by 6 taxa each and *Jasminum* by 5 taxa. Of the total plant species observed, based on the habit, herbs were represented by 51%, followed by 24% of trees, 13% of shrubs and 12% of climbers (Figure 3). Furthermore, of the 335 species found, 64 species are considered as introduced species to the campus and they were found solely in disturbed areas such as roadsides and early succession fields. However, some are widespread through much of the forests.

A large number of alien species were reported from the campus of Bharathiar University which includes *Ageratum conyzoides* L., *Alternanthera pungens* Kunth., *Alternanthera sessilis* (L.) R. Br., *Argemone mexicana* L., *Bidens pilosa* L., *Borassus flabellifer* L., *Calotropis gigantean* R. Br., *Catharanthus roseus* (L.) G. Don, *Chromolaena odorata* (L.) King & H. Rob., *Cleome viscosa* L., *Crotalaria retusa* L., *Croton bonplandianum* Baill., *Cuscuta reflexa* Roxb., *Cyperus difformis* L., *Datura metel* L., *Digera muricata* (L.) Mart., *Echinochloa colona* (L.) Link., *Euphorbia cyathophora* Murr., *Euphorbia hirta* L., *Evolvulus alsinoides* L., *Ipomoea eriocarpa* R. Br., *Lantana camara* L., *Leonotis nepetifolia* (L.) R. Br., *Malvastrum coromandelianum* (L.) Garc., *Martynia annua* L., *Melia azedarach* L., *Mirabilis jalapa* L., *Ocimum americanum* L., *Parthenium hysterophorus* L., *Passiflora foetida* L., *Pedalium murex* L., *Portulaca oleracea* L., *Spermacoce hispida* L., *Stachytarpheta jamaicensis* (L.) Vahl, *Tribulus lanuginosus* L., *Tridax procumbens* L., *Turnera ulmifolia* L. and *Waltheria indica* L. This is clearly indicated as disturbances to the natural setting in the vegetated areas.

The grasslands of the campus comprises the grasses like *Apluda mutica* L., *Cymbopogon caesius* Stapf., *Heteropogon contortus* L., *Rottboellia cochinchinensis* Lour., *Vetiveria zizanioides* (L.) Nash, *Chloris inflata* Link, *Cynodon dactylon* L., *Tragus roxburghii* Panigrahi, *Dactyloctenium aegyptium* L. *Eragrostis indica* L., *E.*

Table 1. List of plants in the Bharathiar University campus, India.

Botanical name	Family	Habit
Abrus precatorius Wall.	Fabaceae	Climber
Acacia auriculiformis L.	Mimosaceae	Tree
Acacia ferruginea DC.	Mimosaceae	Tree
Acacia holosericea L.	Mimosaceae	Shrub
Acacia lenticularis Buch.	Mimosaceae	Tree
Acacia leucophloea Roxb.	Mimosaceae	Tree
Acacia planifrons Wight & Arn.	Mimosaceae	Tree
Acalypha indica L.	Euphorbiaceae	Herb
Achyranthes aspera L.	Amaranthaceae	Herb
Adenanthera pavonina L.	Mimosaceae	Tree
Aerva lanata (L.) A.L. Juss.	Amaranthaceae	Herb
Aerva monsoniae (Retz.) Mart.	Amaranthaceae	Herb
Agave americana L.	Agavaceae	Shrub
Ageratum conyzoides L.	Asteraceae	Herb
Albizia lebbeck L.	Mimosaceae	Tree
Albizia odoratissima L.f.	Mimosaceae	Tree
Allmania nodiflora (L.) R. Br.	Amaranthaceae	Herb
Alloteropsis cimicina (L.) Stapf.	Poaceae	Herb
Alternanthera pungens Nov.	Amaranthaceae	Herb
Alternanthera sessilis (L.) R.Br.	Amaranthaceae	Herb
Alysicarpus hamosus Edgew.	Fabaceae	Herb
Alysicarpus heyneanus Baker	Fabaceae	Shrub
Alysicarpus monilifer L.	Fabaceae	Herb
Amaranthus viridis L.	Amaranthaceae	Herb
Andrographis paniculata (Burm. f.) Wall.	Acanthaceae	Herb
Andropogon pumilus Roxb.	Poaceae	Herb
Aneilema montana Wight	Commelinaceae	Herbs
Anisochilus carnosus (L.f.) Wall.	Lamiaceae	Herb
Anisomeles malabarica (L.) R. Br.	Lamiaceae	Shrub
Annona squamosa L.	Annonaceae	Tree
Apluda mutica L.	Poaceae	Herb
Argemone mexicana L.	Papaveraceae	Herb
Aristida adscensionis L.	Poaceae	Herb
Aristida hystrix L.f.	Poaceae	Herb
Aristida setacea Retz.	Poaceae	Herb
Aristolochia indica L.	Aristolochiaceae	Climber
Artocarpus heterophyllus Lam.	Moraceae	Tree
Asparagus racemosus Willd.	Liliaceae	Climber
Asystasia gangetica (L.) T. And	Acanthaceae	Herb
Axonopus compressus (Sw.) P. Beauv.	Poaceae	Herb
Azadirachta indica A.	Meliaceae	Tree
Bambusa arundinacea (Retz.) Roxb.	Bambusaceae	Tree
Barleria buxifolia L.	Acanthaceae	Herb
Barleria cuspidata F. Heyne	Acanthaceae	Herb
Bauhinia purpurea L.	Caesalpinaceae	Tree
Bauhinia tomentosa L.	Caesalpinaceae	Shrub
Bidens pilosa L.	Asteraceae	Herb
Blepharis repens (Vahl) Roth	Acanthaceae	Herb
Boerhavia diffusa L.	Nytaginaceae	Herb
Boerhavia erecta L.	Nytaginaceae	Herb
Borassus flabellifer L.	Arecaceae	Tree

Table 1. Contd.

Bothriochloa compressa Hook. f.	Poaceae	Herb
Bothriochloa insculpta Hochst.	Poaceae	Herb
Bothriochloa pertusa (L.) A. Camus.	Poaceae	Herb
Bougainvillea spectabilis Willd.	Nyctaginaceae	Shrub
Brachiaria distachya (L.) Stapf.	Poaceae	Herb
Brachiaria ramosa (L.) Stapf.	Poaceae	Herb
Brachiaria mutica (Forssk.) Stapf.	Poaceae	Herb
Brachiaria reptans L.	Poaceae	Herb
Brachiaria semiundulata Stapf.	Poaceae	Herb
Brachiaria semiverticillata Rottl.	Poaceae	Herb
Brachiaria subquadripara Trin.	Poaceae	Herb
Brachiaria eruciformis (Sm.) Griseb.	Poaceae	Herb
Brassica juncea L.	Brassicaceae	Herb
Bulbostylis barbata Rottb.	Cyperaceae	Herb
Bulbostylis puberula Poir.	Cyperaceae	Herb
Caesalpinia pulcherrima (L.) Sw.	Caesalpinaceae	Shrub
Callistemon citrinus Curtis	Myrtaceae	Tree
Calotropis gigantea L.	Asclepidaceae	Shrub
Canthium parviflorum Lam.	Rubiaceae	Shrub
Caralluma bicolor L.	Asclepidaceae	Herb
Caralluma diffusa Wight	Asclepidaceae	Herb
Cardiospermum canescens L.	Sapindaceae	Climber
Cardiospermum halicacabum L.	Sapidaceae	Climber
Cassia absus L.	Caesalpinaceae	Shrub
Cassia fistula L.	Caesalpinaceae	Tree
Cassia roxburghii DC.	Caesalpinaceae	Tree
Cassia siamea Lam.	Caesalpinaceae	Tree
Cassia spectabilis DC.	Caesalpinaceae	Tree
Casuarina equisetifolia J.R	Casurinaceae	Tree
Catharanthus roseus (L.) G. Don.	Apocynaceae	Herb
Ceiba pentandra (L.) Gaertn	Bombacaceae	Tree
Celosia cristata L.	Amaranthaceae	Herb
Cenchrus biflorus Roxb.	Poaceae	Herb
Cenchrus ciliaris L.	Poaceae	Herb
Cenchrus pennisetiformis Hochst	Poaceae	Herb
Cenchrus setigerus Vahl.	Poaceae	Herb
Chloris bournei Rang. & Tadul.	Poaceae	Herb
Chloris inflata Link	Poaceae	Herb
Chloris montana Roxb.	Poaceae	Herb
Chromolaena odorata (L.) K & R	Asteraceae	Herb
Chrysopogon aciculatus Retz.	Poaceae	Herb
Chrysopogon fulvus Spreng.	Poaceae	Herb
Chrysopogon orientalis Desv.	Poaceae	Herb
Cissampelos pareira L.	Menispermaceae	Climber
Cissus quadrangularis L.	Vitaceae	Climber
Citrullus colocynthis L.	Cucurbitaceae	Climber
Cleome burmanni Wight & Arn.	Cleomaceae	Herb
Cleome viscosa L.	Cleomaceae	Herb
Clitoria ternatea L.	Fabaceae	Herb
Coccina grandis (L.) Voigt	cucurbitaceae	Climber
Cocos nucifera L.	Arecaceae	Tree
Cocculus hirsutus L.	Menispermaceae	Climber

Table 1. Contd.

Commelina benghalensis L.	Commelinaceae	Herb
Commelina ensifolia R.Br.	Commelinaceae	Herb
Commelina forskaolii Vahl.	Commelinaceae	Herb
Corchorus aestuans L.	Tiliaceae	Herb
Corchorus trilocularis L.	Tiliaceae	Herb
Cordia sebestena L.	Boraginaceae	Tree
Crescentia cujete L.	Bignoniaceae	Tree
Croton bonplandianum Baill.	Euphorbiaceae	Herb
Crossandra infundibuliformis (L.) Nees	Acanthaceae	Herb
Crotalaria mysorensis Roth.	Fabaceae	Herb
Crotalaria pallida Dryand.	Fabaceae	Shrub
Crotalaria retusa L.	Fabaceae	Shrub
Crotalaria verrucosa L.	Fabaceae	Herb
Cucumis dipsaceus Ehrenb.	Cucurbitaceae	Climber
Cucumis trigonus Roxb.	Cucurbitaceae	Climber
Cuscuta campestris Yun.	Cuscutceae	Climber
Cuscuta reflexa Roxb.	Convolvulaceae	Climber
Cyanotis axillaris (L.) D. Don	Commelinaceae	Herb
Cyanotis cristata (L.) D. Don	Commelinaceae	Herb
Cycas circinalis L.	Cycadaceae	Tree
Cyclea peltata (Lam.)	Menispermaceae	Climber
Cymbopogon caesius Nees	Poaceae	Herb
Cynodon dactylon (L.) Pers.	Poaceae	Herb
Cyperus brevifolia Rottb.	Cyperaceae	Herb
Cyperus compressus L.	Cyperaceae	Herb
Cyperus difformis L.	Cyperaceae	Herb
Cyperus pangorei Rottb.	Cyperaceae	Herb
Cyperus rotundus L.	Cyperaceae	herb
Cyperus stoloniferus Retz.	Cyperaceae	Herb
Cyperus triceps (Rottb.) Endl.	Cyperaceae	Herb
Dactyloctenium aegyptium (L.) Willd.	Poaceae	Herb
Dalbergia sissoo Roxb.	Fabaceae	Tree
Datura metel L.	Solanaceae	Herb
Delonix regia Boj.	Caesalpinaceae	Tree
Desmodium dichotomum Willd.	Fabaceae	Herb
Desmodium laxiflorum DC.	Fabaceae	Shrub
Dichrostachys cinerea L.	Mimosaceae	Tree
Digera muricata (L.) Mart.	Amaranthaceae	Herb
Digitaria bicornis Lam.	Poaceae	Herb
Digitaria ciliaris (Retz.) Koel.	Poaceae	Herb
Diplocyclos palmatus L.	Cucurbitaceae	Climber
Dipteracanthus patulus (Jacq.) Nees	Acanthaceae	Herb
Dodonaea viscosa L.	Sapindaceae	Shrub
Echinochloa colonum (L.) Link	Poaceae	Herb
Echinochloa picta J. Koenig	Poaceae	Herb
Eleusine indica (L.) Gaertn.	Poaceae	Herb
Enneapogon schimperanus Hochst.	Poaceae	Herb
Eragrostiella bifaria (Vahl) Bor.	Poaceae	Herb
Eragrostiella brachyphylla (Stapf.)	Poaceae	Herb
Eragrostis amabilis (L.)Wight & Arn.	Poaceae	Herb
Eragrostis aspera (Jacq.) Nees	Poaceae	Herb
Eragrostis japonica (Thunp.) Trin.	Poaceae	Herb

Table 1. Contd.

Eragrostis maderaspatana Bor	Poaceae	Herb
Eragrostis minor Host.	Poaceae	Herb
Eragrostis nigra Nees *ex* Steud.	Poaceae	Herb
Eragrostis nutans (Retz.)	Poaceae	Herb
Eragrostis riparia (Willd.)Nees	Poaceae	Herb
Eragrostis viscosa (Retz.) Trin.	Poaceae	Herb
Eremopogon foveolatus (Del.) Stapf.	Poaceae	Herb
Eucalyptus tereticornis Sm.	Myrtaceae	Tree
Euphorbia cyathophora Murr.	Euphourbiaceae	Shrub
Euphorbia hirta L.	Euphorbiaceae	Herb
Evolvulus alsinoides L.	Convolvulaceae	Climber
Evovulus nummularius L.	Convolvulaceae	Climber
Ficus amplissma J.E. Sm.	Moraceae	Tree
Ficus bengalensis L.	Moraceae	Tree
Ficus elastica Roxb.	Moraceae	Tree
Ficus hispida L.f.	Moraceae	Tree
Ficus microcarpa L.f.	Moraceae	Tree
Ficus religiosa L.	Moraceae	Tree
Filicium decipiens Wight & Arn.	Sapindaceae	Tree
Fimbristylis ovata Burm. f.	Cyperaceae	Herb
Gmelina arborea Roxb.	Verbenaceae	Shrub
Gloriosa superba L.	Liliaceae	Climber
Gomphrena celosioides Mart.	Amaranthaceae	Herb
Gomphrena globosa L.	Amaranthaceae	Herb
Guaiacum officinale L.	Zygophyllaceae	Tree
Hedyotis aspera Heyne	Rubiaceae	Herb
Hedyotis puberula G. Don	Rubiaceae	Herb
Helicteres isora L.	Sterculiaceae	Shrub
Heliotropium subulatum (DC.) Vatke	Boraginaceae	Herb
Hemidesmus indicus L.	Asclepidaceae	Climber
Heteropogon contortus L.	Poaceae	Herb
Hibiscus lunarifolius Wild.	Malvaceae	Herb
Hibiscus ovalifolius (Forskal) Vahl.	Malvaceae	Herb
Holoptelea integrifolia (Roxb.) Pl.	Ulmaceae	Tree
Hybanthus ennaspermus L.	Violaceae	Herb
Hybanthus puberulus Mill.	Violaceae	Herb
Indigofera colutea Burm. f.	Fabaceae	Herb
Indigofera linnaei Ali.	Fabaceae	Herb
Indigofera longeracemosa Boiv.	Fabaceae	Shrub
Ipomoea eriocarpa R. Br.	Convolvulaceae	Climber
Ipomoea obscura (L.) Ker-Gawl.	Convolvulaceae	Climber
Ipomoea pes-caprae (L.) R. Br.	Convolvulaceae	Climber
Ipomoea qumoclit L.	Convolvulaceae	Climber
Ixora coccinea L.	Rubiaceae	Shrub
Ixora finlaysoniana Wall.	Rubiaceae	Shrub
Jacaranda mimosifolia DC.	Bignoniaceae	Tree
Jasminum angustifolium (L.) Willd.	Oleaceae	Climber
Jasminum auriculatum Vahl	Oleaceae	Climber
Jasminum cuspidatum Rottl.	Oleaceae	Climber
Jasminum grandiflorum L.	Oleaceae	Climber
Jasminum trichotomum Heyne	Oleaceae	Climber
Jasminum wightii Clarke	Oleaceae	Climber

Table 1. Contd.

Jatropha gossypifolia L.	Euphorbiaceae	Shrub
Justicia prostrata (Clarke) Gamble	Acanthaceae	Herb
Kedrostis foetidissima (Jacq.) Cogn.	Cucurbitaceae	Climber
Kigelia pinnata (Jacq.) DC.	Bignoniaceae	Tree
Lagascea mollis Jacq.	Asteraceae	Herb
Lantana camara L.	Verbenaceae	Climber
Leonotis nepetifolia (L.) R. Br.	Lamiaceae	Herb
Leucas aspera (Willd.) Link.	Lamiaceae	Herb
Macrotyloma ciliatum Willd.	Fabaceae	Shrub
Macrotyloma uniflorum Lam.	Fabaceae	Climber
Malvastrum coromandelianum L.	Malvaceae	Herb
Mangifera indica L.	Anacardiaceae	Tree
Manilkara achras (Mill.) Fosb.	Sapotaceae	Tree
Martynia annua L.	Martyniaceae	Herb
Melia azedarach L.	Meliaceae	Tree
Melinis repens Willd.	Poaceae	Herb
Merremia quinquefolia (L.) Hall. f.	Convolvulaceae	Climber
Merremia tridentata (L.) Hall.	Convolvulaceae	Herb
Michelia champaca (L.) Baill.	Magnoliaceae	Tree
Millingtonia hortensis L.f.	Bignoniaceae	Tree
Mimosa pudica L.	Mimosaceae	Herb
Mirabilis jalapa L.	Nytaginaceae	Herb
Momordica charantia L.	Cucurbitaceae	Climber
Morinda coreia Buch.	Rubiaceae	Tree
Moringa pterosperma Gaertn	Moringaceae	Tree
Mukia maderaspatana L.	Cucurbitaceae	Climber
Mundulea sericea Willd.	Fabaceae	Tree
Muntingia calabura L.	Elaeocarppaceae	Tree
Murraya koenigii L.	Rutaceae	Tree
Nerium indicum Mill.	Apocynaceae	Shrub
Nyctanthes arbor-tristis L.	Nyctanthaceae	Tree
Ocimum americanum L.	Lamiaceae	Herb
Ocimum basilicum L.	Lamiaceae	Herb
Oxalis corniculata L.	Oxalidaceae	Herb
Panicum curviflorum Hornem.	Poaceae	Herb
Panicum maximum Jacq.	Poaceae	Herb
Panicum psilopodium Trin.	Poaceae	Herb
Parkia biglandulosa Wight & Arn.	Mimosaceae	Tree
Parthinium hysterophorus L.	Asteraceae	Herb
Paspalidium flavidum Retz.	Poaceae	Herb
Passiflora edulis Sims	Passifloraceae	Climber
Passiflora foetida L.	Passifloraceae	Climber
Pedalium murex L.	Pedaliaceae	Herb
Peltophorum pterocarpum DC.	Caesalpinaceae	Tree
Pennisetum hohenackeri Hochst.	Poaceae	Herb
Pennisetum pedicellatum Trin.	Poaceae	Herb
Pennisetum polystachion (L.) Schult.	Poaceae	Herb
Pergularia daemia Forssk.	Asclepidaceae	Climber
Peristrophe bicalyculata (Retz.) Nees	Acanthaceae	Herb
Perotis indica (L.) Kuntz.	Poaceae	Herb
Phyllanthus acidus (L.) Skeels	Euphorbiaceae	Tree
Phyllanthus emblica L.	Euphorbiaceae	Tree

Table 1. Contd.

Phyllanthus reticulates Poiret,	Euphorbiaceae	Tree
Phyllanthus virgatus Forst.	Euphorbiaceae	Herb
Pithacellobium dulce Roxb.	Mimosaceae	Tree
Plumbago zeylanica L.	Plumaginaceae	Herb
Plumeria alba L.	Apocynaceae	Tree
Plumeria rubra L.	Apocynaceae	Tree
Polyalthia longifolia Sonn.	Annonaceae	Tree
Polycarpaea corymbosa L.	Caryophyllaceae	Herb
Polygala jacobii Chandrabose	Polygalaceae	Herb
Polygala rosmarinifolia Wight & Arn.	Polygalaceae	Herb
Polygala wightiana Wall.	Polygalaceae	Herb
Pommerulla cornucopiae L. f.	Poaceae	Herb
Pongamia pinnata L.	Fabaceae	Tree
Portulaca oleracea L.	Polygalaceae	Herb
Priva cordifolia L.f.	Verbinaceae	Herb
Psidium guajava L.	Myrtaceae	Tree
Pterocarpus marsupium Roxb	Fabaceae	Tree
Ptrocarpus sandalinus L. f.	Fabaceae	Tree
Pupalia lappacea L. A.L.	Amaranthaceae	Herb
Rhynchosia cana DC	Fabaceae	Climber
Rhynchosia minima L.	Fabaceae	Climber
Rottboellia cochinchinensis Lour.	Poaceae	Herb
Roystonea regia H.B.K.	Arecaceae	Tree
Samanea saman Jacq.	Mimosaceae	Tree
Santalum album L.	Santalaceae	Tree
Sesbania grandiflora L.	Fabaceae	Tree
Setaria intermediata Roem. & Schult.	Poaceae	Herb
Setaria pumila (Poir.)	Poaceae	Herb
Setaria verticillata (L.) P. Beauv.	Poaceae	Herb
Sida cordata Burm. f.	Malvaceae	Herb
Sida cordifolia L.	Malvaceae	Herb
Sida rhombifolia L.	Malvaceae	Herb
Solanum surattense Burm.	Solanaceae	Shrub
Spathodea campanulata P. Beauv.	Bignoniaceae	Tree
Spermacoce hispida L.	Rubiaceae	Herb
Spermacoce villosa Sw.	Rubiaceae	Herb
Sporobolus coromandelianus Retz.	Poaceae	Herb
Sporobolus indicus (L.) R.Br.	Poaceae	Herb
Sporobolus maderaspatanus Bor	Poaceae	Herb
Stachytarpheta jamaicensis (L.) Vahl	Verbinaceae	Herb
Stenotaphrum dimidiatum L.	Poaceae	Herb
Striga densiflora (Benth.) Com.	Scorphulariaceae	Herb
Stylosanthes fruticosa (Retz.)	Fabaceae	Herb
Syzygium cumini (L.)	Myrtaceae	Tree
Tabebuia aurea Benth. & Hook.	Bignoniaceae	Tree
Tabebuia pallida (Lindl.) Miers	Bignoniaceae	Tree
Tabebuia rosea (Berol.) DC.	Bignoniaceae	Tree
Talinum portulacifolium Forskl.	Polygalaceae	Herb
Tamarindus indica L.	Caesalpinaceae	Tree
Tecoma stands (L.) Kunth.	Bignoniaceae	Tree
Tectona grandis L. f.	Verbinaceae	Tree
Tephrosia hookeriana Wight & Arn.	Fabaceae	Shrub

Table 1. Contd.

Tephrosia purpurea L.	Fabaceae	Herb
Terminalia catappa L.	Combrataceae	Tree
Thespesia populnea L.	Malvaceae	Tree
Thunbergia fragrans Roxb.	Acanthaceae	Climber
Thunbergia grandiflora Roxb.	Acanthaceae	Climber
Tinospora cordifolia Willd.	Menispermaceae	Climber
Toddalia asiatica L.	Rutaceae	Climber
Trachys muricata (L.) Pers.	Poaceae	Herb
Tragus roxburghii Panigrahi	Poaceae	Herb
Trianthema decandra L.	Aizoaceae	Herb
Tribulus lanuginosus L.	Zygophyllaceae	Herb
Trichodesma indicum L.	Boraginaceae	Herb
Tridax procumbens L.	Asteraceae	Herb
Turnera ulmifolia L.	Turneraceae	Herb
Tylophora indica Burm. f.	Asclepidaceae	Climber
Urochloa mosambicensis Hack.	Poaceae	Herb
Urochloa panicoides P.Beauv	Poaceae	Herb
Vernonia cinerea (L.) Less.	Asteraceae	Herb
Vetiveria zizanioides (L.) Nash	Poaceae	Herb
Vitex negundo L.	Verbinaceae	Tree
Waltheria indica L.	Sterculiaceae	Herb
Wrightia tinctoria L.	Apocynaceae	Tree
Ziziphus mauritiana Lam.	Rhamanaceae	Tree
Ziziphus oenoplia L.	Rhamanaceae	Tree

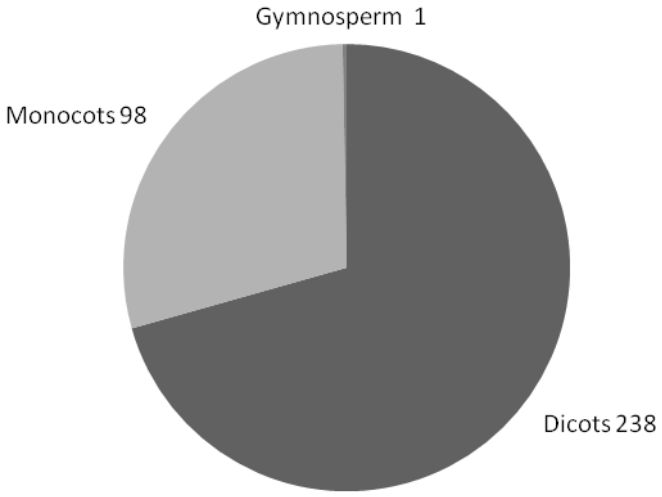

Figure 1. Systematic groups of the plants in the campus area.

aspera Jacq., *Eragrostiella bifaria* Vahl, *Eleusine indica* L., *Axonopus compressus* (Sw.), *Brachiaria distachya* L., *B. repenta* L., *Cenchrus ciliaris* L., *Digitaria bicornis* Lam., *D. ciliaris* Retz., *Echinochloa colonum* L., *Melinis repens* Willd., *Panicum maximum* Jacq., *Setaria maximum* Jacq., *S. pumila* Poir. and *S. verticillata*.

The ground flora here is comparatively sparse, but fairly rich in undisturbed areas. The species *Acalypha indica* L., *Achyranthes aspera* L., *Aerva lanata* (L.) A. Juss., *Alternanthera pungens* Kunth, *Argemone mexicana* L., *Alysicarpus monilifer* L., *Boerhavia diffusa* L., *Cleome viscosa* L., *Crotalaria verrucosa* L., *Croton bonplandianum* Baill., *Datura metel* L., *Dipteracanthus patulus* (Jacq.) Nees, *Euphorbia hirta* L., *Hibiscus ovalifolius* (Forssk.) Vahl, *Indigofera linnaei* Ali, *Lagascea mollis* Cav., *Malvastrum coromandelianum* (L.) Garc., *Peristrophe bicalyculata* (Retz.) Nees, *Polycarpaea corymbosa* (L.) Lam., *Priva cordifolia* (L.f.) Druce, *Tephrosia purpurea* (L.) Pers., *Tribulus lanuginosus* L., *Vernonia cinerea* (L.) Less., *Tridax procumbens* L., *Ageratum conyzoides* L., *Parthinium hysterophorus* L. The species *Argemone mexicana* L., *Talinum portulacifolium* Frosskl, *Hibiscus ovalifolius* (Forsskl.) Vahl, *Malvastrum coromandelianum* (L.) Garcke., *Waltheria indica* L., *Tephrosia purpurea* (L.) Pers., *Turnera ulmifolia* L., *Plumbaga zeylanica* L., *Datura metel* L., *Striga densiflora* Benth. and *Achyranthes aspera* L. are some of the common herbs in the campus.

Some of the common climbers found among the shrubs are *Cissampelos pareira* L. (Buch. - Ham. *ex* DC.) Forman, *Cocculus hirsutus* (L.) Diels, *Cyclea peltata* (Lam.) Hook. f. & Thoms., *Tinospora cordifolia* (Willd.) Miers *ex* Hook. f., *Toddalia aisatica* (L.) Lam., *Cissus*

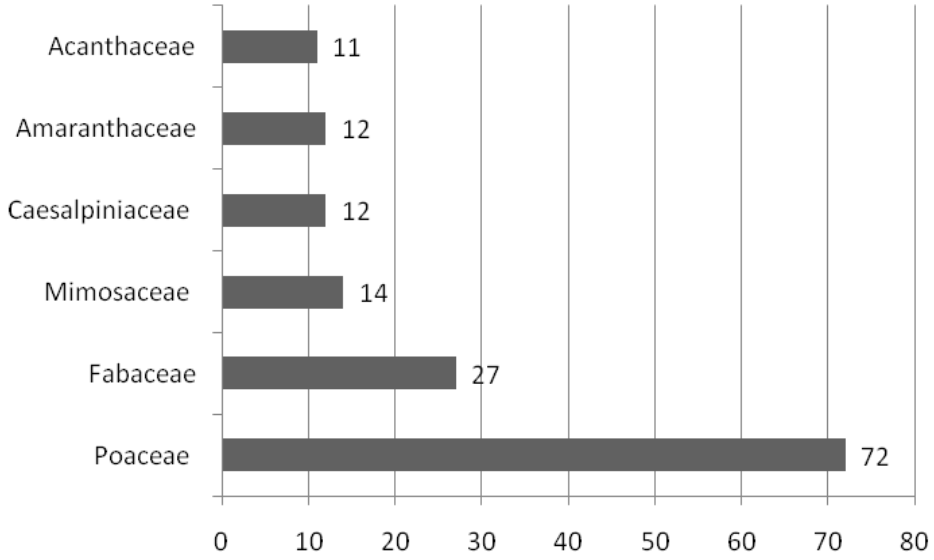

Figure 2. Plant families with higher number of species in the campus area.

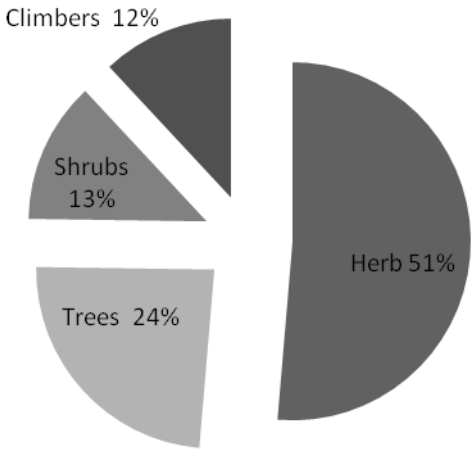

Figure 3. Analysis of habit-wise distribution of plant species in the campus area.

quadrangularis L., *Cardiospermum helicacabum* L., *Abrus precatorius* Wall. *ex* Thw., *Clitoria ternatea* L., *Macrotyloma uniflorum* (Lam.) Verdc. *Passiflora edulis* Sims., *P. foetida* L., *Citrullus colocynthis* (L.) Schrader, *Coccinia grandis* (L.) Voigt, *Mukia maderaspatana* (L.) M.Soem., *Jasminum angustifolium* (L.) Willd., *J. auriculata* Vahl., *J. cuspidatum* Rottl., *J. grandiflorum* L., *J. trichotomum* Heyne *ex* Roth, *Hemidesmus indicus* (L.) R.Br., *Pergularia daemia* (Forssk.) Chiov. and *Tylophora indica* (Burm. f.) Merr.

In the study, ethnobotanically used plants were also identified and are grouped into ornamental (20 species), economic (24 species), edible fruit (17 species), medicinal (22 species), aromatic (six species) and fodder (19 species) (Figure 4). The important medicinal plants growing in the Campus of Bharathiar University includes *Asystasia gangetica* (L.) T. And., *Cardiospermum halicacabum* L., *Catharanthus roseus* (L.) G. Don., *Coccina grandis* (L.) Voigt., *Mukia madraspatana* (L.) M. Roem., *Ocimum americanum* L., *Oxalis corniculata* L., *Trichodesma indicum* (L.) R. Br., *Azadirachta indica* A. Juss, *Dichrostachys cinerea* (L.), *Ficus bengalensis* L., *Jatropha gossypifolia* L., *Wrightia tinctoria* (Roxb.), *Ziziphus mauritiana* Lam., *Cyanodon dactylon* L., *Vetiveria zizanioides* (L.) Nash, *Commelina benghalensis* L., *Cyperus rotundus* L., *Cyanotis axillaris* (L.) D. Don, *Asparagus racemosus* L. and *Gloriosa superba* L.

The only plantation on the campus is made of *Acacia auriculiformis* A. Cunn., *A. ferruginea* DC., *Crescentia cujete* L., *Cycas circinalis* L., *Kigelia pinnata* (Jacq.) DC. and *Markhamia platycalyx* (Baker) Sprague. There are several avenues on the campus made of trees such as *Bauhinia purpurea* L., *Callistemon citrinus* (Curt.) Stapf, *Cassia fistula* L., *C. siamea* Lam., *Casuarina equisetifolia* J.R. & G. Forst., *Delonix regia* (Boj. *ex* Hook.) Raf., *Eucalyptus tereticornis* Sm., *Guaiacum officinale* L., *Parkia biglandulosa* Wight. & Arn., *Polyanthia longifolia* Sonn., *Peltophorum pterocarpum* (DC.) K. Heyne, *Pterocarpus marsupium* Roxb., *Samanea saman* F. Muell., *Santalum album* L., *Thesesia populnea* (L.) Sol. *ex* Correa and *Roystonea regia* (Kunth) O.F. Cook.

Some of the species are utilized as fruit-yielding like *Annona squamosa* L. (Seetha), *Artocarpus heterophyllus* Lam. (Pala), *Mangifera indica* L. (Maa), *Moringa petrygosperma* Gaertn. (Murungai), *Phyllanthus acidus* L. Skeels (Ara-Nelli), *Phyllanthus emblica* L. (Nelli), *Psidium guajava* L. (Koyya) and *Syzygium cumini* (L.) Skeels

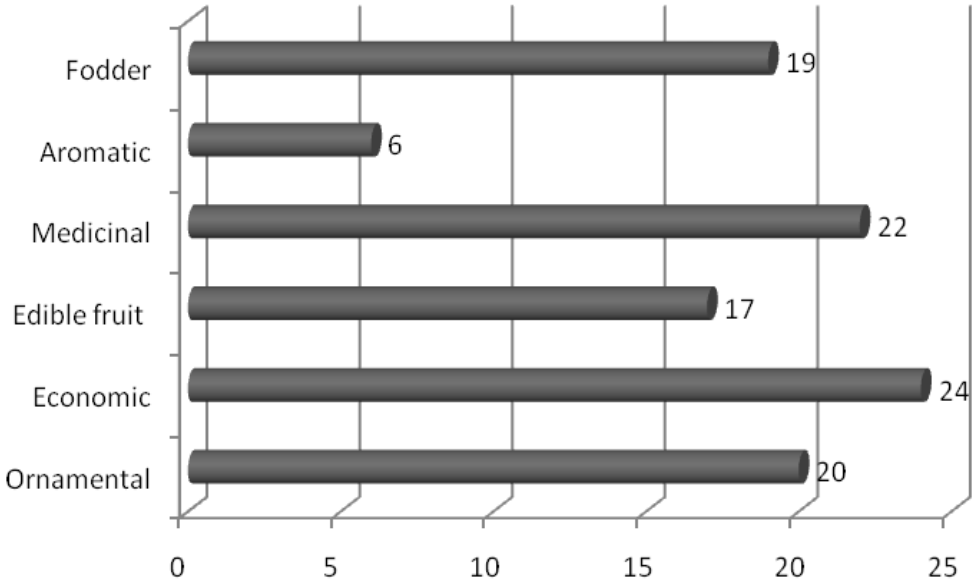

Figure 4. Ethnobotanical usage categories of the plants in the campus area.

(Naval). Species such as *Cordia sebestena* L., *Jacaranda mimosifolia* D.Don., *Millingtonia hortensis* L.f., *Plumeria alba* L., *P. rubra* L., *Tabubia rosea* DC., *Tecoma stans* (L.) Juss. *ex* Kunth are also utilized for their attractive flowers.

Most of the species found are common in the campus, some of the species *Cucumis dipsaceus* C.G. Ehrenb. *ex* Spach, *Caralluma bicolor* Ramach, S. Joseph, H. A. John & C. Sofiya, *Hybanthus puberulus* M. Gilbert are rare species. Some endemic grass species like *Andropogon pumulus* Roxb., *Bothriochlora compressa* (Hook. f.) Henrard, *Chloris bournei* Rang. & Tadul., *Panicum psilopodium* Trin. and *Perotis indica* (L.) O. Kuntz. also occur in the campus. The study suggests that the Campus of Bharathiar University is rich in natural vascular flora, though the floristic composition is dominated by angiospermic plant species.

Conclusion

The biodiversity of the campus is important as it is vital that native and endemic species of flora are conserved. Though there are many more life-forms that need to be identified up to species level, the biodiversity of the campus holds a lot of potential in terms of conservation. The vegetated areas identified during the present study can be accorded special attention and if any development is planned in these areas, it should be reconsidered.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Effect of salt stress (sodium chloride) on germination and seedling growth of durum wheat (*Triticum durum* Desf.) genotypes

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The impact of salt stress under different salinity level (0, 50, 100, 150, 200 mMol of NaCl) on ten genotypes of durum wheat namely: Werd Bled, Hmira, Bidi, Arbi, INRAT 69, Agili, Derbassi and Bayatha, Karim and Maali was conducted. Germination rate were recorded daily using radicle extrusion as a criterion. Morphological studies root length, shoot length, fresh weight and dry weight of root and shoot were also measured. Analysis of variance (ANOVA) showed that germination rate of durum wheat genotypes was significantly affected by the salt stress. Results show a reduction of germination rate in response to the highest dose of NaCl for almost all the varieties except for Maali and Derbassi durum wheat cultivar in case150 and 200 mMol concentrations. After 6 days of germination, these lines showed germination percentage respectively of 70 and 60% against a rate of 0% for Bidi AP4 and Bayatha. For morphological traits, the effect of varieties was highly significant (P<0.01) on almost traits measured expect shoot dry weight, root fresh weight and root dry weight. Results show that all studied traits were significantly (P<0.001) reduced due to salt stress. The data showed that different level of salinity significantly affected the growth attributes by reducing root and shoot length for salinity below 50 mMol NaCl. Fresh weight and dry weight of root and shoot were reduced significantly with subsequent treatment.

Key words: Durum wheat, germination, landraces, salt stress.

INTRODUCTION

Salinity, whether natural or induced, is a serious environmental stress limiting the growth and development of salt sensitive plants. Plants vary greatly in their tolerance to salts. However, the performance of crops under saline conditions depends on seed germination, plantlet appearance, establishment and also tolerance at later stages of growth. Germination is a complicated phenomenon comprising physiological and biochemical variation due to embryo activation. Salinity as a non live stress makes many hardships for seed in germination period either by limiting water absorption by the seeds (Dodd and Donovan, 1999), by affecting the mobilization of stored reserves

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(Bouaziz and Hicks, 1990; Lin and Kao, 1995) or by directly affecting the structural organization or synthesis of proteins in germinating embryos (Ramagopal, 1990). These parameters could be affected by both the ionic and the osmotic components of salt stress although the relative importance of each component differs among species and even among cultivars (Dodd and Donovan, 1999; Davenport et al., 2005). When plant is exposure to salinity by NaCl, water and ion transport processes may be affected and disturb plant nutrient situation and ionic balance or disordered physiological process. Salinity decrease water availability for the seed by taking down osmotic potential and in second stage cause to toxicity and change in enzyme activity. Salt stress affects germination percentage, germination rate and seedling growth in different ways depending on plant species (Ungar, 2005; Gul and Weber, 1999). Therefore, Boubaker (1996) showed that germination and seedling characteristics are also viable criteria for selecting salt tolerance in durum wheat in a screening experiment with eight durum wheat cultivars. Increased salt tolerance requires new genetic sources of this tolerance. Landraces are important genetic resources for improvement of crops in saline areas, since they have accumulated adaptation to harsh environment over long time. The aim of the present study were i) to assess the impact of salt stress on different landraces and varieties of durum wheat at germination and seedling stage ii) to screen out best salinity tolerant durum wheat variety and iii) to assess the various morphological changes associated with the plants under different salinity gradient.

MATERIALS AND METHODS

Plant material

Ten genotypes of durum wheat included Karim, Maali, Werd Bled, Hmira, Bidi, Arbi, INRAT 69, Agili, Derbassi and Bayatha. Seeds were sterilized by 12% bleach for 10 min and then washed 3 times with sterilized water. Germination trials were carried out in sterilized petri dishes containing a sheet of blotting paper, and moistened with distilled water or saline solution (0, 50, 100, 150, 200 mMol of NaCl). Each of the three replicates contained 10 seeds. Each treatment was carried out for 12 days. Germinated seeds were counted, and then these seeds were removed from petri dishes. Seeds were considered germinating with the emergence of the radicle.

Observations and measurements

The percentage of germination of treated genotypes and compared to the control (parent) were determined. Germination percentages were recorded daily up to 6 days using radicle extrusion (≥ 2 mm long) as a criterion. At the end of the germination period, the germination percentage was calculated using the equation:

Germination rate (%) = Number of daily germinated seeds/ total number of seeds planted

Morphological studies root length, shoot length, root and shoot fresh weight, root and shoot dry weights were measured.

Analysis statistic

Statistical analysis including analysis of variance (ANOVA), Duncan's test was performed to study the significance of different salinity gradient on different parameters studied.

RESULTS AND DISCUSSION

For all genotype studied, germination rate were recorded daily up to 6 days. The Figure 1 showed that germination process can be considered in terms of three sequential steps: inhibition corresponding to the time necessary for the apparition of the first germs, metabolism leading to initiation of radicle growth representing a fast increase in the rate of germination, and radical growth leading to radicle emergence corresponding a final rate of germination. After 96 h, all varieties reached 100% of germination rate in distilled water. The varieties Hmira, Maali, INRAT 69 and Ward bled reached 100% of germination rate after 48 h in control conditions. The effect of salt treatment was highly significant on rate germination (Table 1). Germination rate was reduced from 50 mMol NaCl salt concentration onwards for almost all the varieties. There is considerable reduction of germination rate in response to the highest dose of NaCl for almost all the varieties except the results were reciprocal for Maali and Derbassi durum wheat cultivar in case 150 and 200 mMol concentration. After 6 days of germination, these lines showed germination percentage respectively of 70 and 60% against a rate of 0% for Bidi AP4 and Bayatha. Results show that exposure of seeds to stress condition had an effect on germination of seeds. Similar effect was observed in *Limonium stocksii* seeds (Zia and Khan, 2004) and *Salsola imbricata* Forssk (Zaman et al., 2010) where only 5% of seeds germinated at stress conditions but 100% germination was achieved when transferred to distilled water. The reduced level of seed germination may be due to (i) loss of viability at higher salinity level (ii) delaying germination of seeds at salinities that cause some stress to but not percent germination as reported by some workers. The results of salt stress were almost prominent from 100 mMol salt concentration onwards for all the ten durum wheat varieties resulting into germination rate. From the results of this present investigation it can be concluded that seeds of 10 different durum wheat cultivars were susceptible to higher concentrations of salt solutions in germination stage which was supported by the works of Gul and Weber (1999) and Datta et al. (2009). Some authors assessed that germination percentage in salt stress conditions may be used as a valuable criterion for the screening of salinity resistance in plant populations (Ashraf et al., 1987).

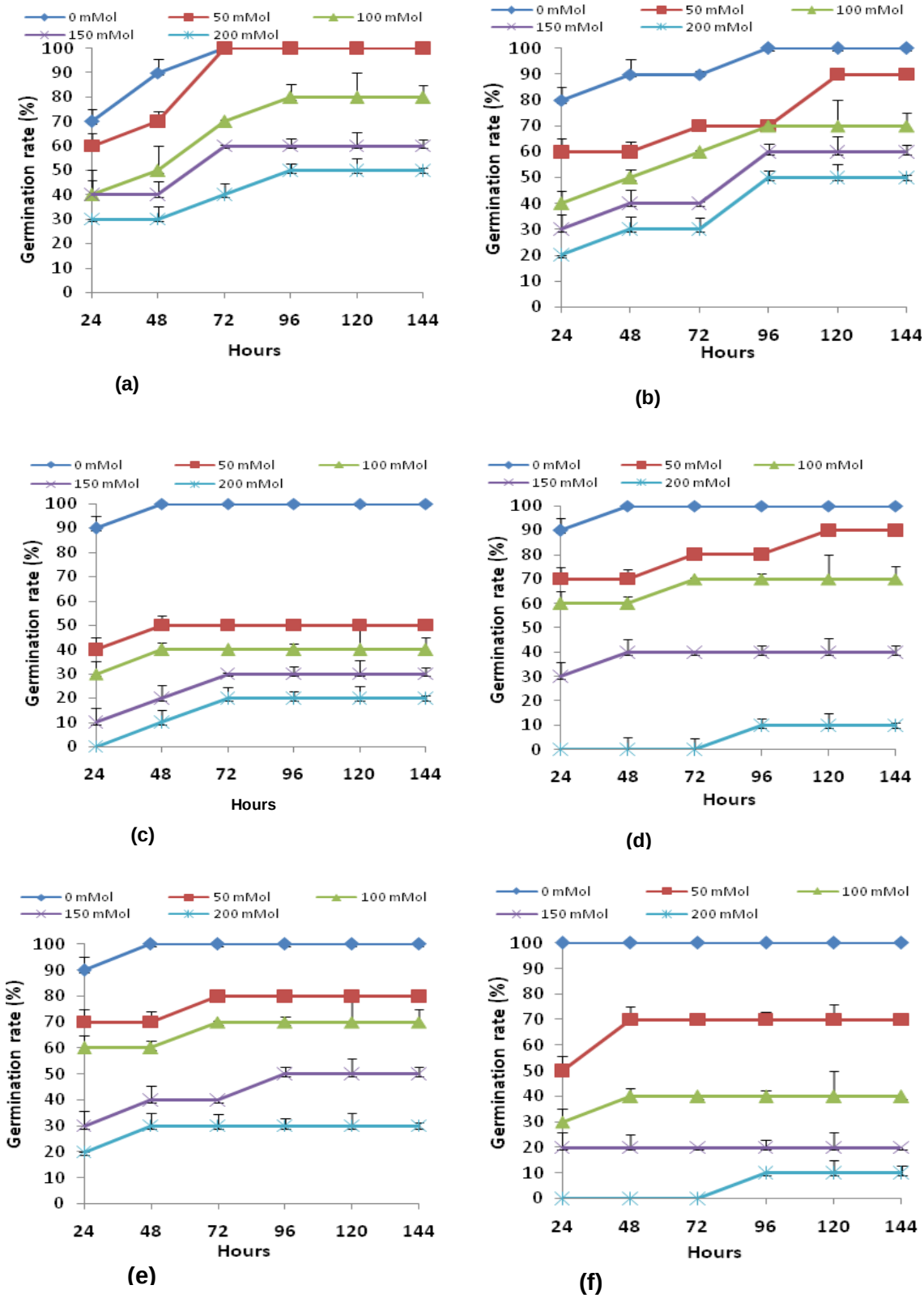

Figure 1. Germination rate in normal (0 mMol NaCl) and in salt stress conditions (50, 100, 150, 200 mMol NaCl) for different durum wheat genotypes studied (a: Agili; b: Arbi; c: Karim; d: INRAT 69; e: Werd Bled Karim; f: Hmira; g: Bidi AP4; h: Bayatha; i: Derbassi; j: Maali).

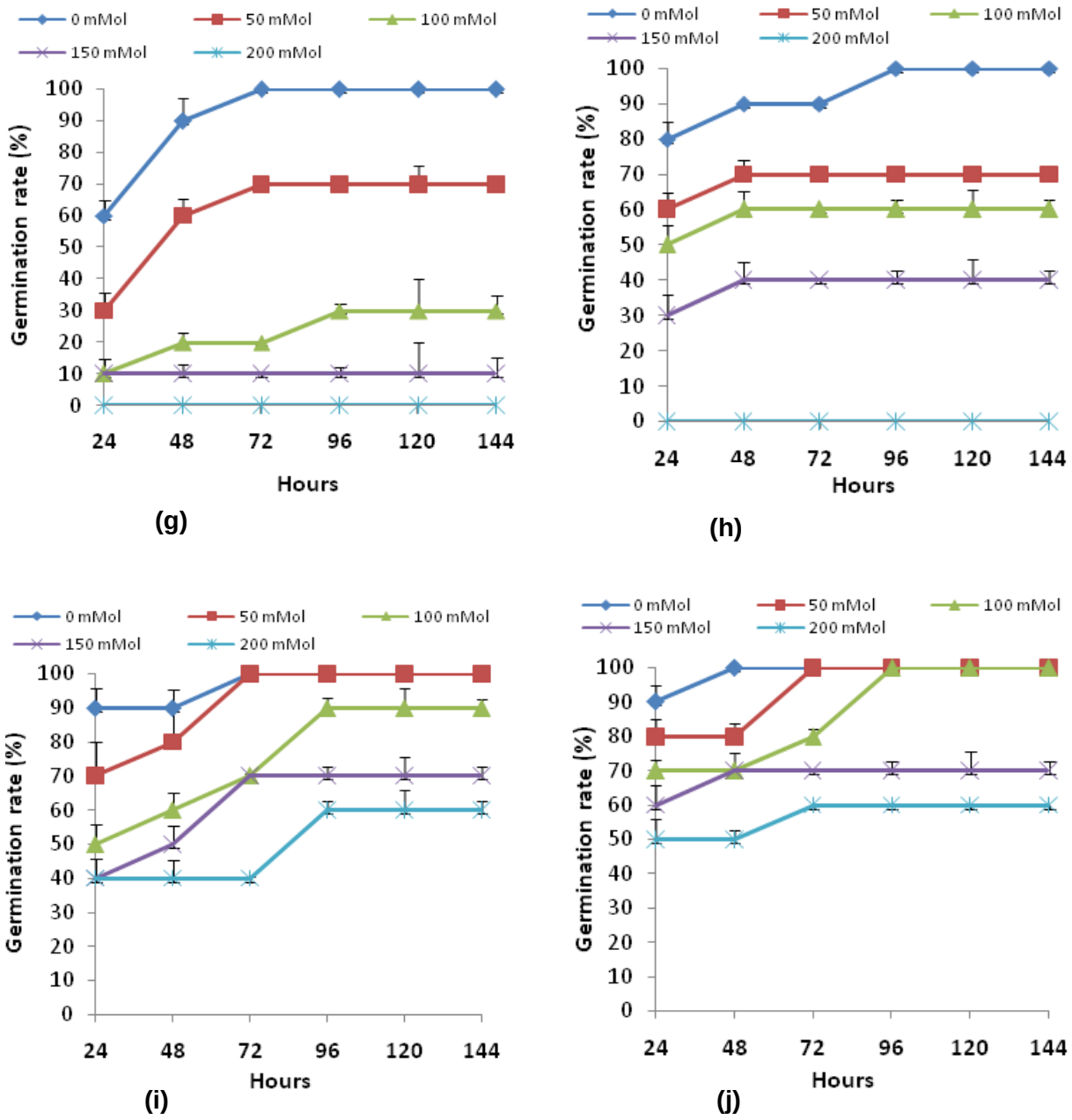

Figure 1. Contd.

Table 1. Variance analysis (mean square and F value) of germination rate in different level of salt stress.

Variation source	df	Mean square	F
Genotype	9	1710.00	9.79**
Treatment	4	2488.33	14.24**
Genotype* Treatment	36	174.25	0.99ns
Error	100	174.66	

**: highly significant at P<0.001. ns: non significant. df: degree freedom.

The study of morphological traits showed that the effect of varieties was highly significant (P<0.01) on almost traits measured expect shoot dry weight, root fresh weight and root dry weight (Table 2). Salinity caused a significant (P<0.01) reduction on all parameter measured at the higher NaCl concentration. Increase in the salinity had an effect on shoot and root length, shoot and root fresh weight, shoot and root dry weight (Table 1). In the current investigation the higher level of salinity had a pronounced effect on root length and shoot length. Datta

Table 2. Variance analysis of shoot length, root length, shoot and root fresh weight, shoot and root dry weight in normal conditions (0 mMol NaCl) and in different salt stress level (50, 100, 150, 200 mMol NaCl) for different durum wheat genotypes studied. Each value represents the mean of 3 replicates.

Parameter	Shoot length	Root length	Shoot fresh weight	Shoot dry weight	Root fresh weight	Root dry weight
Treatment						
T1	3.2^{d}	4.1^{c}	0.19^{c}	0.02^{b}	0.10^{c}	0.01^{c}
T2	2.6^{c}	2.8^{b}	0.14^{b}	0.01^{b}	0.09^{c}	0.01^{b}
T3	2.0^{b}	2.3^{b}	0.11^{bc}	0.01^{b}	0.06^{b}	0.01^{bc}
T4	1.0^{a}	1.3^{a}	0.07^{a}	0.01^{a}	0.03^{a}	0.00^{ab}
T5	0.5^{a}	1.4^{a}	0.09^{ab}	0.00^{a}	0.02^{a}	0.00^{a}
Genotypes						
Agili	1.71^{bc}	2.30^{b}	0.11^{ab}	0.010^{ab}	0.064^{ab}	0.004^{a}
Arbi	2.25^{bc}	2.87^{b}	0.13^{ab}	0.012^{b}	0.072^{ab}	0.005^{a}
Bayatha	1.45^{b}	1.96^{b}	0.10^{ab}	0.010^{ab}	0.060^{ab}	0.005^{a}
Bidi AP4	2.06^{bc}	2.58^{b}	0.12^{b}	0.012^{b}	0.058^{ab}	0.004^{a}
Derbassi	2.00^{bc}	2.74^{b}	0.08^{ab}	0.010^{ab}	0.059^{ab}	0.004^{a}
Hmira	2.07^{bc}	2.58^{b}	0.11^{ab}	0.010^{ab}	0.045^{a}	0.004^{a}
INRAT 69	0.67^{a}	0.92^{a}	0.06^{a}	0.005^{a}	0.057^{ab}	0.003^{a}
Karim	2.05^{bc}	3.12^{b}	0.18^{c}	0.010^{ab}	0.044^{a}	0.007^{a}
Maali	2.65^{c}	2.74^{b}	0.11^{b}	0.013^{b}	0.079^{b}	0.006^{a}
W.Bled	1.99^{bc}	2.52^{b}	0.12^{ab}	0.012^{b}	0.061^{ab}	0.005^{a}
ANOVA						
Genotypes	3.26*	3.04*	3.24*	1.70ns	1.03ns	0.76ns
Treatement	30.38**	20.72**	15.04**	14.26**	20.23**	7.42**
Genotype*Treatment	1.65*	2.30**	5.54**	1.17ns	1.40ns	0.50ns

Values with different superscripted letters are significantly different according to the Duncan's multiple range test ($P < 0.05$).

et al. (2009) showed that different level of salinity significantly affected the growth attributes by reducing root and shoot length for salinity below 125 mMol. The same authors found that the reduction in root and shoot development may be due to toxic effects of the higher level of NaCl concentration as well as unbalanced nutrient uptake by the seedlings. High level of salinity may have also inhibit the root and shoot elongation due to slowing down the water uptake for overall osmotic adjustments of the plant body under high salt stress condition.

The increase of salt stress from 50 mMol onwards significantly reduced the root length and shoot length. The effect of salt stress was completely inhibitory at 200 mMol NaCl concentrations for almost all the varieties. Growth processes are especially sensitive to the effects of salt. Thus, these traits provide reliable criteria for assessing the degree of salt stress and the ability of a plant to withstand it as reported by (Amor et al., 2005).

According Garciarrubio et al. (2003), shoot and root length decrease in salt conditions.

Regarding fresh weight and dry weight the effect of salt stress was pronounced from 50 mMol Nacl concentration onwards. It was completely inhibitory from 150 mMol onwards. The proportion of fresh weight and dry weight allocated to root and shoot decreased with increased NaCl levels. Parida and Das (2005) have shown that salinity can be reduce fresh weight and dry weight.

In conclusion, we revealed in the present work that salt stress delayed and inhibited germination processes and seedling stage in durum wheat by acting on different parameters especially germination percentage, shoot length, root length and shoot fresh weight. These traits may be used as a valuable criterion for the screening of salinity tolerance in durum wheat.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Ethnomedicinal studies on Bondo tribe of Malkangiri District, Odisha, India

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Ethnomedicinal studies revealed the use of 34 angiospermic species by the Bondo tribe of Malkangiri district of Odisha. The traditional medicinal uses were observed to be wide spread and prevalent over modern medicine in the study area. In the present paper, plants for various diseases have been discussed togrther with dosage and mode of administration. Concurrently, correct name, family, local name are also provided for correct identification of the species.

Key words: Bondo, ethnomedicine, Malkangiri district, Odisha.

INTRODUCTION

In the past decade, there was renewed attention and interest in the use of traditional medicine globally. The World Health Organization (WHO) has pointed out that traditional medicine is an important contributor to its health goals. Today, according to the WHO, as many as 80% of the world's people depend on traditional medicine and in India, 65% of the population in the rural areas especially those residing in the remote forests mainly rely on traditional health practices as it is cost effective. Nowadays, the modern people are also using traditional medicinal practices as it has no side effects. Ethnobotany is a very broad field and it is an age old process starting from human civilization and medicine is one of its facet. In Odisha, 62 tribes are living in harmony with the nature in the mountainous forests of different districts. Out of these, 13 tribes are notified as Primitive Tribal Groups (PTG) while two tribes namely Bondo of Malkangiri and Dongaria Kandha of Kalahandi and Raygada districts are very rare and remote tribes under Particularly Vulnerable Tribal Group (PVTG). The present study focused on Bondo tribes of Khairaput block of Malkangiri sub-division. The Bondo with a population of 5895 is one of the primitive tribes found only in the Malkangiri district of Odisha. They are confined to the hill ranges of Khairaput block of this district. Because of the long inhabitation of the tribe in this region, it is known as the Bondo country and the hills present in this region are known as the Bondo hills. The Bondo belongs to south Munda group of austraic family. They are sometimes referred to as the Bondo paraja. There are two important villages namely Mudulipada and Andrahal flanked by a distance of 14 km from each other where the Bondo tribes are living in harmony with nature.

In earlier times, Malkangiri was endowed with rich floristic diversity due to less population pressure coupled with dense forest coverage. In spite of rich and diverse floristic composition, Haines (1921-1925), the pioneer plant explorer for the state of Bihar and Orissa and Mooney

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(1950), the subsequent worker could not botanize this region thoroughly and as such various uses of plants by the natives were not documented in their respective treatise. There is considerable amount of genetic erosion in the plant wealth with the march of urbanization, establishment of factories coupled with the interferences of various categories such as shifting cultivation, illegal felling of tree species for timber and fuel, etc. Paradoxically, the magnitude of devastation is in increasing order during recent times, quite a good number of medicinal and food plants have already been wiped out. On the other hand, establishment of hospitals in remote areas has fascinated the aboriginal people to adopt the modern medical practices. Hence, traditional therapy is almost ignored.

Similarly, their food habit and utilization of plants and plant products for cultural activities have also been changed due to influence of modern civilization. Hence, critical identification as well as conservation of these fast disappearing elements is highly essential. Realizing this, Jain (1970-1971), Pal and Banerjee (1971), Sexena and Dutta (1975), Mudgal and Pal (1980), Subudhi and Choudhury (1985), Sahoo (1986) and Anonymous (1989, 1996) have made some sporadic reports on the ethnobotanical aspects.

Study area

Malkangiri is the southernmost district of Odisha. The district is named after its headquarters town Malkangiri. During the formation of Orissa province in 1936, Malkangiri was a 'Taluk' of Nabarangpur sub-division of Koraput district of Odisha. In 1962, it was upgraded to a sub-division of Koraput district and later on designated as a separate district. Malkangiri lies in between 17°45'N and 18°40' N latitudes and 81°10'E to 82.00' E longitude and situated at an elevation of 641'(feet) from the mean sea level (Map 1). The district spreads over an area of 5791 sq. km (48. 43 km radius) as per the census of 2011. Malkangiri has a population of 613,192, out of which 5895 are Bondo.

The area is of broken mountains intersected by large riverbeds and water courses. The altitude varies from 400 m near western side to 1200 m on the eastern side with mountain peaks and ridges. Sandy and clay type of soil is found to be predominant in the district. The climate of the major portions of the district is influenced by its varied elevation ranges. The minimum and maximum temperatures are 13 and 47°C in the month of December and May, respectively (Indian Meteorological Department, Bhubaneswar). Humidity is generally high especially in the monsoon and post monsoon months. The average annual rainfall is 1,700 mm (67 inches).

METHODOLOGY

Exhaustive seasonal field visits were undertaken (2010-2011) in the aegis of Post Graduate Department of Botany, Utkal University, Bhubaneswar for collection of plants and their relevant information. The plants collected, have been identified in consultation with the regional floras (Haines 1921-1925; Saxena and Brahmam, 1994-1996) and monographs and preserved in the herbarium of the Post Graduate Department of Botany, Utkal University, Bhubaneswar. The information was gathered through oral interviews of the local tribal men, especially older persons, local medicine men and herbalists. During discussions with the tribal peoples, several data like local names, usable parts, medicine preparation methods, mode of application and dosage were recorded. The plants were arranged under respective diseases on which these are used along with family, local name and mode of preparation as well as administration. The medicinal uses of the species have also been confirmed with standard literatures viz. Agarwal and Ghosh (1985), Anonymous (1948-1972), Chopra et al. (1956), Kirtikar and Basu (1935), Satyavati et al. (1987), Saxena and Dutta (1975) and Warrier et al. (1994-1996).

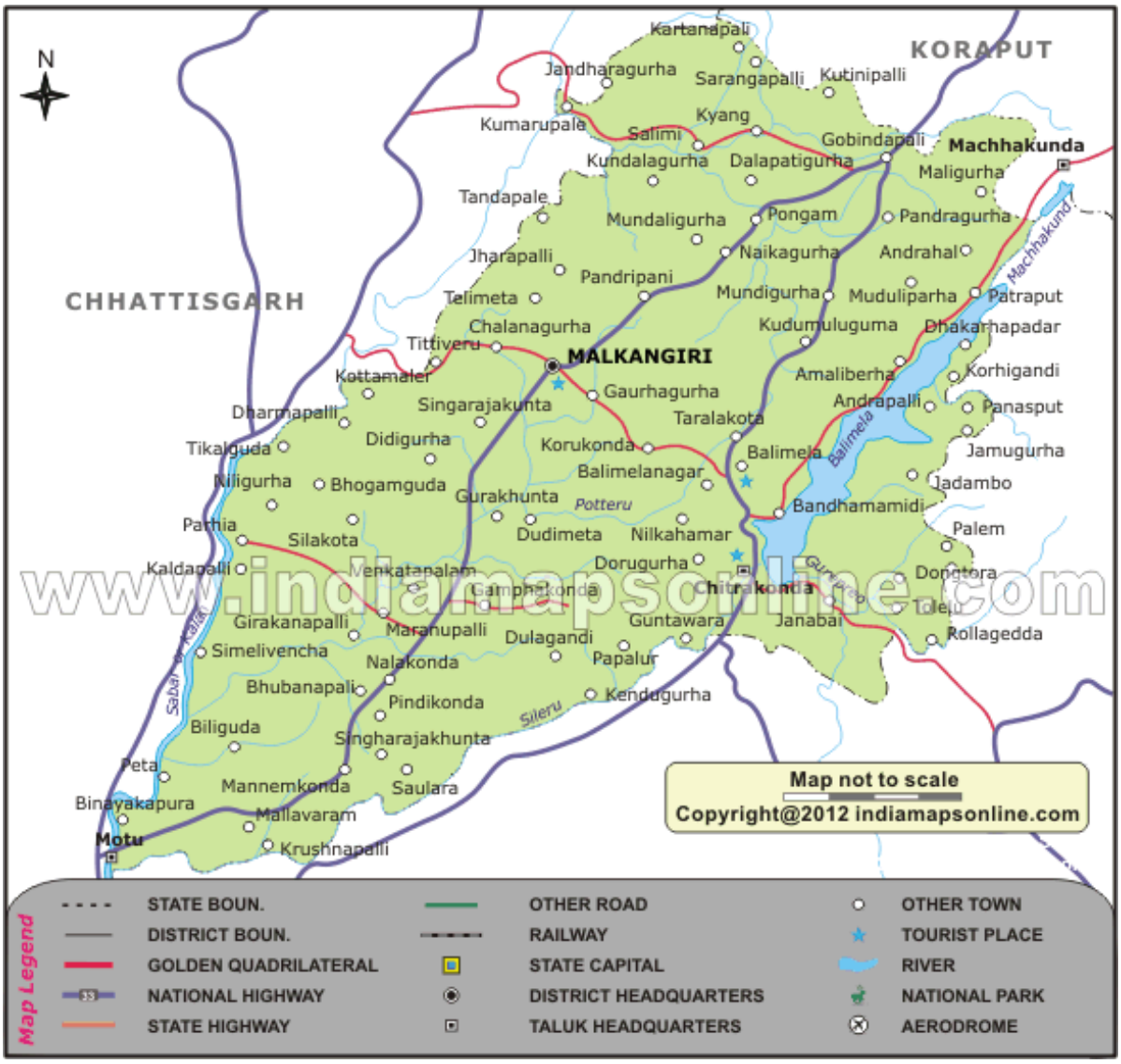
RESULTS AND DISCUSSION

A total of 34 plant species belonging to 33 genera and 25 families were identified as being used for treatment of approximately 17 ailments or therapeutic indications including headache, toothache etc. (Table 1). Fabaceae, Caesalpiniaceae and Acanthaceae families had the largest number of plants used; and the largest numbers of preparations used were for dysentery and skin diseases. Mostly, leaves are used for preparation of medicines for different ailments. Water is used exclusively in the preparation of medicines. The use of *Diospyros melanoxylon* Roxb.*, Nyctanthes arbor-tristis* L.*, Cassia fistula* L.*, Holarrhena pubescens* Wall. ex G.Don and *Hemidesmus indicus* R.Br. by the Bondo tribes for healing different ailments are recorded for the first time and marked with asterisk in Table 1.

Conclusion

Malkangiri, one of the richest botanical treasures in Odisha is under intense biotic pressure owing to forest fire, over exploitation of medicinal plants for drugs and conversion of forest to agricultural lands. These factors of degradation results not only in the depletion of certain valuable interesting medicinal taxa but also leads to substantial reduction in the density and genetic diversity of forest cover. This rapidly damages the natural habitats threatening the very survival of several indigenous species.

Presently, developing nations such as India have an imperative need of a systematic document on the traditional knowledge of various medicinal uses of plants in all autonomous areas or communities, many of which are still largely unexplored. Such documentation is necessary because older people are usually the only custodians of such information and the fast disappearance of traditional cultures and natural resources arising from urbanization and industrialization of such areas suggest that unrecorded information may be lost for ever.



Map 1. Map of Malkangiri District of Odisha.

Table 1. Traditional uses of plants against various diseases.

Therapeutic indication Botanical and Family name	Local name	Plants parts used	Medicinal preparation and dosage
Abortifacient			
Abrus precatorius L. (Fabaceae) (Figure 1)	*Kaincha*	Seeds	Three seeds taken for 4 consecutive days to induce abortion
Plumbago zeylanica L. (Plumbaginaceae)	*Sitaparu*	Root	Two grams of root power with water taken orally for 2 times.
Cough			
Adhatoda zeylanica Medik. (Acanthaceae)	*Basongo*	Leaves	Decoction of seven leaves taken orally for one week.
Barleria prionitis L. (Acanthaceae)	*Tamresa*	Leaves	15 ml of leaf juice mixed with honey given orally for one week.

Table 1. Contd.

Cuts and wounds			
Semecarpus anacardium L. f. (Anacardiaceae)	*Kalabhalia*	Fruits	Oil extracted from the fruits applied externally.
Sida acuta Burm. f. (Malvaceae)	*Bajarmuli*	Leaves	Juice of the leaves applied locally.
Tridax procumbens L. (Asteraceae) (Figure 7)	*Bisal gacha*	Leaves	7-8 leaves rubbed in hand and the juice applied externally.
Diabetes			
Pterocarpus marsupium Roxb. (Fabaceae)	*Bija*	Stem bark	Decoction of the stem bark (2 g) given orally every day.
Syzygium cuminii (L.) Skeels (Myrtaceae)	*Jamukoli*	Leaves and fruits	Juice of leaves and powdered fruit with water taken orally every day.
Dysentery			
Aegle marmelos (L.) Correa ex Roxb. (Rutaceae)	*Bel*	Fruits	10-15 ml of infusion of fruit taken orally twice daily.
Bauhinia vahlii Wight & Arn. (Caesalpiniaceae)	*Sialpatar*	Pods	Decoction of seven pods taken orally for 2 days.
**Diospyros melanoxylon* Roxb. (Ebenaceae)	*Duri*	Stem bark	Crushed stem bark with water given orally for 3 days.
Phyllanthus emblica L. (Euphorbiaceae)	*Anlakoli*	Fruits	Decoction of fruits (seven) taken orally for 3 days.
Fever			
Andrographis paniculata (Burm.f) Wall. ex Nees (Acanthaceae)	*Bhuingkara*	Leaves	50 ml of infusion of leaves taken orally for 3 days.
Argemone mexicana L. (Papaveraceae) (Figure 2)	*Kantakusum*	Root	Fresh root grounded with black pepper and the extract given orally one spoonful twice in a day for 5 days.
**Nyctanthes arbor-tristis* L. (Oleaceae)	*Kokra*	Leaves	Leaf juice together with black pepper is given internally till fever cures.
Gastro–intestinal disorders			
Achyranthes aspera L. (Amaranthaceae)	*Chir-Chir*	Aerial parts	Half glass of decoction of aerial parts taken orally for 2 days.
Asparagus racemosus Willd. (Liliaceae) (Figure 5)	*Pinaspari*	Root	Dried root powder crushed with turmeric and the filtrate taken orally, 2 spoonfuls twice a day for 3 days.
Terminalia chebula Retz. (Combretaceae)	*Harida*	Bark	5 ml decoction of bark taken orally for one week.
Headache			
Ricinus communis L. (Euphorbiaceae)	*Jada*	Seeds	Oil from the seeds applied on head for cooling effect.
Jaundice			
Vitex negundo L. (Verbenaceae)	*Begunia*	Leaves	20 ml of infusion of leaves taken orally for 3 times with a gap of 4 days.
Leprosy			
**Cassia fistula* L. (Caesalpiniaceae)	*Sonari*	Leaves	Decoction of leaves applied on the affected area.

Table 1. Contd.

Costus speciosus (Koenig.) Sm. (Zingiberaceae)	*Keokanda*	Rhizome	Paste of the rhizome with water applied locally.
Liver disorder			
**Butea monosperema* (Lam.) Taub. (Fabaceae) (Figure 3)	*Palaso*	Leaves	A glass of leaf extract taken orally for 2 days.
Rheumatic pain			
Holarrhena pubescens Wall. ex G.Don (Apocynaceae)	*Khucchi*	Leaves	Two to three leaves are attached with the latex of the same plant over back bone and fomented externally.
Lantana camara L. *var. aculeata* (L.) Mold. (Verbenaceae) (Figure 6)	*Nagiri*	Leaves and flowers	Decoction of both parts given orally for 21 days.
Skin diseases			
Azadirachta indica A. Juss. (Meliaceae)	*Nima*	Leaves	Crushed dried leaves with water applied locally till cure.
Calotropis gigantea (L.) R. Br. (Asclepiadaceae) (Figure 4)	*Arakha*	Root	Dried root powder sprayed locally.
Cassia tora L. (Caesalpiniaceae)	*Chhota Chakunda*	Leaves	Leaf paste applied locally for 3 days.
Mimosa pudica L. (Mimosaceae)	*Lajuli*	Root	5 ml of root juice applied locally for one week.
Snakebite			
Strychnos nux-vomica L. (Loganiaceae)	*Kochila*	Root	Root paste applied locally.
Stomach pain			
Ocimum tenuiflorum L. (Lamiaceae)	*Tulsi*	Leaves	A handful of leaves boiled in water and the infusion taken orally till pain relief.
Toothache			
**Hemidesmus indicus* (L.) R. Br. (Asclepiadaceae)	*Chirmar*	Root	Root paste is applied on teeth or a piece of root is crushed by teeth.

Figure 1. *Abrus precatorius*.

Figure 2. *Argemone mexicana.*

Figure 3. *Butea monosperma.*

Figure 4. *Calotropis gigantea*

Figure 5. *Asparagus racemosus.*

Figure 6. *Lantana camara var. aculeatae.*

Documentation of plant materials used in traditional medicine could benefit general health care and promote forest conservation and ecological research. Such plants could also be incorporated into primary health care, as people generally feel safer with indigenous cures and also cost effective as compared to modern drugs. So this will pave way for conservation and to restore the genetic diversity.

Conflict of Interests

The author(s) have not declared any conflict of interests.

Figure 7. *Tridax procumbens.*

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Full Length Research Paper

Assessment of birds of the Arid water bodies in Tigray, Northern Ethiopia

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The ornithological role of lake Hashengie and 10 selected reservoirs have been studied from January to February, 2012 in Tigray, Ethiopia. Birds were surveyed using total and Block count methods from suitable vantage points. Bird species diversity, dominance, and vegetation cover were estimated. A total of 22,845 birds of 67 species belonging to 19 families were recorded. Maximum numbers of species were recorded in Lake Hashengie (65) followed by Hzaeti Wedi Cheber (38) and minimum was recorded in Mai Della reservoir (15). Significant difference in bird species were recorded between the two sites which have maximum number of bird species (Mann-Whitney Test: W = 778.5, P = 0.00). The migratory status of bird species showed that 47 (70 %) were migrants and the rest 20 (29%) were residents. Vulnerable species, Ferruginous duck, *Aythya nyroca,* in Lake Hashengie and globally near threatened species, Rouget's rail *Rougetius rougetii* in Teghane and Ruba Feleg reservoirs were recorded. The highest vegetation cover (65%) was estimated in Tsnkanet. We conclude that the reservoirs and the natural lake intended for irrigation harbor a number of bird species and are an important foraging, breeding, roosting and nesting grounds for the birds.

Key words: Migratory, reservoirs, residential, Hashengie, threatened, vulnerable, Tigray, Ethiopia.

INTRODUCTION

Ethiopia has a large natural and cultural diversity with a gigantic range of climates which result from its topography and latitudinal position. It has a very diverse set of ecosystems ranging from humid forest and extensive wetlands to desert. The great plains of Ethiopia occur atop colossal highland plateaus, cloven into unequal halves by the Great Rift Valley. Many of these mountain ranges reach over 4100 m above sea level, and are home to plentiful endemic species of flora and fauna (Jacobs and Schloeder, 2001). There is a great variation in altitude ranging from 120 m below sea level in Dalol to 4620 m above sea level in Rass Dashen. The differences in altitude and latitude have resulted in a wide variation in climates (rainfall, humidity, temperature etc) and this improbable diversity of ecology is auxiliary mirrored by the diversity of fauna and flora (Jacobs and Schloeder, 2001; Yalden et al., 1996; Yalden and Largen, 1992).

According to Institute of Biodiversity Conservation (IBC) (2009) of Ethiopia's 4th Country Report, there are known to be 284 wild mammal, 861 bird, 201 reptile, 63

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amphibian, 188 fish and 1225 arthropod species with about 10, 2, 5, 54, 0.6 and 21% endemism respectively. Several reports site these variations in the topographic features of the country as one of the reasons to its high faunal and floral diversity and endemism (Jacobs and Schloeder, 2001; Yalden et al., 1996). Ethiopia possesses a great diversity of Lakes, rivers and wetland ecosystems. The Ethiopian aquatic ecosystems are found in many areas and include the major rivers and lakes that are of great national and international importance. The country is well known for its richness in its water potential. There are about 30 major lakes, 12 major river basins and over 70 wetlands that are located in different ecological zones of Ethiopia (IBC, 2009). As a result, Ethiopia is a center of biological diversity with ample endemism.

Ethiopia has a diverse number of both terrestrial and aquatic bird species and one of the most significant in Africa and its divers habitat type definitely contribute for the immensely diverse avifauna. The number of species varies in literature but the most commonly cited number is 861 species of birds (EWNHS, 1996). However, a recently published book on the birds of Ethiopia and Eritrea by Ash and Atkins (2009) minimized to 837 species. Lepage (2013) raises the number to 857. There is no clear estimated number in which the diverse habitat such as National parks, Lakes, Wetlands and Rivers banks are supported to both terrestrial and aquatic birds. Specially, unprotected areas such as reservoirs have never been studied as habitat to feeding, breeding and nesting to water bird diversity in Ethiopia, specifically in Tigray.

Tigray is an arid zone located in Northern Ethiopia. It has only one Natural Lake Hashengie in the southern Ofla Wereda and has many rivers such as Tekezze, Worie, Gba, Tsedya, Gedgeda and Tsalyet. Moreover to this natural lake and rivers, 79 reservoirs have been constructed and continue to construct for the purpose of agricultural irrigation for drought reduction in the region. Farmers intensively use these reservoirs for cultivation of short seasonal crops. The reservoirs are also crucial home for foraging, breeding and nesting of many migratory and residential water birds. A preliminary survey by Tsehaye et al. (2007) established that the reservoirs exhibit a peculiar biodiversity in water birds. Water bird communities represent a potentially useful group of organisms for monitoring changes to freshwater ecosystems. They may be ordered into functional groups representing a combination of diet and habitat use that allow assessment of changes to wetland habitats (Balapure et al., 2013; Kingsford and Porter, 1994). Since water birds frequently show strong dependence on lakes, rivers and proximate wetlands, they are highly sensitive to environmental change and human disturbance.

To our knowledge, the natural Lake Hashengie and the reservoirs are among the least studied water ecosystems with reference to ornithology in the region. There is an imperative need for collecting relevant information on the diversity of the water bird communities to fill gaps on the overall bird list from this region to the country list. For the most part, a systematic bird species list and information on bird diversity are lacking from both the natural lake and unprotected reservoirs. Bibby et al. (1992) reported that preparation of a list of species is basic to the study of avifauna of a site, because a list indicates species diversity in general sense. Characterizing community species composition and water bird dynamics are also important evaluation indicators that reflect habitat quality (Benjamin et al., 2009; Joseph and Myers, 2005; Paillissona et al., 2002).

Therefore, the study was aimed to assess information on the bird diversity, abundance, screening key species of conservational concern and overall threats in both the natural lake and the selected reservoirs for a better understanding of the habitat suitability for water birds and subsequently for future protection and management of such crucial sites.

MATERIALS AND METHODS

Description of the study area

The study was conducted in seven weredas of Tigray; namely Aynalem, Atsbi Wenberta, Enderta, HintaloWajerat, Kilte Belesa, Ofla and Wukro from January to February two times per month in 2012. Water bird survey specially on January and February are appropriate time for estimation of bird diversity and abundance in Ethiopia. Wintering migratory birds are greater than other time in the year. Therefore, our estimation of bird species diversity and abundance both migratory and resident were high. Lake Hashengie (1) from Ofla, Mai Delle (2), Gum Selassa (3) and Mai Gassa I (4) from Hintalo Wajerat, Mai Gassa II (5) and Hizaeti Wedicheber(6) from Enderta, Gereb Beati (7) from Aynalem, Laelay Wukro (8) from Wukro, Teghane (9) and Ruba Feleg(10) from Atsbi Wenberta and Tsinkanet (11) from Kilte Belesa were selected (Figure 1).

The natural Lake Hashengie is fed by a number of small streams from the surrounding areas during the rainy season only. There is no river which flow to the lake permanently and no drainage out of it. The bowl rim forms steep cliffs all around, except in the north-east where there is a long basin. East and north east of the lake is surrounded by flat agricultural land and large areas of marshland when water decreases during the dry season. Scatter houses are situated on the foot of the mountains. The valley in the north-east is a vital area which holds up copious domestic animals. Plant coverage was less in comparison to other natural lakes of Ethiopia. However some very small and scattered shrubs and trees, such as *Croton macrostachyus*, *Vernonia amygdalina* and *Buddleja polystachya*, *Acacia abyssinica*, *A. pilispina*, *Ekbergia capensis, Juniperus procera* and *Olea europaea cuspidata* were found. Nile Tilapia *Oreochromis niloticus* and introduced carp fishes are also found in the lake.

The other water bodies which were assessed were the reservoirs. All the reservoirs are constructed on suitable agricultural lands for irrigation purpose. People use intensively the water for short term growing crops after seasonal crops are harvested and for domestic animal watering during the dry season. Surroundings of the reservoirs are almost green the whole year. From mid- March and end of April water level decreases in most of the reservoirs. *Garra spp.* and introduced *Tilapia spp.* are found in Laelay Wukro, Tsinkanet while in Mai Gassa I and II, Gum Selassa , Hizaeti Wedi

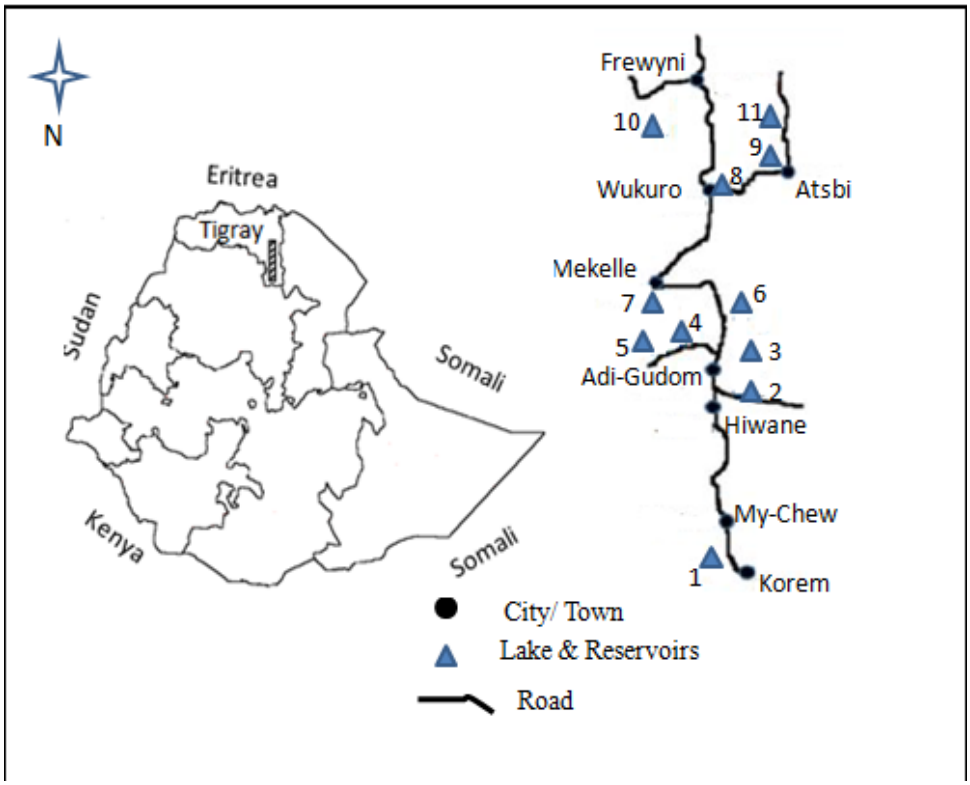

Figure 1. Approximate location of the surveyed lake (1) and reservoirs (2-11) In Tigray, Ethiopia.

Cheber, Gereb Beati have *Garra spp.* only.

Data collection

Data was collected from one natural Lake Hashengie, previously identified as Important Bird Area (IBA) and 10 reservoirs which are ornithologically poorly studied. For areas with a smaller number of water birds, direct counting was adopted while for areas with a larger assemble of water birds, group-number counting following the method by Ma et al. (2006). In this method, a suitable vantage point was selected and all visible birds were counted. Total count was also used wherever possible, by walking around the proximate wetlands or from specific vantage points to count the birds. If not completely covered, the case of Lake Hashengie the percentage of coverage was marked and Block counts were applied to count the birds. Each site was divided into many sections and each section was counted. During the study, birds which were noticed in the sites were classified according to the migratory status as migratory (M) and resident (R). Some bird species migrate while some of them remain throughout the year. Besides, East African migrant, migrant breeding, migrant wintering and Palearctic migrants were also considered as migrant in the appendix only. Based on the frequency of observation birds were also categorized into Common (Com) for birds seen on 10-11 sites; Occasional (Oc) for birds seen on 7-9 sites, Rare (Ra) for birds seen on 1-6 sites. Birds were systematically counted from morning 6:00 to 10:00 h using Celestron (10 × 50) binocular. Identification of the birds to species level was made using appropriate field guides (Stevenson and Fanshawe, 2002; Sinclair and Ryan, 2003; Redman et al*.,* 2009).

The proportion of vegetation cover was recorded in percentage. Three observers were estimated the surrounding vegetation cover and average percentage was taken to each reservoir and the natural lake. In addition, some common plant species to all reservoirs are also recorded by using circular line transect around the reservoirs.

Data analysis

The water bird species diversity was determined using Simpson diversity index as described by Akosim et al. (2008). The model is as follows:

$$D = \sum[-Piln\ Pi]$$

Where, D = Shannon index; P_i is the proportion of the species in the sample. Significant different in bird species between sites which recorded maximum number of bird species was tested using Mann-Whitney Test and tests were set at (P=0.05).

RESULTS

Diversity of birds

In the surveyed, one natural lake and ten reservoirs a total of 22, 845 birds of 67 species belonging to 19 families were recorded (Appendix 1). Maximum numbers of species were recorded in Lake Hashengie (65) followed by Hzaeti Wedi Cheber (38) and minimum was recorded in Mai Della reservoir (15) (Figure 2). There is a significant difference in bird species between the two

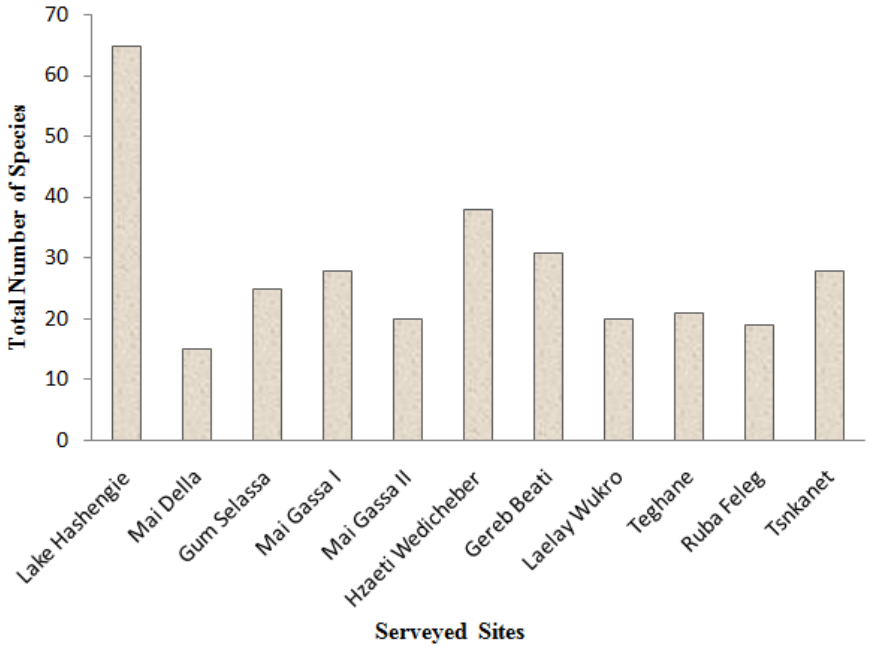

Figure 2. Total number of bird species recorded in each of the study sites in January and February, 2012.

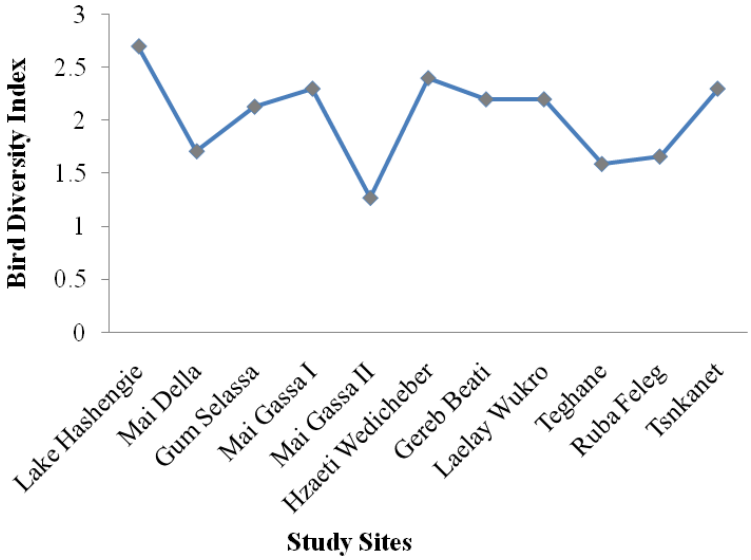

Figure 3. Bird diversity index of the 11 surveyed sites in January-February

sites which recorded maximum number of bird species (Mann-Whitney Test: W = 778.5, P = 0.00). The maximum number of birds were also recorded in Lake Hashengie (18,000) followed by Hzaeti Wedicheber (876) and Tsnkanet (650). Bird diversity was highest in Lake Hashengie (2.7) followed by Hzaeti Wedicheber (2.4) and lowest was in Mai Gassa II (1.27) (Figure 3). Overall, the highest number of individual birds recorded in the sites were Egyptian goose, *Alopochen aegyptiacus* (4,580) followed by little greb, *Tachybaptus ruficollis* (2,100) (Appendix 1).

Lake Hashengie holds the highest number of family 18 (except family Otididae) followed by Hzaeti Wedicheber 17 family (except Phalacrocoracidae, Phoenicopteridae and Threskiornithidae) (Figure 4). The least, 11 family were recorded in May Della and Gum Selassa. All the

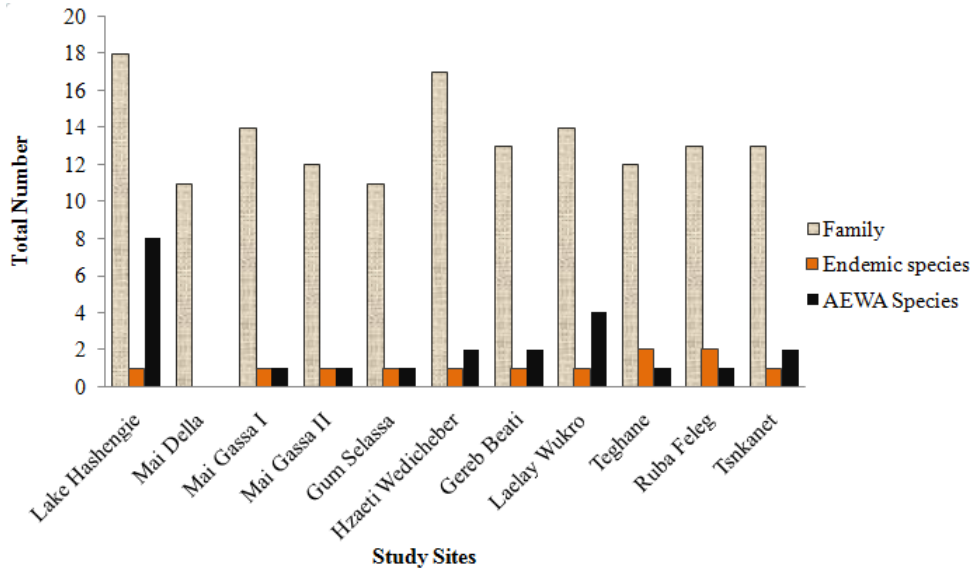

Figure 4. Total number of family, endemic and agreement on the conservation of African-Eurasian Migratory Water birds (AEWA) of bird species recorded in the natural lake and in each Reservoirs of Tigray, Northern Ethiopia.

Table 1. Total number of Species contribution, Resident, Migratory and abundant species in the family of birds recorded in the survey sites.

Family	NS	NRS	NMS	ASF
Anatidae	13	2	11	*Alopochen aegyptiacus*
Anhingidae	1	-	1	*Anhinga rufa*
Ardeidae	7	2	5	*Bubulcus ibis*
Burhinidae	3	3	-	*Burhinus senegalensis*
Charadriidae	4	1	4	*Charadrius tricollaris*
Ciconiidae	5	1	4	*Charadrius tricollaris*
Glareolidae	1	-	1	*Glareola pratincola*
Motacillidae	1	-	1	*Motacilla flava*
Otididae	1	1	-	*Lissotis melanogaster*
Pelecanidae	2	-	2	*Pelecanus onocrotalus*
Phalacrocoracidae	2	-	2	*Microcarbo africanus*
Phoenicopteridae	1	1	-	*Phoenicopterus minor*
Podicipedidae	3	-	3	*Tachybaptus ruficollis*
Rallidae	3	3	-	*Fulica cristata*
Recurvirostridae	3	1	2	*Himantopus himantopus*
Scolopacidae	10	-	10	*Actitis hypoleucos*
Scopidae	1	-	1	*Scopus umbretta*
Sternidae	2	-	2	*Sternula albifrons*
Threskiornithidae	4	3	1	*Threskiornis aethiopicus*
Total	67	18	51	

NS, Number of species; NRS, number of resident species; NMS, number of migratory species; ASF, abundant species in the family.

reservoirs together holds 18 family less than by one from Lake Hashengie. Family Anatidae contributed 13 species, of this 11 are migratory and 2 residents followed by family Scolopacidae 10 species, of this 10 migratory (Table 1). Six family, Scopidae, Phoenicopteridae, Otididae, Motacillidae, Glareolidae and Anhingidae were represented only by one species. The migratory status of bird species showed that 47 (70%) were migrants and the

Table 2. Species dominance and percentage abundance in each of the study sites in February - January in Tigray.

Site	Species abundance	Percent
Lake Hashengie	*Alopochen aegyptiacus*	45
Mai Della	*Charadrius tricollaris*	29
Gum Selassa	*Fulica cristata*	26
Mai Gassa I	*Fulica cristata*	36
Mai Gassa II	*Egretta garzetta*	23
Hzaeti Wedicheber	*Fulica cristata*	38
Gereb Beati	*Alopochen aegyptiacus*	25
Laelay Wukro	*Egretta garzetta*	31
Teghane	*Alopochen aegyptiacus*	35
Ruba Feleg	*Fulica cristata*	42
Tsnkanet	*Alopochen aegyptiacus*	21

rest 20 (29%) were residents. Lake Hashengie 48 species and Hzaeti Wedicheber 30 species had contributed a maximum migratory bird species while the least, 4 species were recorded in Mai Della. Both species, *Alopochen aegyptiacus* and *Fulica cristata* were recorded as abundant species in each of the four different sites. The remaining three sites are dominated by two species (Table 2). The bird species found were categorized into rare 35 (52%), occasional 19 (28%) and common 13 (19%). Three endemic species, *Rougetius rougetii, Vanellus melanocephalus* and *Bostrychia carunculata* and eight species, which are listed under the Conservational agreement of African-Eurasian Migratory Water birds (AEWA) were found in the natural lake and the reservoirs (Figure 4).

Status of vegetation

Percentage proportions of the surrounding vegetation cover and anthropogenic activity were recorded. Tsnkanet, Mai Gassa I, Mai Gassa II, showed better plant coverage than the rest of the surveyed lake and reservoirs. Tsnkanet relatively accounted for the highest 65% of the surrounding cover by vegetation. Some aquatic macrophytes including *Cyperus, Eleocharis, Scirpus, Echinochloa*, *Panicum*, *Alisma*, *Nymphaea, Typha, Paspalidium*, *Potamogeton* were recorded in most of the reservoirs and lake Hashengie.

All surveyed sites were more or less surrounded by agricultural lands and grazing range land except scattered *Acacia species* and other shrubs which grew in the edges. Anthropogenic activities, such as agricultural activity, washing, cattle drink was infrequently observed at Mai Gassa I, Mai Gassa II and Gum Selassa and these sites were far from human settlement. Most surrounding areas of Mai Gassa I and II, Tsenkanet showed diverse vegetation whereas in Laelay Wukro and Teghane the vegetation cover was very less. Below Teghane and Ruba Feleg a very small wetland created by seepage water was present as home of the globally near threatened species Rouget's rail *Rougetius rougetii*. Mai-Della was the only reservoir without any water and vegetation observed during the study. Lake Hashengie was surrounded by degraded agricultural land with no vegetation coverage and supported a number of grazing animals during the dry season.

Feeding habits and activity

Water birds were found to feed on food available in the wetlands. Feeding partitioning was observed among the bird species during the survey. Egyptian goose *Alopochen aegyptiacus* was found feeding at the water part, open agricultural land and mud reservoirs having no water. Ferruginous duck *Aythya nyroca* and Garganey *Anas querquedula,* little grebe *Tachybaptus ruficollis*, Great crested grebe *Podiceps cristatus,* Great white pelican, *Pelecanus onocrotalus*, Red-knobbed coot *Fulica cristata,* Eurasian coot *Fulica atra* were observed feeding in the pelagic column of water. Common greenshank *Tringa nebularia,* Common sandpiper *Actitis hypoleucos,* Spur-winged goose *Plectroptenus gambensis,* Three-banded plover *Charadrius tricollaris,* Wood sandpiper *Tringa glareola,* Senegal thick-knee *Burhinus senegalensis,* African wattled lapwing *Vanellus senegallus* were seen foraging at edge of water. Cattle egret *Bubulcus ibis,* Little egret *Egretta garzetta,* Sacred ibis *Threskiornis aethiopicus,* Rouget's Rail *Rougetius rougetii,* Watled ibis *Bostrychia carunculata* foraged in the proximate wetlands. Little greb, Red-knobbed coot, Yellow-bill duck, Egyptian goose, Great crested grebe frequently dived into water for feeding. Fighting among water birds was not common during feeding except in Egyptian goose. The most aggressive behavior with noise was shown by Spur winged lapwing towards other birds feeding at the edge of water. Feeding activity was highest in the early morning and late afternoon. During late morning and afternoon sunning in mixed flocks of Great white pelican, Yellow-bill stork and Cattle egrets were common. Egyptian goose and Yellow-bill duck were observed to flock in large number as independent group during sunning. For overnight roosting, most of the water birds aggregated at the edge of the water.

DISCUSSION

Diversity of avian species varied in relation to modified habitats, such as hedgerows, surrounding vegetation composition, wetland structure above and below and anthropogenic effect. Species richness and abundance of birds varied between sites and possibly influenced by altitude and by the type of vegetation (Hailemariam et al., 2013) Lake Hashengie holds the highest number of bird species. We predict that this is the maximum number of

water birds in the lake. Since, large numbers of migratory birds are added to the resident species, this time is the most appropriate time to count migratory birds in Ethiopia. It is the only natural lake covering large area and previously identified as Important Bird Area (EWNHS, 1996). Lake Hashengie may be the first distinction in Ethiopia to Palearctic migrant birds as temporal site after crossing the Palearctic continent. This total bird report in lake Hashengie can approve to the previous total bird estimations by different scholars. Ethiopian Wildlife and Natural History Society (EWNHS) (1996) reported the lake probably holds 20,000 water birds on a regular basis and a total of 17,000+ was recorded in January. We have counted also 56 individuals of the globally vulnerable species of *Aythya nyroca* and endemic species of *Bostrychia carunculata* in the lake. Birds such as, *Vanellus senegallus, Vanellus spinosus, Mycteria ibis, Threskiornis aethiopicus, Plectropterus gambensis, Aythya fuligula, Anas undulata* and *Anas strepera* which are listed under the agreement on the Conservation of African-Eurasian Migratory Water birds were found. Even if such important birds are found in the lake, some species such as the threatened species *Rougetius rougetii* which was reported previously in the lake were absent during our survey. The species predominantly occurs in wetlands and marshy areas (del Hoyo et al. 1996). It has been recorded foraging in open meadows, on bare mud and in shallow waters (Urban et al. 1986; del Hoyo et al. 1996). However, wetlands and marsh lands important habitat for hiding this bird in the surrounding lake is drying by overgrazing of cattle. Czech and Parsons (2002) pointed that natural wetlands continue to decrease in area throughout world. Lake Hashengie, like a number of other Ethiopian lakes such as Lake Tana by Shimelis and Afewerk (2008) is experiencing serious environmental problems as a result of overgrazing, agricultural encroachment and the unregulated use of agrochemicals. Fishing activity, agricultural expansion in the shoreline and other high anthropogenic disturbance is the current growing impact around the lake. This may the explanation for the absence of this species during our survey. Even if, we did not able to compare with such previous reports, we can swear this may have clearly effect on the total bird abundance and richness in the lake.

The reservoirs are also home to 62 species of the total 67 species (except *Aythya nyroca, Anhinga rufa, Anas querquedula, Microcarbo africanus* and *Phalacrocorax carbo).* The reservoirs share a number of common birds and important conservational concern of African-Eurasian Migratory Water birds (*Anas undulata, Threskiornis aethiopicus, Vanellus senegallus* and *Vanellus spinosus*). A Key Ethiopia highland endemic species *Vanellus melanocephalus* and *Rougetius rougetii* are also found in Teghane and Ruba Feleg*.* This is a highly evident to the reservoirs role in supporting important conservational concern birds in the region.

Most of the migrant species were migrant wintering. Hamerkop *Scopus umbretta,* Abdim's stork *Ciconia abdimii,* Black headed heron *Ardea melanocephala,* Grey headed heron *A. cinerea* , Purple heron *A. purpurea* Cattle egret *Bubulcus ibis,* Egyptian goose*, Alopochen aegyptiacus,* Little egret *Egretta garzetta,* Sacred ibis *Threskiornis aethiopicus,* Yellow-bill stork *Mycteria ibis* were migrant breeding. The Herons and Abdim's stork commonly breed in Alamata near Lake Hashengie, in Mekelle city near Gereb Beati and in Wukro town near to Laelay Wukro. We have found Egyptian goose with their three chickens and two eggs of other Goose in Tsnkanet. Some birds, for example, Spot-breasted Plover, Blue-winged Goose, Rouget's Rail, White-winged Flufftail, Wattled Crane, Corn Crake, Shoebill, Black-winged Pratincole, Great Snipe, and Lesser Flamingo in general favor, feed and/or breed in wetlands (Mengistu, 2000). We have found also, hedgerows around reservoirs and old plant trees in towns near the reservoirs are good opportunity as breeding site of both migratory and resident species. Report indicated, hedgerows are also serve as a corridor and refuge and play a role in soil conservation and runoff catchments and provide nesting, feeding and wintering sites for birds (Kati and Sekercioglu, 2006; Rappole et al., 2003; Stewart, 2001).

Frequencies of sighting large number of birds were still higher in Lake Hashengie than the reservoirs. This may in terms of area coverage and nature of the lake is better than the reservoirs. Large size as compared to small size might contribute to the highest bird species diversity and evenness. This is because of the availability of multiple and variety of alternative feed sources for bird; moreover, large area is inaccessible for people contributing to a favorable condition for breeding, feeding and nesting sites (Shimelis and Afework, 2008; Smith, 1992). Besides, farmers extensively use water for irrigation and degrade lands for plantation during the dry season. This leads in some of the reservoirs, specifically to late March, water level falls and most of the migratory birds move from the reservoirs lake Hashengie and elsewhere and this may be the possible reason for their less sighting frequency. In habitats where the intervention of humans is less and minimum, the diversity as well as the evenness of species is higher than the fragmented ones where intensive farming is carried out (Rana, 2005). Water dependant feeding may have its own impact up on the diet of water birds. *Aythya nyroca* and *Anas querquedula, Tachybaptus ruficollis, Podiceps nigricollis, Anas clypeata, Anas undulate* are sighted to feed on significantly deeper water. Various studies reported that water level and the bird abundance are inter-related (Colwell and Taft, 2000). Typical Our result also showed that in Mai Della, which were almost dry during the survey recorded small number of bird species in comparison to the other reservoirs. Considering the negative effect of pestsides, insectsides, herbsides and other chemicals, agricultural practices around the

reservoirs provide alternative food resources to water birds during the dry months such as, *Alopochen aegyptiacus*, *Bostrychia carunculata*, *Threskiornis aethiopicus, Plegadis falcinellus, Ardea purpurea, Egretta garzetta, Ardea cinerea, Ardea melanocephala, Bubulcus ibis, Lissotis melanogaster, Motacilla flava* and others which prefer near water areas. On the other side, the *Bostrychia carunculata* and *Rougetius rougetii* which are recorded as rare during the survey are completely dependent in wetland and marshland habitats near reservoirs are at high risk to chemicals used in the agriculture. Especially, *Rougetius rougetii* which depend on such kind of habitat for breeding and feeding may become endangered in the near future. del Hoyo et al. (1996) supports that the bird breeds in marshy areas within high altitude montane grasslands and moorlands . Overall, the population of this specie is suspected to be in decline owing to ongoing habitat destruction. Grazing and agricultural fields were used more by *Alopochen aegyptiacus* than other birds. We have observed high number of Egyptian goose which fed in water and on open agricultural land far from water in most of our survey. They are generalist and sometimes difficult to category as terrestrial or aquatic birds since they are dominating the agricultural fields.

Conservational perspectives

Report by Jeffery et al. (2004) large number of breeding populations of palarearctic migrants birds were recorded in Ethiopia. The country also hosts many important resting and feeding areas for birds, including millions of migrates crossing the Sahara Desert (Şekercioğlu, 2012). 47 migratory bird species were recorded including palarearctic species in both the reservoir and the natural lake. However, in Ethiopia, several ecosystems of high biological importance are threatened and there is a need for strong conservation action that should be supported by legislation (Pol, 2006). To our understanding, attempts to conserve faunal diversity specifically avifauna around reservoirs have received little attention. Awareness creation on conservation of bird species and other biodiversity in and around the reservoirs to local people and agricultural experts are decisive. Study by Hailemariam and Tsegazeabe (2013) indicates, establishment of local people awareness on ecological benefits of birds is crucial for conservation activity. Successful conservation of the avian species will depend on community attitude, management of water level, application of chemicals and anthropogenic disturbance around the natural lake and reservoirs. Further similar survey and intensive studies spread over different seasons of the year are needed. This could help in producing other globally interesting birds which are absent in our study for further notice in the conservation of the lake, reservoirs and their proximate flora and fauna.

Conclusion

Overall, the surveyed sites comprised water bird species of resident, migratory, globally threatened and vulnerable bird species. The natural lake, the reservoirs and their proximate wetlands are the only breeding sites to this water bird species in the region. During our observation, most of the reservoirs are relatively suitable for breeding to many birds than the natural lake Hashengie. They can be alternative promising sites to increase bird diversity in such kind of arid regions. But, the sites are still unprotected, undefined and dwindling in area by agricultural expansion and other anthropogenic factors. However, these sites could be additional to the IBA sites to Ethiopia in general and specifically to the region for the future when protection and estimation of the total populations of bird species of the 79 reservoirs is continued.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Assessment of downstream impact of Bahir Dar tannery effluent on the head of Blue Nile River using macroinvertebrates as bioindicators

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A study was conducted to determine the downstream impact of Bahir Dar Tannery wastewater on the head of Blue Nile River using macroinvertebrates as bioindicators. Four sampling sites (one upstream and three downstream) were selected along the river and samples were collected from October to March, 2010/11. Macroinvertebrates were collected using standard dip net based on the Rapid Bioassessment Protocols for use in streams and wadeable rivers and identified to the family level. A total of 9,162 individuals belonging to 28 families were collected during the study period. Results of analysis of variance (ANOVA) showed that, there was significant difference in macroinvertebrate metrics among sampling sites. Percent Ephemeroptera Plecoptera Trichoptera (EPT) Index, Shannon Diversity Index and Benthic Macroinvertebrate Index were higher and percent Diptera, Chironomidae and Hilsenhoff Family level biotic index were lower at the reference site. The categorization of sites based on Benthic macroinvertebrate index value indicated that the site just below the effluent discharge and 200 m from it were severely to slightly, the last downstream site moderately to less and the reference or upstream site very little to none impacted. The water quality at these sites was also very poor to poor, fair to good and very good to excellent, respectively. The most impacted sites ranked last in all sensitive metrics while the reference ranked first in sensitive metrics indicating the severe impact of the effluent on downstream sites. The result gave the trends of pollution of the river by the effluent and the urgent need for measures to be taken.

Key words: Tannery effluent, macroinvertebrates, bioindicators, Blue Nile River.

INTRODUCTION

Rapid population growth, urbanization and industrial development have been adversely degrading the environment (Mason, 1990) by their effect through loss of biodiversity and pollution from wastes. Industrialization, like other human activities that impact on the environment, often results in pollution and degradation. It carries inevitable costs and problems in terms of pollution of the air, water resources and general degradation of the natural environment (Suflita et al., 1983). Industrial waste is the most common point source of water pollution in the present day (Ogedengbe and Akinbile, 2004) and it increases yearly due to the fact that industries are

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increasing because most countries are getting industrialized. In Ethiopia too, industries are increasing in number turning out wastes which are peculiar in terms of type, volume and pollution strength depending on the type of industry, raw materials used and process and technological variations applied to the process.

As compared to other industries, leather tanning is one of the most polluting activities (Khan et al., 1999) as it consumes huge amount of water in several stages, generating an enormous sum of liquid effluents (Farenzena et al., 2005) which are hazardous for the environment to which they are discharged. Tannery wastewater is highly polluted in terms of biological oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), Nitrogen, conductivity, sulphate, sulphide and chromium (Mondal et al., 2005) and in most developing countries tannery effluents are discharged directly into sewers or water bodies without treatment (Verheijen et al., 1996; Favazzi, 2002). In Ethiopia also industries turnout wastes directly into the nearby water bodies. This makes industrial and chemical pollution to become the third major problem in the country and one of the great environmental concerns (Zinabu and Zerihun, 2002). This is becoming evident through the pollution of water bodies and human habitat in the major cities, rivers and lakes. So it is very important to assess the ecological impact of the wastes.

Usually, chemical and physical monitoring was widely utilized to assess the extent of pollution of water bodies from point and non-point sources. Recently, rivers sustaining rich and diverse fauna have been recognized for their resource value (Abel, 1996). A more comprehensive approach of biological assessment of water quality recently introduced the Benthic Macro-invertebrate Index (BMI) (Karr, 1981). This has led to an increased focus towards stream ecological well being, and the use of ecological indicators' of water quality (Yandora, 1998).

In Ethiopia and to larger extent the whole of Africa, the use of macro-invertebrate for assessment and monitoring of stream conditions is still not well practiced. However, rapid bio-assessment of water quality in rivers has been used in a National Biomonitoring Programme in South Africa (Dallas, 1997). In East Africa, only few studies have attempted to describe the structure and composition of macro-invertebrates in lotic systems. Mathooko (2002), Barnard and Biggs (1988) and Kinyua and Pacini (1991) in Kenya and Tumiwesigye et al. (2000) in Uganda studied the macro-invertebrate composition of the rivers and lakes. In Ethiopia, Baye (2006) and Solomon (2006) studied the relation between physicochemical change and biological communities in rivers with different sources of pollution. Hayal and Seyoum (2009) studied water quality and macroinvertebrates index of biotic integrity of wetlands. On the other hand, Birnesh (2007) studied downstream pollution profile of Tikur Wuha River from point source. So in Ethiopia, the use of macroinvertebrates in assessing pollution status is in its infant stage. Hence, this study aims to assess the downstream impact of Bahir Dar Tannery effluent on the Blue Nile River using macroinvertebrate as bioindicators.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Bahir Dar, the capital city of Amhara Region which is situated on the southern shore of Lake Tana, the source of Blue Nile (Abay) River. Bahir Dar Textile factory and Tannery are the most important industries in the city. Both the textile factory and the tannery discharged their effluent directly into the Blue Nile River. The downstream part of the river is used for domestic activities including drinking, irrigation and recreation (swimming and bathing). The use of the river in this way may lead to bioaccumulation of toxic pollutants like chromium which is hazardous for human beings as well as livestocks.

Sampling

The study was conducted from October, 2010 to March, 2011. This time was selected to sample from both dry and wet periods so as to avoid possible seasonal effect. Based on the method stated in Klemm et al. (1990) which is mostly used to specify sites for studying pollution from point sources, four sampling sites (one upstream and three downstream) were established on the study area. All the sites had almost similar microhabitats (pools and vegetated areas) and designated as S_1 to S_4 as shown in Figure 1. Qualitative macroinvertebrate data collection was carried out at the same sampling sites based on the Rapid Bioassessment Protocols that are used in streams and wadeable rivers (Barbour et al., 1999). Macroinvertebrates were sampled using standardized dip net (500 µm mesh size). To maintain the consistency of sampling effort, a sample was generally obtained within 30 min at each site and a sampling reach length of 100 m was used. Then macroinvertebrates collected from all microhabitats of each site were pooled so as to obtain a single sample from each site. In the field, macroinvertebrate samples were preserved in 70% ethanol or 10% formalin (for highly polluted sites) for later sorting and identification. All the organisms in the sample were enumerated and identified to the lowest practical taxonomic level (family level) using a dissecting microscope and standard keys (Edmondson, 1959; Jessup et al., 1999; Gooderham and Tysrlin, 2002; Bouchard, 2004).

Data analysis

Macroinvertebrate metrics were calculated from the sample data and final Benthic Macroinvertebrate Index (BMI) was calculated from aggregation of these metrics

Metrics selection and index development

Metrics to be included in the Benthic Macroinvertebrate Index (BMI) for this study were selected from a list of macroinvertebrate community attributes by testing their responsiveness to disturbance and redundancy with other metrics. Based on this, eight non-redundant metrics (Percent Taxa Richness, Percent Ephemeroptera Plecoptera Trichoptera (EPT) Index, Percent Diptera, Percent Chironomidae, Percent Dominant Taxa, Percent Non-Insect Taxa, Hilsenhoff Family-level Biotic Index (HFBI), and Shannon Diversity Index (SDI) that responded well to disturbance

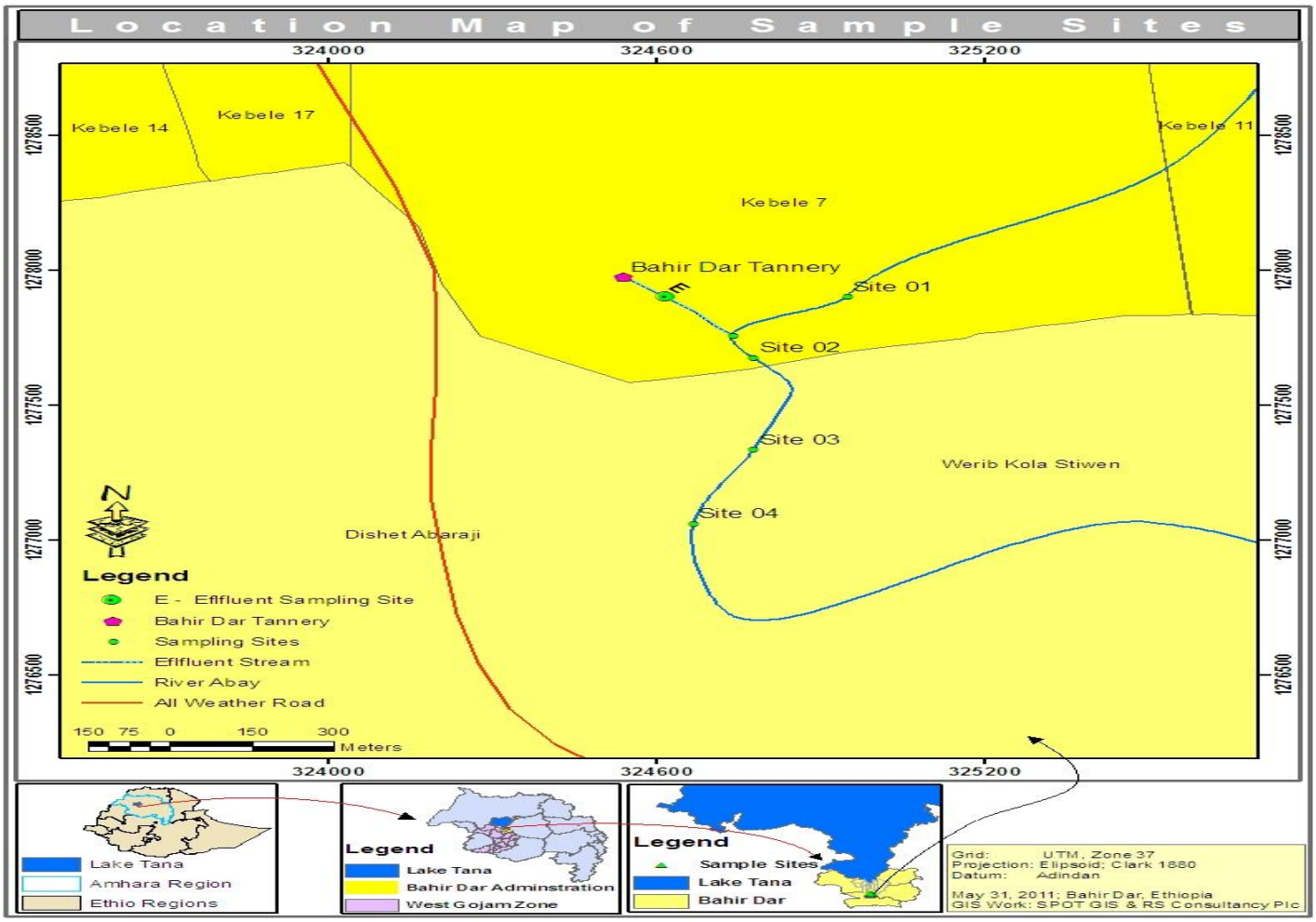

Figure 1. Map showing the study location and sampling sites along the Blue Nile River.

were selected. The metrics values were then converted to a standardized score using scoring criteria by examining relationships between individual metric scores and an indicator of impairment across a range of impairment levels, including undisturbed reference conditions. The standardized scores were then added to produce the final multimetric score of Benthic Macroinvertebrate Index (BMI) for each site. BMI values were calculated in this way for each site and then standardized to 100-point scale. Based on this BMI, value the sites were categorized in to various impairment levels which in turn determine the water quality at each site (Table 3).

Statistical data analysis

Macroinvertebrate percentage data were Arcsine transformed before analysis. One-way ANOVA was used to compare the magnitude of macroinvertebrate metrics among the sampling sites. Means were separated using Tukey HSD.

RESULTS AND DISCUSSION

A total of 28 taxa comprising 9,162 individuals were collected from the four sites during the study period. As shown in Table 1, the total number of taxa present at each site ranged from 18 (S_2) to 25 (S_1), while the total number of individuals present at each site ranged from 988 (S_1) to 5129 (S_2). The major components of the community were Chironomidae (3520), Ephydridae (1584), Clucidae (860), Baetidae (458). The families least encountered were Heptagenidae (1), Caenidae (5) Hydropsychidae (6) and Gerridae (9). The EPT families, Aeshnidae and Naucoridae were absent from the most impacted sites (S_2 & S_3) while Clucidae, Ephydridae, and Chironomidae were more abundant at these sites (Table 1). The result also showed that the number of individuals increased with increase in perturbation while the number of taxa showed a decreasing trend.

Macroinvertebrate metrics characterization along Blue Nile River

Benthic macroinvertebrate assemblage data which were

Table 1. Number of macroinvertebrates collected from the study sites in 2010/11.

Taxon order/family	Pollution. tolerance	Number collected at sampling site				Total
		1	2	3	4	
Ephemeroptera (mayflies)						
Baetidae	5	260	0	0	198	458
Caenidae	6	5	0	0	0	5
Heptagenidae	3	1	0	0	0	1
Trichoptera (caddis flies)						
Hydropsychidae	4	6	0	0	0	6
Odonata (damselflies and dragonflies)						
Aeshnidae	3	83	0	0	40	123
Coenagrionidae	9	9	48	26	17	100
Libelulidae	9	13	29	10	22	74
Hemiptera (water or true bugs)						
Belostomatidae	9	26	59	156	64	305
Corixidae	8	34	87	14	82	217
Geridae	6	1	0	3	5	9
Naucoridae	8	0	0	0	24	24
Nepiedae	7	10	0	16	0	26
Notonectidae	9	25	16	18	14	73
Pleidae	8	6	17	10	16	49
Veliidae	7	9	13	2	26	50
Coleoptera (beetles)						
Dytiscidae	5	92	127	87	13	319
Elmidae	4	45	9	17	25	96
Haliplidae	5	55	137	154	13	359
Hydrophilidae	5	46	302	52	9	409
Diptera (two winged / true flies)						
Ceratopogonidae	6	3	0	18	3	24
Chironomidae	8	82	2338	714	386	3520
Culicidae	8	12	725	96	27	860
Ephydridae	6	0	1028	406	150	1584
Syrphidae	10	0	140	0	0	140
Mollusks (snails)						
Planorbidae	7	4	9	12	36	61
Physidae	8	15	0	27	17	59
Arachnida						
Hydracarina (water mites)	6	62	19	1	7	89
Hirudinae (Leeches)	10	84	26	0	12	122
Total Individual		988	5129	1839	1206	9162
Total taxon		25	18	20	23	28

Table 2. Effect of the tannery effluent on macroinvertebrate metrics at different Sites along Blue Nile River in 2010/11.

Parameter	%Taxa richness	% EPT	% Diptera	% Dominant taxa	% Non-insect taxa
Sampling sites					
S_1	78.0[a]	32.9[a]	9.7[c]	37.0[a]	14.9[a]
S_2	87.5[a]	0.0[b]	81.8[a]	42.5[a]	1.0[b]
S_3	75.0[a]	0.0[b]	68.4[a]	40.5[a]	2.2[b]
S_4	78.0[a]	18.2[ab]	46[b]	34.6[a]	6.0[ab]

Sampling sites	Macro-invertebrate metrics			
	% Chironomidae	HFBI	SDI	BMI
S_1	8.0[b]	6.0[b]	2.2[a]	33[a]
S_2	42.5[a]	7.3[a]	1.7[c]	18[b]
S_3	40.5[a]	7.1[a]	1.8[bc]	19[b]
S_4	31.9[a]	6.9[a]	2.0[ab]	23[b]

Means within a column followed by the same letter are not significantly different from each other according toTukey HSD ($p<0.05$).

Table 3. Categorization of sites in to different impairment levels based on BMI results

BMI Value	Water quality characterization	Impairment	Sites at each impairment level
20-46	Very poor to poor	Severe to slight	S_2 and S_3
46-72	Fair to good	Moderate to less	S_4
72-100	Very good to excellent	Very little to none	S_1

condensed into eight metrics represented different ecological characteristics along the river gradient. The results indicated that the reference site (S_1) was different from the downstream sites, with slightly better biological activity at the reference site. Metric scores for each study site (Table 2) showed that the metrics closely follow pollution stress gradient. Percent Dipterans, % DT, and HFBI increased with increase in perturbation while % EPT and SDI showed a decreasing trend.

Percent taxa richness

The mean value of this metric ranged from 75% (S_3) to 87.5% (S_2). Taxa richness normally decreases with decreasing water quality (Vinson, 2006). Unlike the findings of Yandora (1998) and Birnesh (2007) and what is stated above, in this study, there was no significant difference in percent taxa richness among sampling sites (F=2.03, P=0.18, R2=0.74) (Table 2) and the upstream site showed lower diversity than the first downstream site. This might be due to the elimination of the sensitive taxa at the impacted sites.

Plafkin et al. (1989) stated that sites with greater than 26 taxa as non-impacted, 19-26 as slightly impacted, 11-18 as moderately impacted and 0-10 as severely impacted. Based on this criterion, the upstream site falls in slightly impacted range while the site just below the effluent falls in the moderately impacted range. So the low taxa richness at downstream sites is attributed to the low water quality and the strong negative response of percent taxa richness.

Percent EPT

The metrics has a zero value at severely impacted sites (S_2 and S_3) and its value ranged from 0 (S_2 and S_3) to 32.9 (S_1). There was significant difference among sampling sites (F=5.82, P=0.017, R^2=0.73); downstream sites having significantly lower value than the reference (upstream) site. Here, the last downstream site also had significantly higher value than the two downstream sites (Table 2), but there was no difference between S_1 and S_4 and also between S_2 and S_3.

Organisms in the EPT orders are qualified as indicators of good water quality. The higher the EPT index, the cleaner the stream (Perry, 2005). So their complete absence S_2 and S_3 and presence at the upstream site showed how seriously pollution affected these organisms. Yandora (1998), Baye (2006) and Birnesh (2007) reported the same result in absence of EPT at impacted sites.

Percent Diptera, Dominant Taxa and Chironomidae

The value of percent Dipterans ranged from 9.7 (S_1) to 81.77 (S_2). Its values showed significant variation among sampling sites (F=94.36, P<0.0001, R^2=0.97); the upstream site having significantly lower value than the downstream sites. But the last downstream site (S_4) also had significantly lower percent diptera than the rest downstream sites while S_2 and S_3 did not vary significantly (Table 2). This indicated the organic pollution load at downstream sites.

Percent chironomidae values ranged from 8.02 (S_1) to 42.48 (S_2). This index significantly vary among sampling sites (F=23.93, P=0.0001, R^2=0.89); upstream site having significantly lower value than downstream sites. But the three downstream sites did not vary significantly (Table 2). The large abundance of chironomidae at downstream sites is an indication of organic pollution and nutrient enrichment. Yandora (1998) reported that a sample in which greater than 50% is chironomidae suggested eutrophic condition and chironomidae increase with a decrease in water quality. Weigel et al. (2002) also reported that chironomids were the only taxa at sites with severe point-source pollution.

Percent Chironomidae and percent Dominant Taxa showed similar trend. The two metrics had almost similar value at the downstream sites showing chironomids were the dominant taxa at downstream sites. But percent dominant taxa did not show significant variation among sampling sites (Table 2). Percent dominant taxon at S_2 and S_3 was higher than S_1 and it is the contribution of chironomidae. Its average values at these sites were 42.5 and 40.5%, respectively. Percent dominant taxa greater than 45 indicate impaired, 40-45 possible impaired and less than 40 unimpaired (Barbour et al., 1999) condition. In this study, S_2 and S_3 indicated possible impaired condition while S_1 (8.02) and S_4 (31.9) indicated unimpaired condition.

Hilsenhoff family-level biotic index

The value of this metrics ranged from 6 (S_1) to 7.3 (S_2). There was significant difference in its value among sampling sites (F=15.48, P=0.0007, R^2=0.85). The reference site scored a significantly lower value than the three downstream sites while the downstream sites did not show significant variation among them (Table 2). High values are indicative of organic pollution while low values are indicative of clean water (Hilsenhoff, 1988). In this study, the higher values at S_2 and S_3 are indicators of the organic pollution load from the tannery effluent.

Shannon diversity index

The value of this metrics followed a decreasing trend from reference site to the severely impacted sites indicating that it has been affected by pollutants and it was able to discriminate mild and severe impacts from reference condition. Its value ranged from 1.7 (S_2) to 2.2 (S_1) and it significantly vary among sampling sites (F=11.37, P=0.002, R^2=0.81). The reference site had significantly higher diversity than the two consecutive adjacent downstream sites (S_2 and $S_{3)}$. Site four also had significantly higher value than S_2. But SDI value of the upstream site did not show significant difference with the last downstream site and also S_2 with S_3 and S_3 with S_4 did not show significant variation (Table 2). The results of Baye (2006), and Birnesh (2007) also showed the decreasing trend of this index along pollution gradient.

Benthic Macroinvertebrate Index (BMI)

The BMI developed from the selected metrics ranged from 45 (S_2) to 81 (S_1) (Table 2). Its value showed significant difference among sites; the reference site (S_1) having higher value than the three downstream sites. But the downstream sites did not show significant variation among them (Table 2).

Categorization of Sites Based on BMI Values

Even though, the above macro-invertebrate metrics categorize the sites into different impairment levels, the BMI calculated from the condensation of the metrics categorize the four sites into three actual impairment levels with their water quality status. Based on this, S_2 and S_3 were categorized into water quality status of very poor to Poor and impairment level of sever to slight. The other downstream site (S_4) was categorized in the fair to good water quality and moderate to less impairment level. But the upstream (reference) site was under very good to excellent water quality and very little to non-impairment level (Table 3). The values of this metric followed pollution gradient, decreased with increase in pollution. The categorization of sites based on BMI values showed that the tannery effluent is seriously affecting the downstream sites (Figure 2).

Conclusion

The discharge of the highly concentrated pollutants into the river caused severe damage on the ecosystem. The impairment level at the two immediate downstream sites was severe while it was little to none at the reference site. Similarly, the water quality at the two immediate downstream sites was poor and the reference had excellent water quality. This high impairment of the downstream sites made the water unfavorable for domestic, agricultural and aesthetic use as pollutants like

Figure 2. Plates showing some of the study sites and disturbances by the tannery effluent.

chromium from the tannery had a bio-accumulating effect. The state of the downstream sites must regularly be brought to public awareness by arranging continuous meeting with the community and telling the information for them. The development of tanning industries in Ethiopia is an encouraging phenomenon due to the country's large livestock population and government's development policy since it improves the economy and standards of living of citizens. However, the associated pollution which results from the discharge of wastewater into the environment without considering its due ecological consequences could overweigh the benefits. This can be threatening and lead towards a devastating environmental condition, unless industrial wastes are managed properly. So, environmental protection laws which consider technical and financial capability of the industries must be established so as to control industrial pollution. Not only establishment, the laws should also be enforced and environmental standards with their protocols should be followed with strict and continuous monitoring.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Amphibian diversity and distribution in Courtallam, South Western Ghats Foothills, India

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An amphibian survey was conducted in Courtallam at the foothill of Southern Western Ghats and a total of 584 sightings of amphibians belonging to 17 species, six families and 14 genera were obtained between January and December 2012. Cluster analysis and multi dimensional scaling (MDS) analyses revealed diversity pattern(s) of similarity among group and between groups of amphibians in Courtallam.

Key words: Amphibians, foothill, Western Ghats, PRIMER and cluster analysis.

INTRODUCTION

The Western Ghats mountain range of southwestern India, considered as one of the 25 biodiversity hot spots in the world, Myers et al. (2000) is a hot spot of biological diversity. This region has vast number of flora and fauna, and also many endemic and endangered species. Amphibians are represented by high species richness and endemism in India, with two major centres of diversities: the north east India and the Western Ghats (Inger and Dutta, 1986; Jayaram, 1974). Globally 7,044 species of amphibians have been reported (Frost, 2013), and 342 species are known from India (Dinesh et al., 2012). Of the 157 species reported from the Western Ghats, 135 (85.99%) are endemic to the hill range (Dinesh and Radhakrishnan, 2011). Though there are few studies that have looked at the ecological aspects of the amphibians in the Western Ghats, inventories of amphibians are available for many parts of the Ghats; 33 species from the Kerala part of the Nilgiri Biosphere Reserve (Easa 1998), 35 from Kalakad Wildlife Sanctuary (Cherian et al., 2000), 32 from Kalakad-Mundanthurai Tiger Reserve (Vasudevan et al., 2001), and 40 from Anamalai Hills (Kumar et al., 2001)

However, amphibian diversity of the Western Ghats is facing major threats due to deforestation, human dominated land-scapes and rapid urbanization resulting in land use changes, loss and modification of habitat, pollution and traffic noise (Aravind and Gururaja, 2011). Amphibians in India are highly diverse with 337 species of which 301 are anurans (Anil et al., 2011a, b; Biju et al., 2011; Dinesh et al., 2011). The amphibians in India are beginning to be studied in detail (Dutta, 1997), and species are being discovered even now (Robin et al.,

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2013). To implement conservation programmes for amphibians it is important to understand the factors that control their diversity in the region. Amphibians play an important role in the ecosystem because they feed on insects, including many pest species of agricultural crops. They are also important food sources for many larger animals such as water birds, mammals, reptiles, and even spiders and large insects. They often have economical importance to humans as a food source (Mazzoni et al., 2003; Daszak et al., 2004), medical resource in some regions (Chinese medicine) (Zhou et al., 2006), and as an important potential source of future pharmaceutical drugs (Clarke, 1997). In this study, we presented a list of amphibians in and around wetlands of the study area

Most of the endemic species have restricted distribution, confined to the rainforests of the Western Ghats (Vasudevan et al., 2001). This tropical region is covered by large expanses of brooks, swamps, ponds and farm lands all of which have considerable amount of vegetation, breeding ground for amphibians. This area greatly supports the amphibian diversity and provides suitable shelter for the different species of amphibians. In this study, we conducted an extensive amphibian survey in Courtallam at the foothills of the Southern Western Ghats from January to December 2012.

MATERIALS AND METHODS

Study area

Courtallam (8.9342°N 77.2778°E; mean elevation of 160 m (520 ft)) is situated in the southern Western Ghats abutting Tirunelveli district of Tamilnadu. Courtallam has a mosaic and diverse geographical and physical features such as hills and low plains, thorn scrub jungles, rivers and cascades, thick inland forest. The mean daily maximum temperature is 30°C. The weather is quite hot in May and June and the maximum temperature sometimes reaches 39°C. This region enjoys winter (December to March), Summer (April - June), Southwest monsoon (June to September and North east monsoon (October to November). The month of November is generally with maximum rainfall. The annual precipitation ranges from 801 to 1000 mm. The study area includes six wetlands which spread across Tenkasi and chosen randomly for the study (Figure 1). The part of the study area, especially around landscape is dominated by agricultural lands and wetlands which are either rain fed or reservoir fed. Some mountain slopes are protected as reserved forests under the control of the Forest Department.

Survey

In the selected sampling sites, amphibians were systematically sampled between 18:30 - 20:30 h from January to December 2012, to quantify seasonal changes in diversity. In the study, we analyzed the weekly field observations that were made throughout the study period. Using *ad hoc* searches, we sampled the amphibian diversity in different sites, quadrat search (size: 5 x 5 m) were demarcated on the forest areas and searched thoroughly by two observers for a period of one year between January and December 2012 on a seasonal basis; dry (December-May) and wet (June-November) seasons (Bhupathy and Sathishkumar, 2013) and time-constrained (visual encounter) survey (Figure 1). Survey was done along streams, in agricultural land and forest patches. No specimens were collected for want of permits but each morpho species was photographed for proper identification. The exact location of different amphibian species was noted. All species encountered were identified using Bossuyt and Dubois (2001), Daniels (2005) and Biju and Bossuyt (2009) and the same were later confirmed by consulting taxonomists.

RESULTS AND DISCUSSION

Diversity of amphibian in the study sites

Seventeen (17) species of amphibians belonging to six families and 14 genera were documented (Table 1). Of the six families, Dicroglossidae had the highest number of species (nine species), followed by Microhylidae (three species), Bufonidae (two species), Rhacophoridae (one species), Ranidae (one species) and Nyctibatrachus (one species). Among the seventeen species, *Duttaphrynus melanostictus* and *Duttaphrynus scaber* were most common. It was a commonly encountered species and showed high relative abundance near human habitation. Family Dicroglossidae comprised of nine species and was widespread in the study area. *Sphaerotheca breviceps, Sphaerotheca rolandae,* was rare, each species were found only in burrows on river bank surveyed (Table 1; Plates 1, 2 and 3); *Holobatrachus tigerinus*, *Holobatrachus crassus, Euphlyctis aloysii and Euphlyctis cyanophlyctis* showed widespread occurrence and were relatively more common than the other species. This family represents most common and diverse habitat dwellers in this region. They can be observed in majority of the habitats, including human habitations

Family Rhacophoridae were mainly found in cultivation areas. However, common species, *Polypedates maculates* showed vide distribution even in other locations in the study area. Microhylid frog, *Microhyla rubra* showed restricted distribution and was found only in one site. *Uperodon systoma* was found with repeated occurrence in the same study area site 2, 3 and 6 and *Ramanella variegata* was found in all sites expect site 6 and its occurrence was more common. Microhylid frogs are known for their loud shouts during breeding season. *Nyctibatrachus aliciae* and *Clinotarsus curtipes* were found rarely in forest areas and only one specimen was observed in sites 5 and 2

Amphibians detected outside the sampling period were broadly categorize as being found in three habitats; forest, water and cultivation areas .The highest number of species were sighted on water (7 species) followed by forest areas (5 species) and cultivation areas (5 species).

Many species were sighted on agricultural lands species like *P. maculates, Fejervarya sahyadrensis* and *Fejervarya limnocharis* (Table 1; Plate 1, 2 and 3). Some frog species like *D. melanostictus* and *D. scaber* were distributed all over the study area while others were

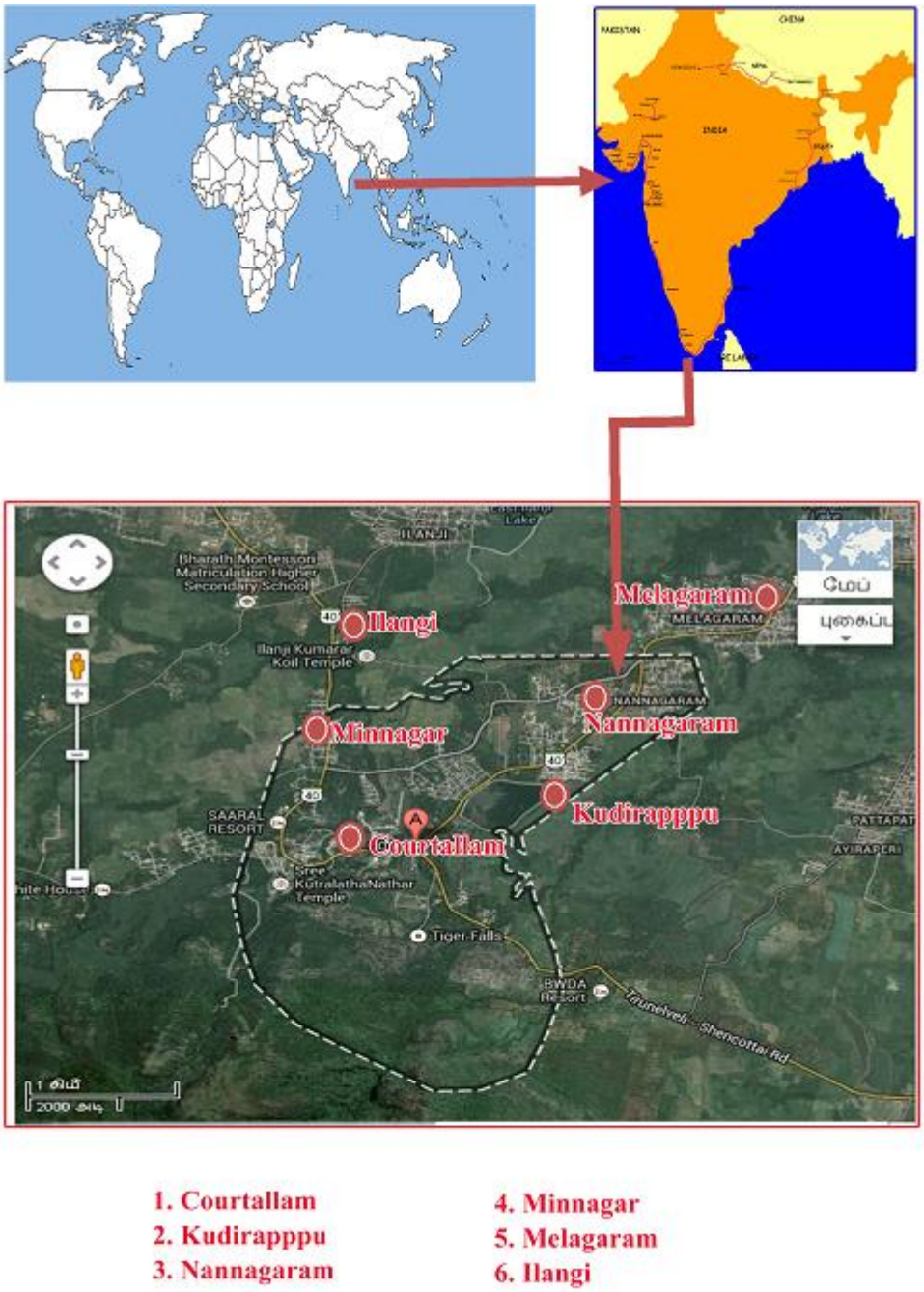

Figure 1. Map showing location of study area and points 1-6 indicate order in which wetlands were sampled.

found only in some places. *Euphlyctis aloysii* and *Holobatrachus* was found only in ponds and water logged areas. *Nyctibatrachus aliciae, Ramanella variegata* and *Clinotarsus curtipes* were found in forest areas. Many frogs were also observed to be dead on the road due to encounters with passing vehicles. The intensity of the road-kill will increase drastically due to the new state highway, and will be a major cause for the decline in the populations.

Amphibian populations have been declining worldwide due to a number of environmental and human factors with habitat destruction, alteration and fragmentation considered to be the primary causes (Krishnamurthy, 1996; Kumar et al., 2002). As development continues to alter natural landscapes, habitat patches become increasingly isolated from one another and the intervening

Table 1. Amphibian species recorded across sampled study area. Number 1 - 6 indicates individual wet lands as in Figure 1; +indicates presence; C-cultivation lands.

Taxa	1	2	3	4	5	6	Micro habitat
Family: Rhacophoridae							
Polypedates maculatus (Gray, 1833)	+	+	+	+	+		C
Family:Dicroglossidae							
Fejervarya sahyadrensis (Annandale, 1919)	+			+			C
Fejervary limnocharis (Gravenhorst, 1829)					+	+	C
Euphlyctisaloysii (Joshy, Alam, Kurabayashi, Sumida and Kuramoto, 2009)	+			+	+	+	W
Euphlyctis cyanophlyctis(Schneider, 1799)		+	+	+			W
*Euphlyctis hexadactylus(*Lesson,1834)		+	+		+	+	W
Hoplobatrachus tigerinus(Daudin, 1802)	+	+	+	+	+	+	W
Hoplobatrachus crassus (Jerdon 1853)	+	+	+		+	+	W
Sphaerotheca breviceps (Schneider, 1799)						+	W
*Sphaerotheca rolandae (*Dubois ,1983)			+				W
Family :Nyctibatrachidae							
Nyctibatrachus aliciae (Inger, Shaffer, Koshy and Bakde, 1984)					+		F
Family: Bufonidae							
Duttaphrynus melanostictus(Schneider, 1799)	+	+	+	+	+	+	C
Duttaphrynus scaber(Schneider, 1799)	+	+	+	+	+	+	C
Family: Microhylidae							
Microhylarubra (Jerdon, 1854)	+	+		+	+	+	F
Ramanella variegata (Stoliczka, 1934)	+	+	+	+	+		F
Uperodon systoma(Schneider, 1799)		+	+			+	F
Family: Ranidae							
Clinotarsus curtipes (Jerdon, 1853)		+					F

W, water; f, forest area.

matrix is less suitable for amphibian movement.

To improve conservation effects and to help the change habitat loss, the design of traditional land uses can be adapted to include critical habitat environments that are spatially arranged with respect to the physiological constrains of amphibians. Landscapes throughout the world are being modified drastically by humans, with profound effects on wildlife.

Statistical analysis (multivariate analysis of variance) shows the fact that there is a significant difference noticed in the diversity and the distribution pattern among 17 frog species ($F=55.25$; $p < 0.001$***) in the study area. It further proves that the number of individuals of the frog species, *D. melanostictus* is significantly more than the rest 16 frog species. This dominance may be due to the high adaptability of *D. melanostictus* to the study area. Such a way, there is a significant difference evidenced in the distribution pattern of frog species in the 12 months ($F=4.44$; $p < 0.001$***) during the study period.

Diversity and density of frogs over 12 month's period using the ecological software, PRIMER

Plymouth Routines In Multivariate Ecological Research (PRIMER) is an international software been exclusively used to analyze data of ecological studies. The scope of PRIMER is to analyze data from community ecology and environmental science which is multivariate in character. Cluster analysis and multi dimensional scaling (MDS) of PRIMER is used to find out similarity among group and between groups of organisms in a given area.

The dominance plot (Figure 2) further confirms the fact that the frog species are more and predominant in October and it is least in March. The MDS demonstrate that there are two groups in which October lie at the

Plate 1. Amphibian recorded in the study area.

centre in a group and the March lie at the centre in another group showing that the number of individuals as well as number of species are more in October and least in March (Figure 3).

The cluster analysis further proves that there are two cluster groups. The months of January, February, March, April and May form a cluster and June, July, August, September, October, November and December form

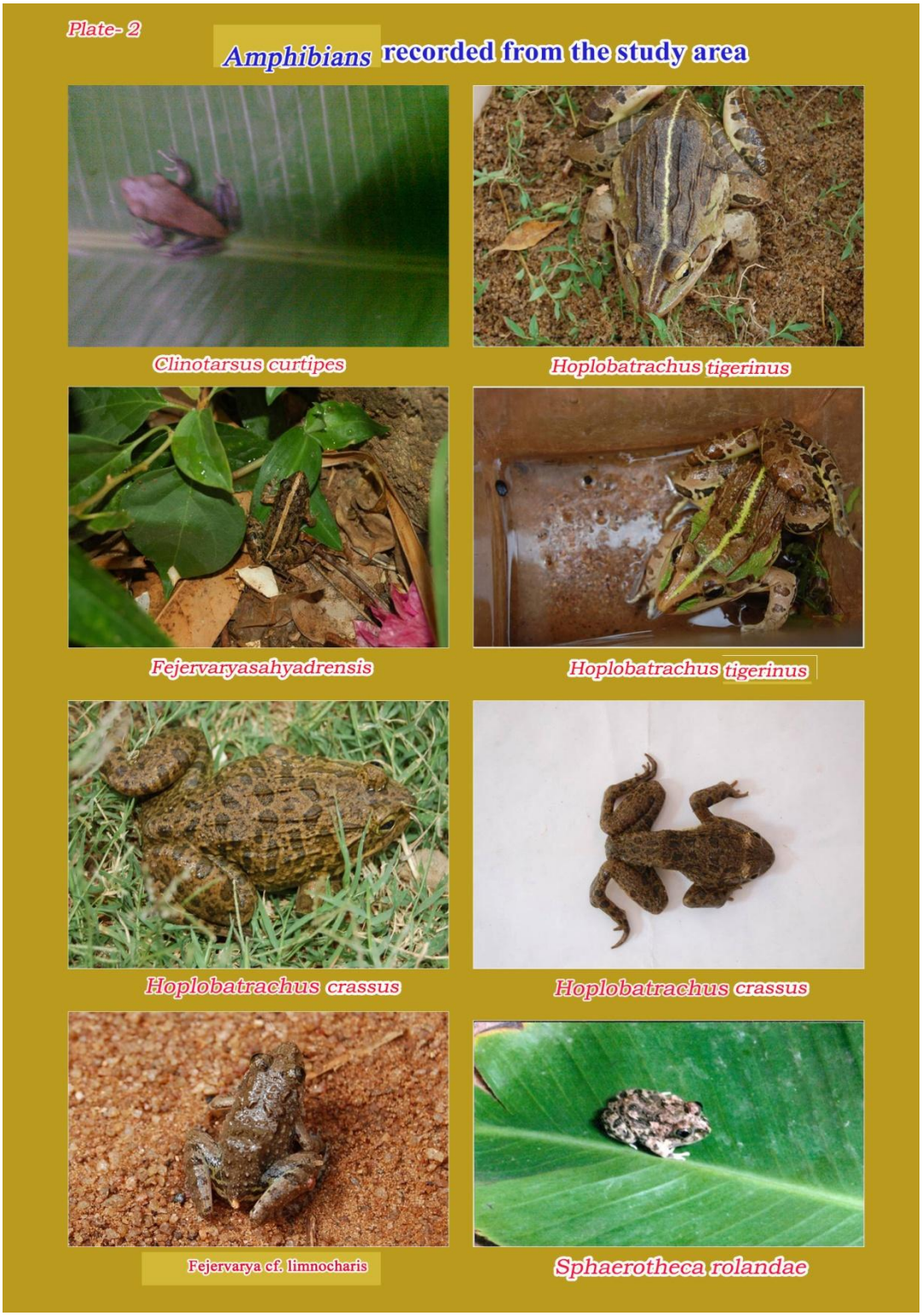

Plate 2. Amphibian recorded in the study area.

another cluster in which, the number of individuals as well as number of species of frogs are predominant in the month of October and least in March (Figure 4).

Frog diversity over the seasons using PRIMER

According to Karuppasamy (2008), the year is divided

Plate 3. Amphibian recorded in the study area.

into four season's namely 1) late post-monsoon (Mar, April and May), 2) pre-monsoon (June, July and Aug), 3) monsoon (September, October and November) and 4) post-monsoon (December, January and February). Pre-monsoon includes dry months whereas, monsoon and post monsoon seasons comprise rainy and wet months and the late post monsoon comprises moderate dry and wet months. The dominance plot of PRIMER further demonstrates the fact that the diversity of frogs is significant in monsoon and it is slightest in the late post monsoon seasons (Figure 5). Likewise, the MDS shows the diversity pattern of frogs in the study sites over four

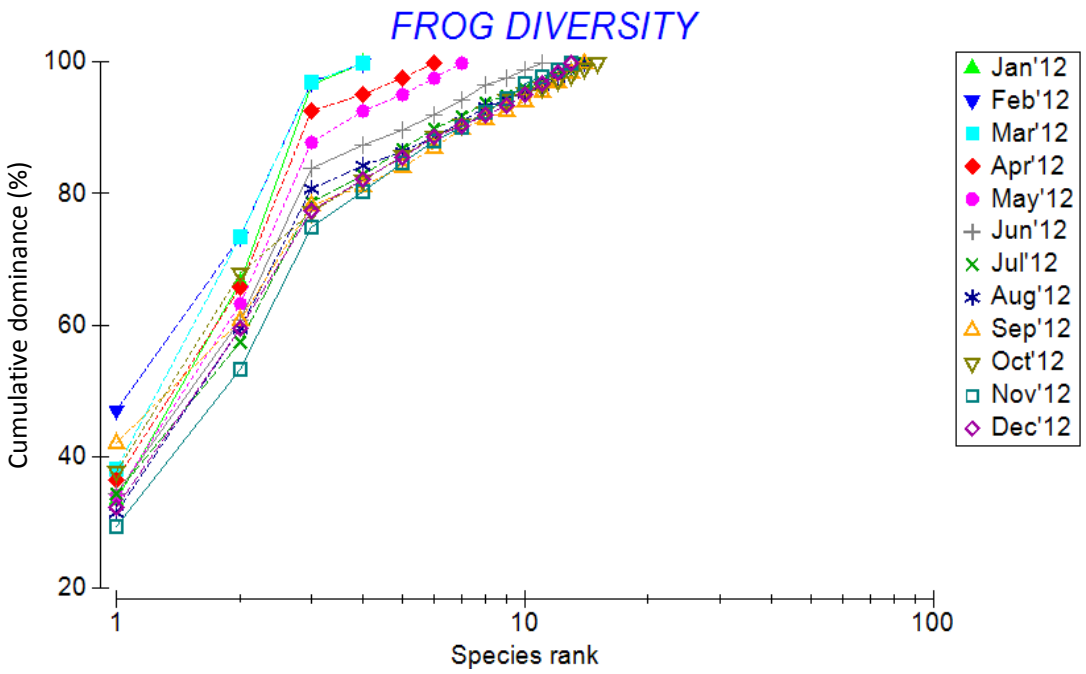

Figure 2. Dominance plot of frog diversity in and around Courtallam between January and December 2012 using PRIMER.

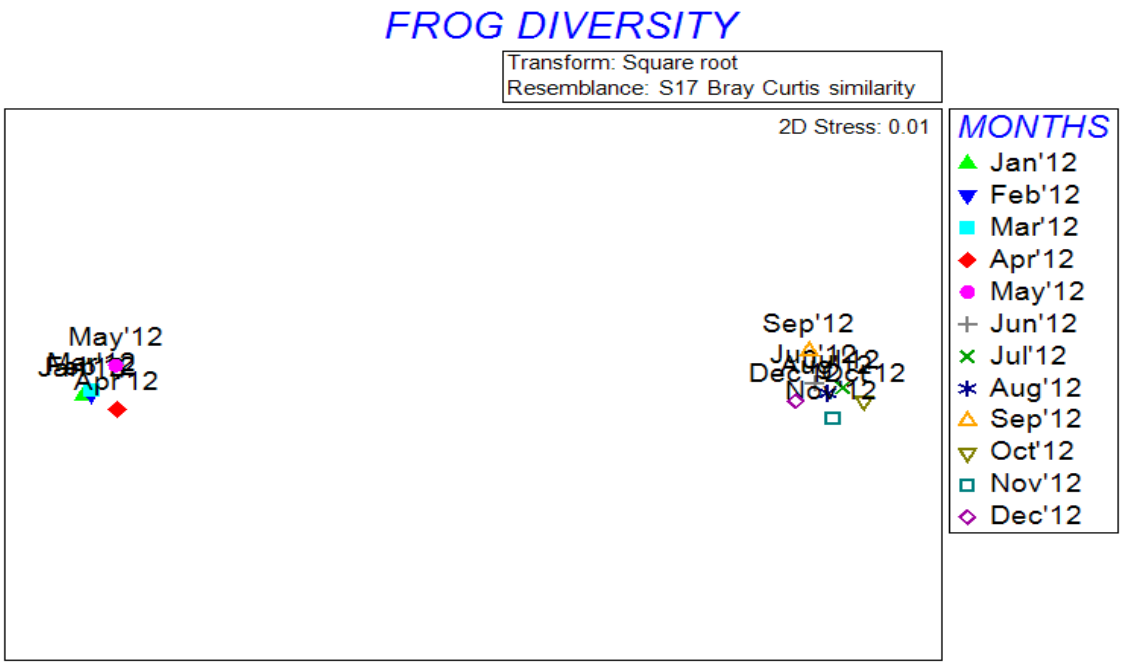

Figure 3. multi dimensional Scaling (MDS) of frog diversity in and around Courtallam over 12 months in 2012 using PRIMER.

different seasons and demonstrate seasonal diversity during the study period (Figure 6). Cluster analysis (Figure 7) illustrates two groups of diversity pattern in which LPM and POM form a group and PRM and MON form an another group, indicating seasonal diversity of frogs over dry and wet seasons in the year during the

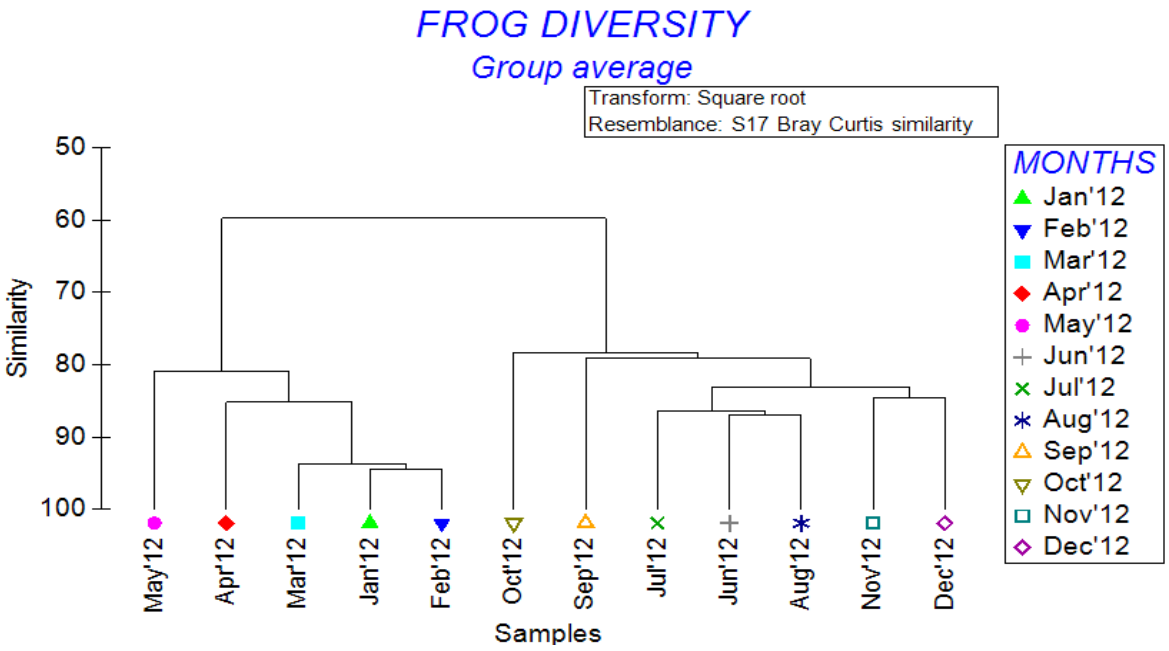

Figure 4. Cluster analysis of frog diversity in and around Courtallam over 12 months using PRIMER.

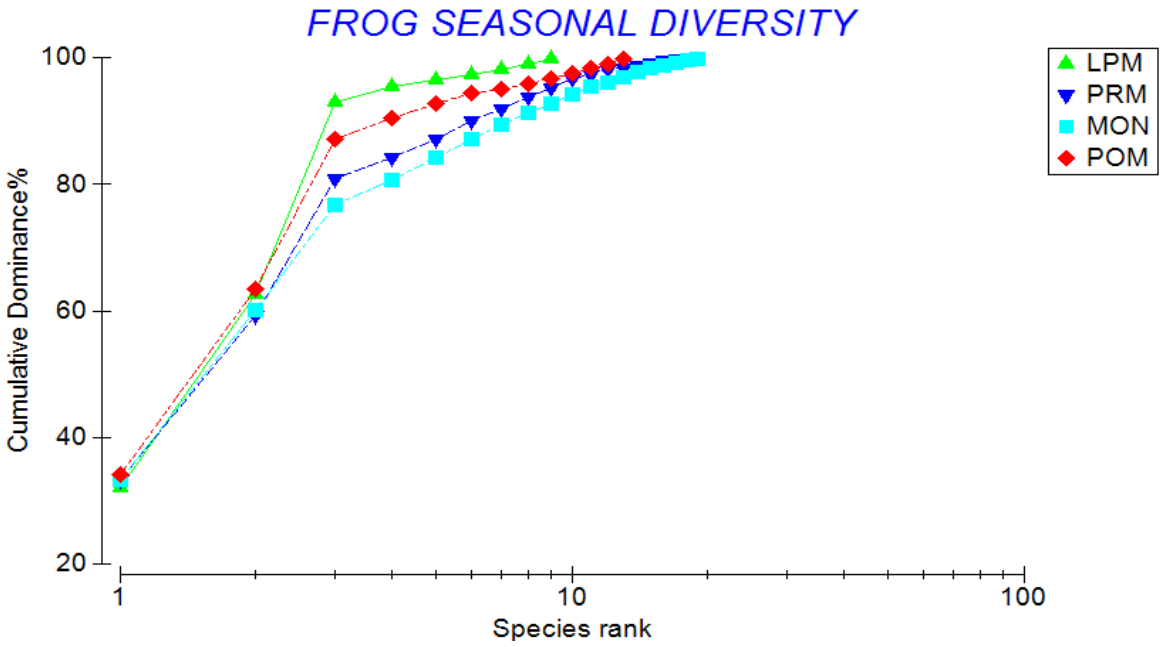

Figure 5. Dominance plot of seasonal diversity of frog species in and around Courtallam in the year 2012 (LPM- late post monsoon, PRM- premonsoon, MON- monsoon, POM-post monsoon).

study period.

Diversity indices of frogs among 17 species

The diversity indices like Margalef's richniess (d), Pielous's evenness (J'), Shanon's richness (H') and Simpson's richness (1/λ) reveal that even though four frog species are found throughout the year in all 12 months, wherein the number of individuals of three species like *D. melanostictus* (n=261), *D. scaber* (n= 197) and *Polypedates maculates* (n=28), the values of

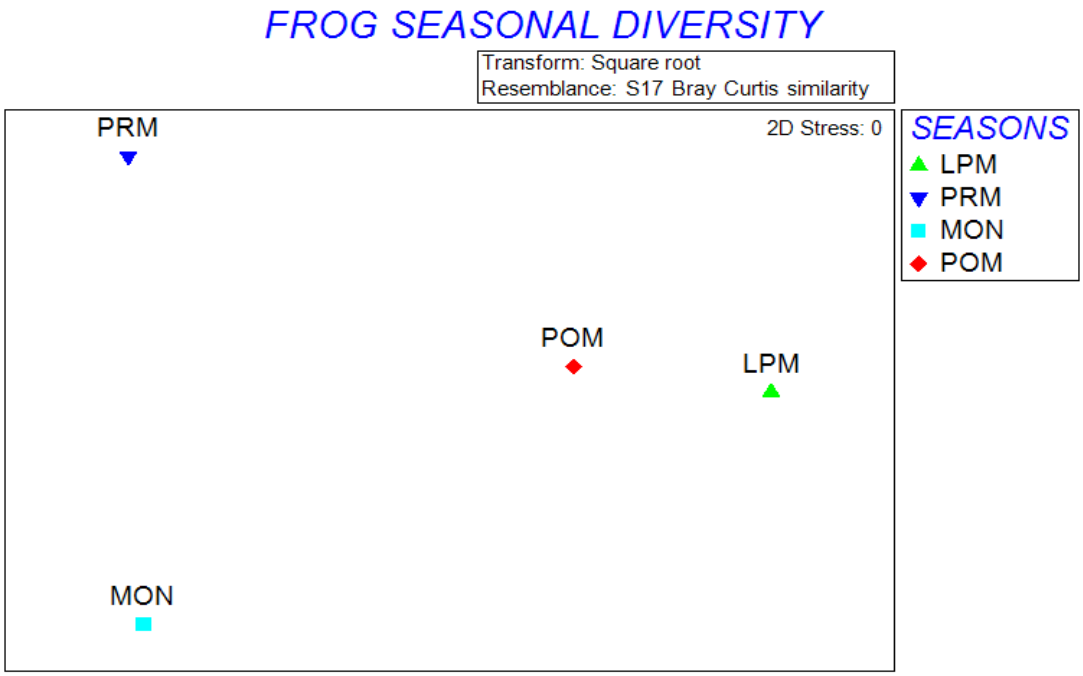

Figure 6. MDS plot of seasonal diversity of frogs in and around Courtallam in the year 2012 (LPM- late post monsoon, PRM- premonsoon, MON- monsoon, POM-post monsoon).

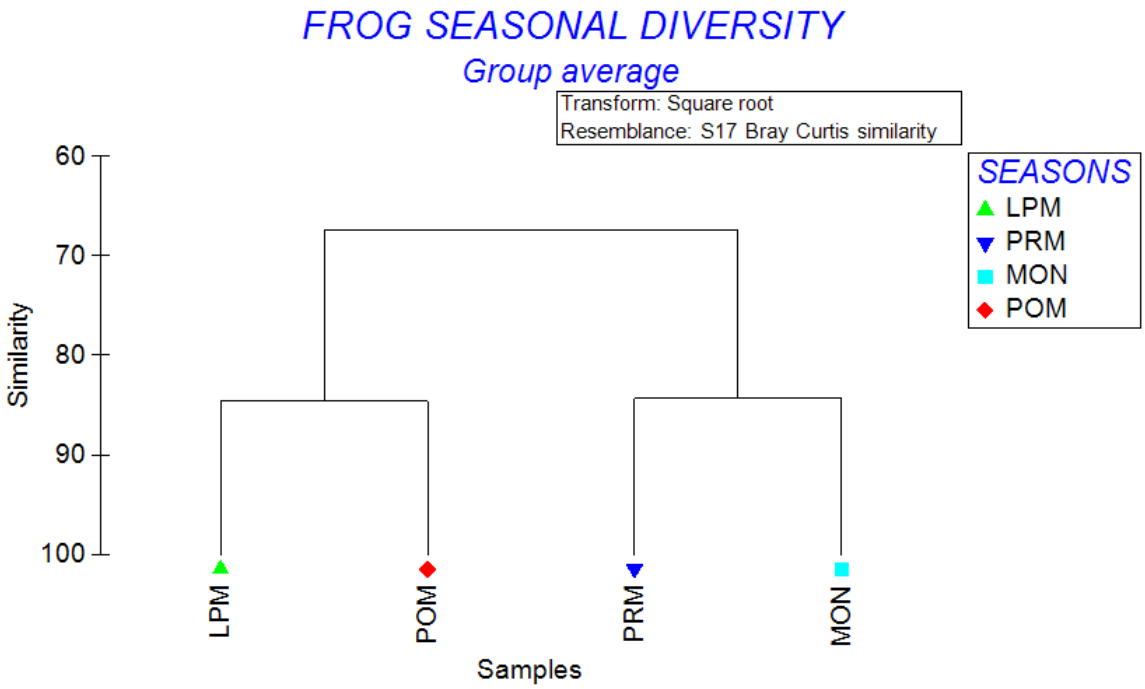

Figure 7. Cluster plot of seasonal diversity of frogs in and around Courtallam in the year 2012 (LPM- late post monsoon, PRM- premonsoon, MON- monsoon, POM-post monsoon).

diversity indices, are predominantly significant for the frog species *P. maculates* (d=3.301118; J'=0.978856; H'= 3.565765; 1/λ= 0.92328) than *D. melanostictus* (d=2.74681; J'=0.961036; H'= 3.445278 (Table 2).

Table 2. Diversity indices of 17 frog species collected over 12 months period in 2012 (N- Number of individuals; d- Margalef's richness, J' - Pielou's evenness, H'- Shanon's richness, 1/λ - Simpson's richness; 0 - denotes insufficient number for analysis).

Frog species	N	d	J'	H'(log2)	1-Lambda'
Polypedates maculates	28	3.301118	0.978856	3.565765	0.92328
Fejervarya sahyadrensis	2	1.442695	0	0	0
Fejervarya limnocharis	2	1.442695	0	0	0
Hoplobatrachus crassus	10	2.171472	0.946412	2.446439	0.888889
Hoplobatrachus tigerinus	12	2.717007	0.951796	2.855389	0.904242
Euphlyctis cyanophlyctis	3	0.910239	0.918296	0.918296	0.666667
Euphlyctis alloysi	3	0.910239	0.918296	0.918296	0.666667
Euphlyctis hexadactylus	3	1.820478	0	1.584963	0
Sphaerotheca breviceps	1	0	0	0	0
Sphaerotheca rolandae	1	0	0	0	0
Nyctibatrachus aliciae	1	0	0	0	0
Duttaphrynus melanostictus	261	2.74681	0.961036	3.445278	0.913831
Duttaphrynus scaber	197	2.78207	0.963193	3.453012	0.915159
Uperodon systoma	5	1.864005	0.950964	1.921928	0.9
Ramanella variegate	19	2.03774	0.953066	2.675596	0.877193
Microhyla rubra	10	2.605767	0.94957	2.721928	0.903333
Clinotarsus curtipes	1	0	0	0	0

1/λ= 0.918516), *Duttaphrynus scaber (*d=2.78207; J'=0.963193; H'= 3.453012; 1/λ= 0.91515159) and *(*d=2.74681; J'=0.961036; H'= 3.445278; 1/λ= 0.913831). This is mainly due to the deviation among the number of individuals collected in these four species every month during the study period.

Conclusion

Due to habitat loss, fragmentation and urbanization, a vast land area that provide roost resource for amphibians starts depleting at a greater rate. Hence study on the diversity and habitat is a need of the hour in order to make conservation priorities. This study generated a base line data on the amphibian fauna of this region, which may help in further studies.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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