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Growth hormone genotyping by *Msp*I restriction enzyme and PCR-RFLP method in Aceh cattle breed at Indrapuri District, Aceh Province, Indonesia

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ABSTRACT

Putra WPB, Hartatik T, Sumadi. 2014. Growth hormone genotyping by Msp*I restriction enzyme and PCR-RFLP method in Aceh cattle breed at Indrapuri District, Aceh Province, Indonesia. Biodiversitas 15: 1-5.* The objective of this research was to identify growth hormone (GH) gene in Aceh cattle at Indrapuri's Breeding and Forage Centre (IBFC) of Aceh Cattle. Fourty one cattle consisting of 21 male and 20 female cattle were used in this study. Polymerase Chain Reaction (PCR) - Restriction Fragment Length Polymorphism (RFLP) and sequencing method was used to detect *Msp*I site on GH gene. Based on the sequencing, it can be concluded that all cattle were monomorphic. The frequency of TT genotype and T allele were 1.00 relatively. The transition of C (*cytosine*) into T (*thymine*) on 1549 position caused the lost of restriction site. The insertion of T and G (*guanine*) on 1542 and 1552 position caused the length of GH gene were 329 bp in Aceh cattle.

Key words: Aceh cattle, GH gene, PCR-RFLP, sequencing, *Msp*I restriction enzyme

INTRODUCTION

Aceh cattle were one of Indonesian beef cattle suitable to be bred in Indonesia. This type of cattle adapts well to Indonesian environment, tropical climate, and is able to live on local water and food (Sari et al. 2010). Aceh cattle is able to adapt well, but its productivity is still lower than that of the imported one. By improving the productivity of Indonesian local cattle, it is hoped that the breeders' (especially IBFC of Aceh cattle) interest inbreeding local cattle will increase, so that the population of local cattle is increasing and is able to reduce Indonesian dependency on beef and cattle from other countries.

The GH gene is a single peptide of molecular weight equal to 22-kD secreted from *pituitary* gland in circadian and pulsatile manner, the pattern of which plays important role in postnatal longitudinal growth and development, tissue growth, lactation, reproduction, as well as protein, lipid and carbohydrate metabolism (Dybus et al. 2002). GH gene with its functional and positional potential has been widely used for marker in several livestock species including the Indonesian local cattle (Jakaria et al.. 2009; Sutarno 2010). Molecular genetic markers in animal breeding programs could make selection precise and efficient. Some of this markers are called candidate gene, e.g. the growth hormone genes, which are usually selected because there are biological significance on their quantitative traits of interest.

The studies of GH gene *Msp*I locus of Indonesian beef cattle have been reported in Ongole crossbred cattle (Sutarno et al. 2005; Sutarno 2010), Madura cattle (Purwoko et al. 2003), Pesisir cattle (Jakaria et al. 2007), Bali cattle (Jakaria et al. 2009) and Grati dairy cows (Maylinda 2011). Their studies indicated that polymorphism was found on Ongole crossbred cattle, Madura cattle, Pesisir cattle and Grati dairy cows. Bali cattle was monomorphic and the frequency of TT genotype and T allele were 1.00 the same as Ongole cattle in India (Lagziel et al. 2000). The research of GH gene using *Msp*I restriction enzyme in Aceh cattle has never been reported. Based on description above it is necessary to carry out a research to identify the genotype of GH gene *Msp*I in selected Aceh cattle at IBFC of Aceh cattle.

MATERIALS AND METHODS

Blood sample

The genomic DNA was extracted from blood using Sambrook et al. (1989). The blood samples were taken from 41 cattle at IBFC of Aceh cattle. The blood sample from Aceh cattle was taken using *venoject* (Vacutainer®, USA) 5 ml on jugular vein, and then it was kept in the refrigerator (4 ^{0}C) for later laboratory analysis. The DNA isolation, extraction, amplification and digestion were all carried out in Laboratory of Animal Breeding, Faculty of Animal Husbandry, Gadjah Mada University, Yogyakarta.

Figure 1. The profile of locally Aceh cattle breed (photo: Bahrul Mahdi).

Genome DNA extraction

Genome DNA extraction was carried out using Sambrook et al. (1989) method which was modified using buffer lysis cell on each sample containing of 15 µl 10% SDS (Sodium Dodecyl Sulphate), 6 µl ddH_2O and 7.5 µl proteinase-K. The DNA was precipitated using 71 µl 5 M NaCl and 600 µl 96 % ethanol. The precipitate was washed three times by adding 1ml 70 % ethanol, centrifuged with the speed 12,000 rpm for 5 minutes. Then the DNA precipitate was dissolved in 100 µl ddH_2O. The quality of the total genome was analyzed using by 0.8 % agarose gels electrophoresis in 1 x TBE (Tris-Boric-EDTA). Agarose gels were made by weighing 0.10 g agarose powder and placed into 12.5 ml buffer 1x TBE. Loading samples were done by dropping 1 µl DNA genome, 1 µl loading dye (Fermentas) and 5 µl ddH_2O into each well of agarose gel. to run the electrophoresis procesed. The products of electrophoresis were immersed in the 0.1 µl ethidium bromide (EtBr) at 50 Volt for 15 minutes

DNA amplification

The DNA was amplified with Polymerase Chain Reaction (PCR). Each PCR reaction was made with the volume of 10 µl with the composition of 5 µl PCR master mix (KAPA2G Fast ReadyMix PCR Kits, USA); 0.5 µl primer forward and reverse; 0.5 µl DNA and 3.5 µl ddH_2O. The forward primer (GH*Msp*I-F) was 5'-CCCACGGGCAAGAATGAGGC-3' and reverse primer (GH*Msp*I-R) was 5'-TGAGGAACTGCAGGGGCCCA-3' (Mitra et al. 1995). The position of both primers for GH gene is showed in Figure 1. The PCR protocols to amplify the fragment were done by the initial denaturation temperature steps at 94 ^{0}C for 5 minutes for 1 cycle, followed by 30 cycles of denaturation at 94 ^{0}C for 1 minute, annealing at 60 ^{0}C for 50 seconds, elongation or extension at 72 ^{0}C at 1 minute and a final extension at 72 ^{0}C at 5 minutes (Zhou et al. 2005). The PCR products were then subsequently electrophorated using 1 % agarose gels in buffer 1x TBE. Agarose gels were made by weighing 0.10 g agarose powder and placed into 12.5 ml buffer 1x TBE. Loading samples were done by dropping 1 µl PCR product, 1 µl loading dye and 5 µl ddH_2O into each well of agarose gel and into control well of DNA ladder (ΦX174 DNA/BsuRI/HaeIII) to run the electrophoresis process. The products of electrophoresis were immersed in the 0.3 µl EtBr at 50 Volt for 15 minutes to identify the length of the band. The picture of DNA band products were visually taken on the UV transiluminator (UVP TEM-40, USA) using camera and compared with DNA ladder (marker) for allele and genotype identified.

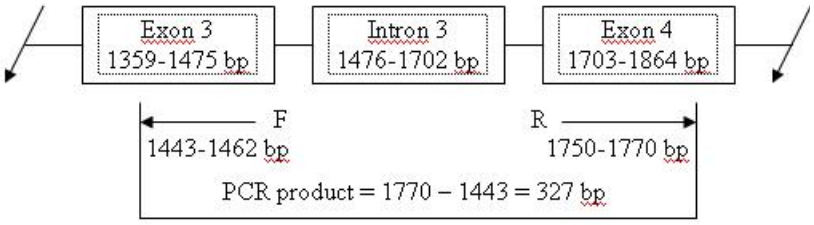

Figure 2. The position of Forward and Reverse primer in PCR product of GH gene

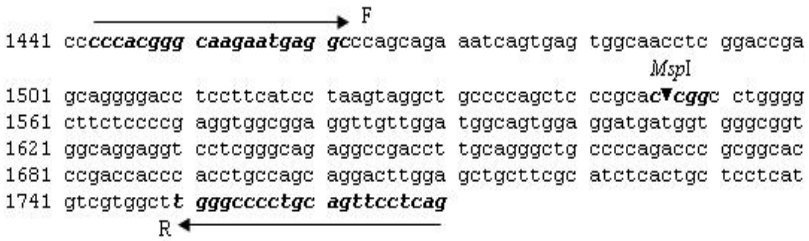

Figure 3. Position of Forward and Reverse primer based on GenBank (accessed code M57764) and position of *Msp*I restriction site

Genotyping for GH gene

The GH gene fragments were digested by the PCR-RFLP method with *Msp*I restriction enzyme. The PCR product of GH gene was digested 37 ^{0}C for 3 hours by *Msp*I restriction enzyme. Reactants consisted of 1.2 µl Buffer 10x; 8.7 µl ddH_2O; 0.1 µl *Msp*I restriction enzyme and 2 µl PCR product. A 1.5 % agarose gels were made by weighing 0.20 g agarose powder and placed into 13 ml buffer 1x TBE. Loading samples were done by dropping 10 µl PCR product of digested, DNA mixed with 2.5 µl loading dye into each well of agarose gel and into control well of marker to run the electrophoresis procesed. The products of electrophoresis were immersed in the 0.2 µl EtBr at 50 Volt for 15 minutes to identify polymorphism of alleles based on the length of the band. The picture of DNA band products was visually taken on the UV transiluminator using camera and compared with marker for allele and genotyped identification. The *Msp*I restriction enzyme recognized only the restriction site of four nucleotides for C↓CGG (Figure 2). The CC genotype consisted of two bands (104 bp and 223 bp), CT genotype consisted of three bands (104 bp, 223 bp, 327 bp) and TT genotype consisted of one band (327 bp).

Sequencing of GH gene fragment

The PCR products of five cattle were used for sequence analyses. Each reactant consisted of 30 µl PCR product; 10 µl forward and 10 µl reverse primer (10 pmol/UI) repaired for sequencing process by Macrogen-BioSM Indonesia. Sequences of GH *Msp*I gene were used to find nucleotide mutation in that's fragments.

Data analysis

PCR-RFLP data were analyzed by allele frequency (Falconer and Mackay 1996). The allele frequency was calculated by counting method as:

$$p = \frac{2(CC)+(CT)}{2N} \text{ and } q = \frac{2(TT)+(CT)}{2N}$$

Where p is the C allele frequency, q is the T allele frequency and N is the total number of cattle tested. The sequencing results were paralleled with the GH gene sequences from GenBank accessed code M57764, JN232516, EF592533 and EF592534 by alignment software (BioEdit and ClustalW).

RESULTS AND DISCUSSION

Allele frequency of GH *Msp*I gene

The DNA restriction of fragments resulted in one genotype. Sequencing and genotyping of GH *Msp*I gene showed 329 bp for TT genotype in all samples (Figure 3). Study of GH *Msp*I gene in several worlds cattle reported that the frequency of T allele was higher in *Bos indicus* (hump) cattle group and lower in the *Bos taurus* (humpless) cattle group (Lagziel et al. 2000). The same research results were also obtained that the frequency of T allele 1,00 in Bali cattle (Jakaria et al. 2009) and Ongole cattle (Lagziel et al. 2000). The comparation of T allele and TT genotype frequency which used same primer (Mitra et al. 1995) to other breed cattle in Indonesia is shown in Table 1.

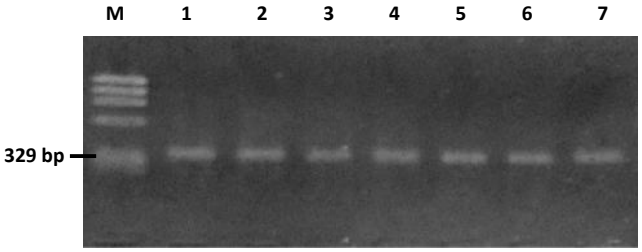

Figure 4. Genotyping result of GH *Msp*I gene detected by 1.5 % agarose gel. M : marker (ΦX174 DNA/BsuRI/HaeIII), 1 : PCR product (329 bp), 2-7 : TT genotype (329 bp)

Sequencing for GH *Msp*I Gene

The samples which could be sequenced were five samples from IBFC of Aceh cattle. The failure of sequence was caused by unsuccessful amplification, limited number of DNA, and too many peak duplication on sequence graphic. The analysis on the diversity of nucleotide

Table 1. The T allele frequency of GH gene in Indonesian beef cattle breeds

Cattle breeds	N	Frequency					Breed type	Authors
		Genotype			Allele			
		CC	CT	TT	C	T		
Bali	47	0.00	0.00	1.00	0.00	1.00	humpless	Jakaria et al., 2009
Limousine	22	0.41	0.45	0.14	0.64	0.36	humpless	Jakaria et al., 2009
Simmental	18	0.77	0.23	0.00	0.89	0.11	humpless	Jakaria et al., 2009
Grati	43	0.16	0.35	0.49	0.34	0.66	humpless	Maylinda, 2011
Pesisir	133	0.05	0.30	0.65	0.20	0.80	hump	Jakaria et al., 2007
PO	114	0.43	0.50	0.07	0.74	0.26	hump	Sutarno et al., 2005
Madura	49	0.23	0.22	0.55	0.44	0.56	hump	Purwoko et al., 2003
Aceh	41	0.00	0.00	1.00	0.00	1.00	hump	Research result

Note: N : individual number.

Table 2. The variation of Single Nucleotide Polymorphism (SNP) which has been identified in the third intron region from GH gene on several cattle

Position	Single Nucleotide Polymorphism (SNP)					Amino acid changes	Type of mutation
	Bos taurus [1]	Vechur [2]	Butana [3]	Kenana [4]	Aceh [5]		
1542	-	T	T	T	T	CCC(*Pro*) > CTC(*Leu*)	Insertion
1549	C	T	T	T	T	CCG(*Pro*) > CTG(*Leu*)	Transition
1552	-	G	G	G	G	GCC(*Ala*) > GGG(*Gly*)	Insertion
1615	G	G	G	-	G	GGC(*Gly*) > GGG(*Gly*)	Deletion
1669	G	A	A	A	A	CAG(*Gln*) > CAA(*Gln*)	Transition
1670	A	G	G	G	G	ACC(*Thr*) > GCC(*Ala*)	Transition
1695	C	T	T	T	T	ACC(*Thr*) > ATC(*Ile*)	Transition
1697	T	T	T	-	T	TGC(*Cys*) > GCC(*Ala*)	Deletion

Note: 1 = GenBank (M57764); 2 = GenBank (JN232516); 3 = Genbank (EF592534); 4 = GenBank (EF592534); 5 = sequencing results; *Pro* = prolin; *Leu* = leusin; *Ala* = alanin; *Gly* = glisin; Gln : glutamin; *Thr* : threonin; *Ile* : isoleusin; *Cys* = sistein

sequence was conducted using alignment software. The sequence of Aceh cattle DNA was parallel with the sample comparison sequence from GenBank accessed code M57764, JN232516, EF592533 and EF592534.

The result of GH *Msp*I gene nucleotide sequence in Aceh cattle, the change from C to T nucleotide was found on position 1549 bp and 1695 bp. The transition of C into T on position 1549 changed the *Msp*I restriction site. This result is similar to that of Musa et al. (2013) on Kenana cattle and Butana cattle. Transition mutation of T into C on 1549 position was found in Iranian native cattle such as Mazandarani, Golpaygani and Sarabi (Zakizadeh et al. 2006). Based on this sequence results it was concluded that several mutation found in this region. The variation of Single Nucleotide Polymorphism (SNP) which has been identified in the third intron region from GH gene on several cattle showed in Table 2. Sari et al. (2011) reported that one new mutation on fifth exon on 2230 bp in which C nucleotide turned into T nucleotide, and this was called silent mutation (CTC/*Leu* > CTT/*Leu*). Based on the sequencing result, it was concluded that the sequence of Aceh cattle on third intron was similar to that of *Bos indicus* groups (Vechur, Butana and Kenana).

CONCLUSION

Based on our research results, it can be concluded that the T allele was common allele in Aceh cattle at IBFC of Aceh cattle. The GH *Msp*I gene was monomorphic in Aceh cattle. The mutations occurred between C (*cytosine*) to T (*thymine*) on 1549 position changed *Msp*I restriction site. The GH *Msp*I gene nucleotide sequence of Aceh cattle on third intron region was similar to that of *Bos indicus* based on the GenBank sequence.

ACKNOWLEDGEMENTS

The authors would like to thank to all staff at IBFC of Aceh cattle for their help in collecting sample. Thanks are due to all staff at Laboratory of Animal Breeding, Faculty of Animal Husbandry, Gadjah Mada University, Yogyakarta for their tangible help during the study and most particularly their skillful assistance in DNA analysis.

REFERENCES

Dybus A. 2002. Associations og growth hormone (GH) and prolactin (PRL) genes polymorphism with milk production traits in Polish Black and White cattle. J Anim Sci 20: 203-212

Falconer DS, Mackay TF. 1996. Introduction to Quantitative Genetics. 4th ed. Benjamin-Cummings Publishing Company, New York.

Jakaria DD, Noor RR, Martojo H, Duryadi D, Tappa B. 2009. Identification of growth hormone (Gh) gene *Msp*I and *Alu*I loci polymorphism in beef cattle. Proceedings of the 1st International Seminary of Animal Industry. Bogor Agricultural University, Bogor, 23-24 November 2009. [Indonesian]

Jakaria DD, Noor RR, Martojo H. 2007. Evaluation of genetic diversity of growth hormone (GH) gene on West Sumatera Pesisir cattle using PCR-RLFP marker. J Indon Trop Anim Agric 30: 1-10 [Indonesian]

Lagziel A, Danise S, Hanotte O, Dhara S, Glazko V, Broadhead A, Davoli R, Russo V, Soller M. 2000. Geographic and breed distribution of an *Msp*I PCR-RFLP in the bovine growth hormone (bGH) gene. Anim Genet 31: 210-213.

Maylinda S. 2011. Genetic polymorphism of growth hormone locus and its associations with body weight in Grati dairy cows. Int J Biotechnol Mol Biol Res 2 : 117-120.

Mitra AP, Sciilee CR, Balakrisiinan, Pirciiner F. 1995. Polymorphisms at growth hormone and prolactine loci in Indian cattle and buffalo. J Anim Breed Genet 112: 71-74.

Musa LMA, Reissmann M, Ishaq IA, Rahamtalla SA, Brockman G, Peter JK. 2013. Characterization of the growth hormone gene (GH1) in Sudanese Kenana and Butana cattles. J Anim Prod 3: 28-34.

Purwoko A, Sutarno, Etikawati N. 2003. DNA polymorphism at locus-2 growth hormone gene of Madura cattle growth. Biodiversitas 4: 7-11

Sari EM, Noor RR, Sumantri C, Trimargawati E. 2010. Identification of genotype DNA microsatellite in association with performance of Indonesian Aceh cattle. J Genet Eng Biotechnol 8: 43-51

Sari EM, Noor RR, Sumantri C, Yunus M, Han JL, Muladno. 2011. Identification of Single Nucleotide Polymorphism on growth hormone gene in Aceh cattle. Med Pet 36: 21-25.

Sutarno, Junaidi A, Baharudin T. 2005. DNA polymorphism at locus-2 growth hormone gene of Madura cattle. Biodiversitas 6: 77-81.

Sutarno. 2010. Genetic variation among Indonesian native cattle breeds based on polymorphisms analysis in the growth hormone loci and mitochondrial DNA. Biodiversitas 11: 1-5

Zakizadeh S, Rahimi G, Ashtiani SRM, Javaremi AN, Shahrbabak MM, Reinecke P, Reissmann M, Masoudi AA, Amirinia C, Mirhadi SA. 2006. Analysis of bovine growth hormone gene polymorphisms in three Iranian native breeds and Holstein cattle by RFLP-PCR. Biotechnology 5: 385-390.

Zhou GL, Jin HG, Liu C, Guo SL, Zhu Q, Wu YH. 2005. Association of genetic polymorphism in GH gene with milk production traits in Beijing Holstein cows. J Biosci 30: 595-598.

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Four newly recorded species of Dryopteridaceae from Kashmir valley, India

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ABSTRACT

Mir SA, Mishra AK, Reshi ZA, Sharma MP. 2014. Four newly recorded species of Dryopteridaceae from Kashmir valley, India. Biodiversitas 15: 6-11. Habitat diversity, elevation, cloud cover, rainfall, seasonal and temperature variations have created many ideal sites for the luxuriant growth of pteridophytes in the Kashmir valley, yet all the regions of the valley have not been surveyed. In Kashmir valley the family Dryopteridaceae is represented by 31 species. During the recent extensive field surveys of Shopian district four more species viz., *Dryopteris caroli-hopei* Fraser-Jenkins, *Dryopteris blanfordii* subsp. *nigrosquamosa* (Ching) Fraser-Jenkins, *Dryopteris pulvinulifera* (Bedd.) Kuntze and *Polystichum Nepalense* (Spreng) C. Chr. have been recorded for the first time from the valley. The taxonomic description, synonyms, distribution and photographs of each species are given in this article.

Key words: *Dryopteris*, Kashmir valley, Shopian, pteridophytes, new records

INTRODUCTION

The ferns originated in ancient tropical habitats and have been successful in many types of environments for thousands of millennia. According to Rothwell and Stockey (2008) ferns first appeared in the fossil record during the Middle Devonian 390 million years ago. Ferns have continued to evolve and diversify up to the recent ages. However according to Chapman (2006) about 15% of all fern and lycophyte species may not yet be known to science. The total number of known ferns is estimated at about 12000 species worldwide belonging to 225-230 genera (Kramer and Green 1990) and 37 families (Smith et al. 2006). Dryopteridaceae is a large and diverse family of leptosporangiate ferns that have a world-wide distribution, but it has the highest density of genera and species in the temperate regions of the Northern Hemisphere, especially in the hills and mountains of eastern Asia (Ching 1965; Tryon and Tryon 1982; Wu and Ching 1991; Wu 2000). Ching (1965) founded the family *Dryopteridaceae* based on the type genus *Dryopteris* Adans. The members of this family are usually terrestrial and medium-sized plant bearing creeping, ascending or erect rhizome clothed with non-clathrate scales at apices; petioles with numerous vascular bundles arranged in a ring; pinnate or forking veins; and rounded to reniform spores with winged perine. This family includes about 1700 species belonging to 40-45 genera, of which the two largest genera are *Dryopteris* with 225-300 species (Kramer 1990; Fraser-Jenkins 1986; Zhang et al. 2012), and *Polystichum* with 260-300 species (Barrington 1995; Mabberley 1997; Kung et al. 2001; Driscoll and Barrington 2007). The characteristic features of *Dryopteris* genus are the presence of ctenitoid hairs on fronds, absence of groove on costae and costules. The other genus, *Polystichum* is characterized by absence of ctenitoid hairs on fronds and presence of an adaxial groove on costae and costules.

The Kashmir valley or the Vale of Kashmir, a deep elliptical bowl-shaped valley beautifully enclosed in a magnificent amphitheater of mountain ranges- the Great Himalayas and the Pir Panjal, is the central division of Jammu and Kashmir State (Wadia 1975). Total area of the valley is about 15,948 km^2, virtually 64% of which being hilly. Altitude of the valley plain at its summer capital Srinagar is 1,675 m above mean sea level (Srivastava 1998) and the highest peak among its surrounding mountains is that of the 'Kolahoi or Gwashibror' with an altitude of 5,420 m. Owing to the vast variety of edapho-climatic and physiographic heterogeneity, the valley harbors diverse ecosystem types, including lakes, springs, rivers, cultivated fields, orchards, subalpine and alpine meadows, mountain slopes and terraces, permanent glaciers, etc., which equally support diverse floristic elements (Gupta 1982; Singh et al. 1998) and renders suitable habitat for supporting rich flora of cryptogams, especially pteridophytes. Therefore the study was taken to explore in-depth pteridophyte wealth of Shopian district, Kashmir Himalaya.

MATERIALS AND METHODS

Study area

The study was carried out in Shopian district of Kashmir valley. The region is located in the south and

south-west extremity of the valley in close proximity of Pir-Panjal range (Figure 1). Most of the area of this district is hilly with the altitudinal range from 1700 to 4500 meters. The district lies between latitude of $33^0 20'$ and $34^0 54'$ N and longitude of $73^0 35'$ and $75^0 35'$ E. Total area of Shopian district is 812.70 km^2, of which more than half about 442.98 km^2 is occupied by alpine zone with a considerable portion under meadowlands and glaciers. The temperature ranges from an average daily maximum of 32ºC and minimum of 15ºC during summer to an average daily maximum of 4ºC and minimum of - 4ºC during winter (Bhat et al. 2012). It receives annual precipitation of about 1050 mm. The district also possesses rich soil diversity, namely hill soils, alluvial soils and Karewa soils (Raza et al. 1978). Great altitudinal variation and contours of hills shapes the district into a gradually heightening slope with a wavy appearance that adds magnificent variation in vegetation. Besides, edapho-climatic variations, mountain slopes and terraces, permanent glaciers, large number of stream and streamlets and significant precipitation in this district have built many ideal sites for the luxuriant growth of pteridophytes. Although, some earlier works on pteridophytes of the valley had been done by Clarke (1880), Beddome (1883, 1992), Stewart (1945, 1951, 1972 and 1984) and Kapur (1985), the collective contribution of these workers resulted in the discovery of only 90 species and 4 varieties (belonging to 29 genera) from Kashmir (Dar et al. 2002). In this connection, attempts have been made to explore in-depth the Perido-flora of this area.

Regular field trips were carried out in and around different areas of Shopian district for the collection of fern and fern allies from June to November during the years 2011 and 2012. During the survey we not only confirmed the presence of the various species of Dryopteridaceae reported earlier, but also discovered four more species viz., *Dryopteris blanfordii* subsp. *nigrosquamosa*, *Dryopteris caroli-hopei and Dryopteris pulvinulifera*, *Polystichum Nepalense* that constitute new records for Kashmir valley. The specimens were identified by the consultation of relevant literature and study of herbarium specimens deposited in the Herbarium, Botanical Survey of India (BSI), Dehradun. Help has also been taken from Dr. H. C. Panday (Scientist 'D') and Brijesh Kumar from BSI, Dehradun. The voucher specimens are deposited in Department of Botany, Jamia Hamdard and in the Herbarium of University of Kashmir (KASH).

RESULTS AND DISCUSSION

A detailed account comprising taxonomic descriptions, synonyms, distribution and figures of these newly recorded species is provided here under:

Dryopteris blanfordii

Dryopteris blanfordii subsp. *nigrosquamosa* (Ching) Fraser-Jenk., Bull. Brit. Mus. (Nat. Hist.), Bot. 18: 388 (1989).

Dryopteris nigrosquamosa Ching, Bull. Fan Mem. Inst. Biol. 2: 194 (1931); *Dryopteris gushaingensis* Ching, Fl. Xizangica 1: 269 (1983).

Rhizome long, obliquely ascending, thick, clothed with scales. Stipes ca. 8 cm long, longitudinally grooved, densely fibrillose and scaly: scales broadly ovate, fuscous-brown, concolorous, crinkled, margins with filamentous projections, apex acuminate, gradually smaller upward, lanceolate to linear, sparse higher up, stipe base dark-brown; rachis scaly and fibrillose; fibrils dark-brown at base, higher up light-brown. Lamina 2-pinnate, ca. 40 cm long, 12 cm broad, lanceolate to oblong-lanceolate, slightly tapered below to a truncate base, thinner with herbaceous texture, adaxially glabrous, apex acuminate; pinnae ca. 18 pairs, ca. 7 cm long, 1.5-2 cm broad, slightly distant, alternate, horizontally spreading, shortly stalked, oblong-lanceolate, apex acuminate: pinnules ca. 14 pairs, separated, lanceolate to oblong-lanceolate, sessile, slightly oblique, lowest pair of pinnules slightly stalked and large than those above it, further up narrowly attached and becoming widely attached to the pinna costa, lobed; lobes narrow, rectangular with truncate apices, upper lobes becoming pointed and ending in a single acute tooth, segment apex rarely sharply serrate. Veins pinnate, forked; costae and costules sparsely scaly. Sori indusiate, round, in

Figure 1. Research site "Shopian" located at south-west of Kashmir, Jammu and Kashmir, India

1 row on each side close to the costa, usually only upper half of lamina fertile; indusia rounded to reniform, membranous, margin entire irregular. Spores dark-brown, perinate, perine folded.

Figure 2: A, B, C

Habitat: Steep Abies forests

Specimen examined: Shopian, Dubjan, 2750 m alt., 05.07.2011, Shakoor Ahmad, 847 (KASH).

Distribution: China (Fraser-Jenkins 1989).

Dryopteris caroli-hopei

Dryopteris caroli-hopei Fraser-Jenk., Bull. Brit. Mus. Nat. Hist. Bot. 18: 422 (1989).

Aspidium dilatatum var. *patuloides* H. Christ, Societe Botanique de France 1: 41, 1905; *Dryopteris pseudomarginata* Ching, Sporae Pterid. Sin. 327: 1976.

Rhizome, short stout, prostrate, scaly: scales adnate, brown, ovate-lanceolate. Stipe long, c 30-45 cm, thick, 0.4-0.5 cm, stramineous, base brownish, densely scaly; scales pale-brown, ovate-lanceolate, apex acuminate, stipe upward with sparsely adpressed scales and fibrils. Lamina large, 2-3 pinnate, ovate-lanceolate, c 65 cm long and 40 cm broad, pale-green, costa sparsely linear-lanceolate scaly, basal pinnae tripinnate, pinnate on the upper part, apex acuminate and pinnate; pinnae c 23 pairs, up to 20 cm long and 7 cm broad, obliquely spreading, alternate, stalked, triangular lanceolate, matted upper surface, costa sparsely fibrillose on lower surface; pinnules c 12-18 pairs, up to 4 cm long, 1.5 cm broad, short stalked, sessile upwards, alternate, narrowly triangular lanceolate, apex acute, pinnatisect; pinnulet or pinnule lobes, c 8-10 pairs per pinnule, adnate to costule, ovate-lanceolate, with rounded and obliquely pointed apices, margin serrate, pinnules on the basiscopic side of the pinnae in the lower half of the frond are longer than those on the acroscopic side. Veins simple or forked, conspicuous abaxially, slightly distinct adaxially, 8-10 pairs per pinnule. Sori indusiate, small, rounded, not crowded, one per segment, entire lamina fertile, indusia brown; round-reniform, entire, persistent. Spores pale-brown, perinate.

Figure 2: D, E, F

Habitat: Near stream banks under shade

Specimen examined: Shopian, Imamsahib, 1866 m alt., 15.07.2011, Shakoor Ahmad, 844 (KASH).

Distribution: India (Arunachal Pradesh, Manipur, Meghalaya, Nagaland, Uttar Pradesh, Jammu division.), Bhutan, China (Tibet, Yunnan), Nepal (Khullar 2000; Chandra 2000).

Dryopteris pulvinulifera

Dryopteris pulvinulifera (Bedd.) Kuntze, Revis. Gen. Pl. 2: 813 (1891).

Dryopteris harae H. Ito, Fl. E. Himalaya 1: 476 (1966); *Lastrea pulvinulifera* Bedd., Ferns Brit. India, (1870); *Nephrodium pulvinuliferum* (Bedd.) Baker, Syn. Fil. (1874); *Nephrodium sparsum* var. *squamulosum* C. B. Clarke, Trans. Linn. Soc. London, Bot. 1: 524 (1880); *Lastrea pulvinulifera* var. *zeylanica* Bedd., Suppl. Ferns S. India (1876).

Rhizome short-creeping, thin, densely clothed with bright golden, linear-lanceolate scales. Stipes long, 30-35 cm, almost the same length as the lamina, dia. 0.2 cm, pale, base curved just above the point of attachment, densely scaly; scales long, narrowly lanceolate, glossy, bright golden in color, stipe upward glabrous or containing scattered, narrowly lanceolate, dark scales; rachis glabrous, except for dense covering of small, dark-brown, hair-like scales, especially near the attachment of costa to the rachis. Lamina lower part 4-pinnate, upper part 3-pinnate, deltoid-lanceolate, apex acuminate, c 45 cm long, c 40 cm broad, dark-green adaxially, herbaceous; pinnae c 20 pairs, alternate, overlapping, deltoid-lanceolate; pinnules c 17 pairs in largest pinna, triangular lanceolate, shortly petiolate, pinnate, base cunate, apex acuminate, basal basiscopic ones longest; pinnulets c 11 pairs in the largest pinnule, obliquely spreading, deeply pinnatifidly lobed, acroscopic lobes more developed, wider and longer, apices acutely pointed and bearing a few insignificant, small, acute teeth; pinnulet segments or ultimate segments longer on the acroscopic side of the pinnulet, ending in a few small acute teeth; costa with sparse small, black-brown scales adaxially. Veins pinnate. Sori indusiate, rounded, small, regularly in one row on each side of costule; indusia rounded-reniform, thin, lifting deciduous. Spores regular.

Figure 2: G, H, I

Habitat: Growing on steep forest floor under shade

Specimen examined: Shopian, Heerpur, 2600 m alt., 08.07.2011, Shakoor Ahmad, 813 (KASH).

Distribution: India (Sikkim, Darjeeling, Meghalaya, Nagaland), Bhutan, China, Nepal, Sri Langka, Philippines (Khullar 2000; Chandra 2000).

Polystichum nepalense

Polystichum nepalense (Spreng.) C. Chr. Index Filic. fasc. 10: 84 (1906).

Aspidium nepalense Spreng, Syst. Veg. 4: 97 (1827); *Polystichum atroviridissimum* Hayata, Icon. Pl. Formosan. 4: 190 (1914).

Rhizomes erect to sub-erect, thick, scaly; scales light brown. Stipes c 5 cm long, straw colored, scaly and fibrillose, basal scales ovate to lanceolate, pale-brown, paler higher up on stipe, glossy, margin with short projections, apex acuminate; rachis fibrillose and sparsely clothed with small cuspidate scales intermixed with a number of large ovate, light-brown ones. Lamina pinnate, linear-deltoid or lanceolate, c 24 cm long and 4 cm broad, coriaceous; pinnae c 28 pairs, falcate, alternate, up to 2.5 cm long and 0.7 cm broad (largest), acute, shortly petiolate, adpressed scales on abaxial side, adaxially glabrous, base auriculate, auricle attached to the rest of the pinna, margin irregularly more or less entire or slightly serrate with pale colored teeth, lower pinnae slightly reduced in size compared to above. Veins and veinlets numerous in small groups. Sori indusiate, many, medial in one row on either side of mid-vein; indusia brown, membranous, large, margin undulate, persistent. Spores dark-brown, perinate.

Figure 2: J, K, L

Habitat: Rocky meadows near stream

Figure 2. A, B, C. *Dryopteris blanfordii* subsp. *nigrosquamosa*; D, E, F. *Dryopteris caroli-hopei*, G, H, I- *Dryopteris pulvinulifera*; J, K, L- *Polystichum Nepalense*

Specimen examined: Shopian, Secjan, 2400 m alt., 15.09.2011, Shakoor Ahmad, 928 (KASH).

Distribution: India (Arunachal Pradesh, Darjeeling hill, Himachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Uttarakhand) Afghanistan, Bhutan, China (Tibet, Yunnan), Japan, Myanmar, Nepal, Philippines, Sri Langka, Vietnam (Khullar 2000; Chandra 2000).

Discussion

Ferns inhabit a great variety of substrates, climates, and light regimes, both in habitats dominated by flowering plants and those where few angiosperms can survive. They also represent a critical evolutionary step, bridging the functional gap between nonvascular bryophytes and seed-bearing vascular plant. The earlier fern collectors in the Kashmir were R. McLeod and T. Thomson. Subsequently many European (mainly British) botanists gathered collections from Kashmir, notable among them being J. Winterbottom, J.E.T. Atchinson, V. Jacquemont, H. C. Levinge, E.W. Trotter, A. Meebold, W.N. Kolz, J. Marten, G.A. Grammie, C. Stokoe, J. C. Mcdonell etc. The classical work of Clarke (1880), Beddome (1883, 1892) and Hope (1899-1904) also include several ferns from the Kashmir. Ralph Randles Stewart (1937, 1945, 1951, 1957 and 1972) is utmost fern collector of Kashmir. Recently Wani et al. (2012) presented an up-to-date account of fern and fern allies of Kashmir valley, Gurez and Ladakh. The authors also included ecological status, phytogeographical affinity and the distributional data of collected ferns. Of the total taxa reported, 30 taxa belong to family *Dryopteridaceae*, 20 to *Woodsiaceae* and 13 taxa to the family Aspleniaceae. 47 taxa (42%) were recorded to be rare or endangered.

The four species of pteridophytes mentioned above have been reported from other parts of the world and also from different states of our country, India. The three species *D. blanfordii* subsp. *nigrosquamosa*, *D. pulvinulifera* and *Polystichum Nepalense* are new to the Jammu and Kashmir state, whereas the fourth *D. caroli-hopei* has earlier been reported from the Jammu division only. *D. caroli-hopei* differs from *D. Pulvinulifera* in having thick rhizome, broad-ovate stipe scales, 2-3-pinnate pale-green lamina and lobed pinnules with bluntly acuminate apex. *P. Nepalense* differs from its closest species *P. lonchitis* in bearing broad base and pinnae margin more or less entire or slightly serrate. Similarly *D. blanfordii* subsp. *nigrosquamosa* contrasts from *D. blanfordii* subsp. *blanfordii* by long-sub-erect rhizome, short stipe densely clothed with fuscous-brown ovate scales and shallowly lobed pinnules.

CONCLUSION

Since exploration, inventory and documentation of phytodiversity (including non-flowering plants), is a minuscule step in the larger goal of sustainable utilization of earth's resources, the present study was undertaken to document the Pteridophytic wealth of district Shopian. The present communication reports the four species of ferns, viz. *Dryopteris caroli-hopei* Fraser-Jenkins, *Dryopteris blanfordii* subsp. *nigrosquamosa* (Ching) Fraser-Jenkins, *Dryopteris pulvinulifera* (Bedd.) Kuntze and *Polystichum Nepalense* (Spreng) C. Chr that constitute new record for Kashmir valley.

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REFERENCES

Barrington DS. 1995. Polystichum. In: Davidse G, Sousa M, Knapp S (eds) Vol. 1. Flora Mesoamericana. Universidad Nacional Autonoma de Mexico, Mexico City, Mexico.

Beddome RH. 1883. Handbook to the ferns of British India, Ceylon and Malay Peninsula. Thacker Spink and Co, Calcatta.

Beddome RH. 1892. Supplement to the ferns of British India, Ceylon and Malay Peninsula. Thacker Spink and Co, Calcutta.

Bhat Ta, Nigam G, Majaz M. 2012. Study of some medicinal plants of the Shopian District, Kashmir (India) with emphasis on their traditional use by Gujjar and Bakerwal Tribes. Asian J Pharm Clin Res 5 (Suppl 2): 94-98.

Chandra S. 2000. The Ferns of India Enumeration, Synonyms & Distribution. International Book Distributors, Dehra Dun, India.

Chapman AD. 2006. Numbers of Living Species in Australia and the World. Report for the Department of the Environment and Heritage, Canberra, Australia.

Ching RC. 1965. Dryopteridaceae-A new fern family. Acta Phytotax Sin 10: 1-5.

Clarke CB. 1880. A Review of ferns of Northern India. Trans Linn Soc (Bot) London 1: 425-611.

Dar GH, Bhagat RC, Khan MA. 2002. Biodiversity of the Kashmir Himalaya. Anmol Publications Pvt Ltd, New Delhi.

Driscoll HE, Barrington DS. 2007. Origin of Hawaiian *Polystichum* (Dryopteridaceae) in the context of a world phylogeny. Amer J Bot 94: 1413-1424.

Fraser-Jenkins CR. 1986. A classification of the genus *Dryopteris* (Pteridophyta: Dryopteridaceae). Bull Br Mus Nat Hist hist ser 14: 183-218.

Fraser-Jenkins CR. 1989. A monograph of *Dryopteris* Pteridophyta: Dryopteridaceae in the Indian Subcontinent. Bull Brit Mus Nat Hist Bot 18: 323-477.

Fraser-Jenkins CR. 1991. An outline monographic study of the genus *Polystichum* in the Indian Subcontinent. In*:* Bhardwaj TN, Gena CB (eds). Aspects Plant Science 13: 249-287.

Gupta RK. 1982. Mediterranean influence in the flora of Western Himalaya. In*:* Paliwal, GS (eds) The vegetational wealth of the Himalayas. Puja Publishers, New Delhi, India.

Hope CW. 1903. The ferns of Northwestern India Including Afghanistan the Trans-Indus Protected Areas & Kashmir. J Bombay Nat Hist Soc 14: 720-749.

Kapur SK. 1985. Contribution to the Pteridophytic flora of the Jammu and Kashmir. J Econ Tax Bot 6: 503-514.

Khullar SP. 2000. An illustrated Fern Flora of West Himalaya. Vol. II. International Book Distributors, Dehra Dun, India.

Kramer KU. 1990. Dryopteridaceae. In*:* Kramer KU, Green PS (eds) The Families and Genera of Vascular Plants. Vol. 1. Pteridophytes and Gymnosperms. Springer, Berlin.

Kramer KU, Green PS. 1990. The families and genera of vascular plants. Vol. 1. Pteridophytes and Gymnosperms. Springer, Berlin.

Kung HS, Chu, WM, He ZR, Zhang LB. 2001. *Polystichum*. In*:* Wu CY (ed) Vol. 5. Flora Reipublicae Popularis Sinicae. Science Press, Beijing.

Mabbrley DJ. 1997. The plant book. Cambridge University Press, New York, USA.

Pryer KM, Schneider H, Smith AR, Cranfill R, Wolf PG, Hunt JS, Sipes SD. 2001. Horsetails and ferns are a monophyletic group and the closest living relatives to seed plants. Nature 409: 618-622.

Raza M, Ahmad A, Mohammad A. 1978. The Valley of Kashmir, a geographical interpretation. Vikas Publication, New Delhi.

Rothwell GW, Stockey RA. 2008. Phylogeny and evolution of ferns: a paleontological perspective. In: Ranker TA, Haufler CH (eds) Biology and Evolution of Ferns and Lycophytes. Cambridge University Press, Cambridge, UK.

Singh DK, Uniyal BP, Mathur R. 1998. Jammu and Kashmir. In*:* Singh NP, Singh DK (eds). Floristic diversity and conservation strategies in India. Botanical Survey of India, Kolkata, India.

Smith AR, Pryer K, Schuettpelz E, Korall P, Schneider H, Wolf PJ. 2006. A classification for extant ferns. Taxon 55: 705-731.

Srivastava HP. 1998. Kashmir. Collier‘s Encyclopedia.

Stewart RR. 1937. The flora of Ladak, Western Tibet. II. List of Ladak plants. Bull Torr Bot Club 43: 625-626.

Stewart RR. 1945. Ferns of Kashmir Himalaya. Bull Torrey Bot Club. 72: 399-426.

Stewart RR. 1951. The Ferns of Pehlgam, Kashmir. J Indian Bot Soc. 30: 137-142.

Stewart RR. 1957. The fern and fern allies of West Pakistan. Biologia. 3: 1-32.

Stewart RR. 1972. An annotated catalogue of the vascular plants of West Pakistan and Kashmir In: Nasir E and Ali SI (eds.) Flora of West Pakistan. Fakhri Press, Karachi.

Tryon MR, Tryon AF. 1982. Ferns and Allied Plants (With Special Reference to Tropical America). Springer, New York.

Wadia DN. 1975. Geology of India. Tata McGraw Hill, New Delhi.

Wani MH, Shah MY, Naqshi AR. 2012. The ferns of Kashmir-an update account. Indian Fern J 29: 100-136.

Wu SG. 2000. Dryopteridaceae. In*:* Flora Reipublicae Popularis Sinicae. Science Press, Beijing.

Wu SH, Ching RC. 1991. Fern Families and Genera of China. Science Press, Beijing.

Zhang LB, Zhang L, Dong SY, Sessa EB, Gao XF, Ebihara A. 2012. Molecular circumscription and major evolutionary lineages of the fern genus *Dryopteris* (Dryopteridaceae). BMC Evol Biol 12: 180.

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Distribution of mangrove species reported as rare in Andaman and Nicobar islands with their taxonomical notes

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ABSTRACT

Ragavan P, Ravichandran K, Jayaraj RSC, Mohan PM, Saxena A, Saravanan S, Vijayaraghavan A. 2014. Distribution of mangrove species reported as rare in Andaman and Nicobar islands with their taxonomical notes. Biodiversitas 15: 12-23. During the recent field survey it was found that among 15 rare mangroves in Andaman and Nicobar Islands, ten rare species i.e. *Acanthus ebracteatus, Acrostichum speciosum, Bruguiera cylindrica, Cynometra iripa, Cynometra ramiflora, Lumnitzera racemosa, Rhizophora* hybrids, *Sonneratia alba, Sonneratia griffithii* and *Xylocarpus mekongensis* are present in Andaman and Nicobar islands. In addition to *Acanthus volubilis, Brownlowia tersa* and *Sonneratia ovata* are recorded after their first report.

Key words: Andaman and Nicobar islands, mangroves, rare species

INTRODUCTION

Rarity in natural systems is common and is most often defined by two attributes: a species' distribution and its abundance. Species are considered rare if their area of occupancy or their numbers are small when compared to the other species that are taxonomically or ecologically comparable (Flather and Sieg 2007). Mangrove forests are unique plant communities of the critical interface between terrestrial, estuarine, and near-shore marine ecosystems in tropical and subtropical regions (Polidoro et al. 2010). Despite its ecological and economical values, globally mangrove areas are disappearing at the rate of approximately 1% per year (FAO 2003, 2007). However, little is known about the effects of either widespread or localized mangrove area loss on individual mangrove species or populations due to the lack of species information. The mangroves of Andaman and Nicobar islands (ANI) are gregarious, dense and diverse in nature and found along the tidal creeks, bays and lagoons. However, the mangrove plant diversity in many areas of ANI has not drawn much attention. Only few references are available regarding the mangrove diversity in ANI (Sahni 1957; Blasco 1977; Mall et al. 1987; Dagar et al. 1991; Singh and Garge 1993; Debnath 2004; Mandal and Naskar 2008; Kathiresan 2008). Among them Dagar et al. (1991) critically surveyed the mangroves of ANI and listed out 34 true mangrove species. After that Kathiresan (2008) reported the occurrence of 36 mangrove species in ANI; of which 15 species were rare i.e *Acanthus ebracteatus, Acrostichum speciosum, Aegialitis rotundifolia, Bruguiera cylindrica, Bruguiera sexangula Ceriops decandra, Cynometra iripa, Cynometra ramiflora, Kandelia candel, Lumnitzera racemosa, Rhizophora lamarckii, Sonneratia alba, Sonneratia apetala, Sonneratia griffithii and Xylocarpus mekongensis.* After that no such detailed survey has been taken place in ANI and the occurrence of certain mangroves species *viz. Aegialitis rotundifolia, Aglaia cucullata, Rhizophora x lamarckii, Sonneratia griffithii, Xylocarpus mekongensis* and *Acanthus volubilis* were doubted by earlier studies (Mall et al 1987; Dagar et al 1991; Debnath 2004). Further, the mangroves of rare occurrence are poorly understood for their ecology and biology (Kathiresan 2008). So it became necessary to find out the truth behind the existence and distribution of these rare species, because species composition of mangroves is a basic and important prerequisite to understanding all the aspects of their structure and function, as well as their biogeographical affinities for their conservation and management (Jayatissa et al. 2002; Wang et al. 2003).

MATERIALS AND METHODS

Random survey was carried out in major creeks/ mangroves areas in 8 forest division of Andaman and Nicobar islands (ANI), Bengali bay, India (Figure 1; Table 1). The total of 30 sites were visited and it was achieved using a combination of road plus small boat transportation to gain access to the extensive range of mangrove area.

Further searching was done along the edge of the mangrove forest and inside the mangrove area by walking. Even in some small islands such as Havelock and Neil, the exploration was done by walking around the beaches and by boat around the island. Targeted species was counted in each observed site. The status of each species was assessed based on the frequency of occurrence in sampling sites (Kathiresan 2008). As we adapted random survey to cover extensive range of area, each site was considered as single sample unit and species status was assessed based on percentage frequency of each species (Table 2). All sites have been visited at least once at the time of flowering of the different species to cross-check identification with flower-based diagnostic features. As many as 2-5 specimens for each species were sampled, each sample was supposed to have flowers and hypocotyls/ fruits, and grouped according to the morphological characters. The collected plants were packed separately in polythene bags and brought to lab for analyzing taxonomically with prior assessments (Duke and Bunt (1979), Tomlinson (1986), Duke and Jackes (1987), Banerjee et al. (1989), Duke (1991, 2006a), Kathiresan (2002), Kathiresan (2000), Debnath (2004), Dagar et al. (1991), and Giesen et al. (2006). Herbarium was prepared for each observed species and deposited at Botanical Survey of India (BSI), Regional Centre at Port Blair.

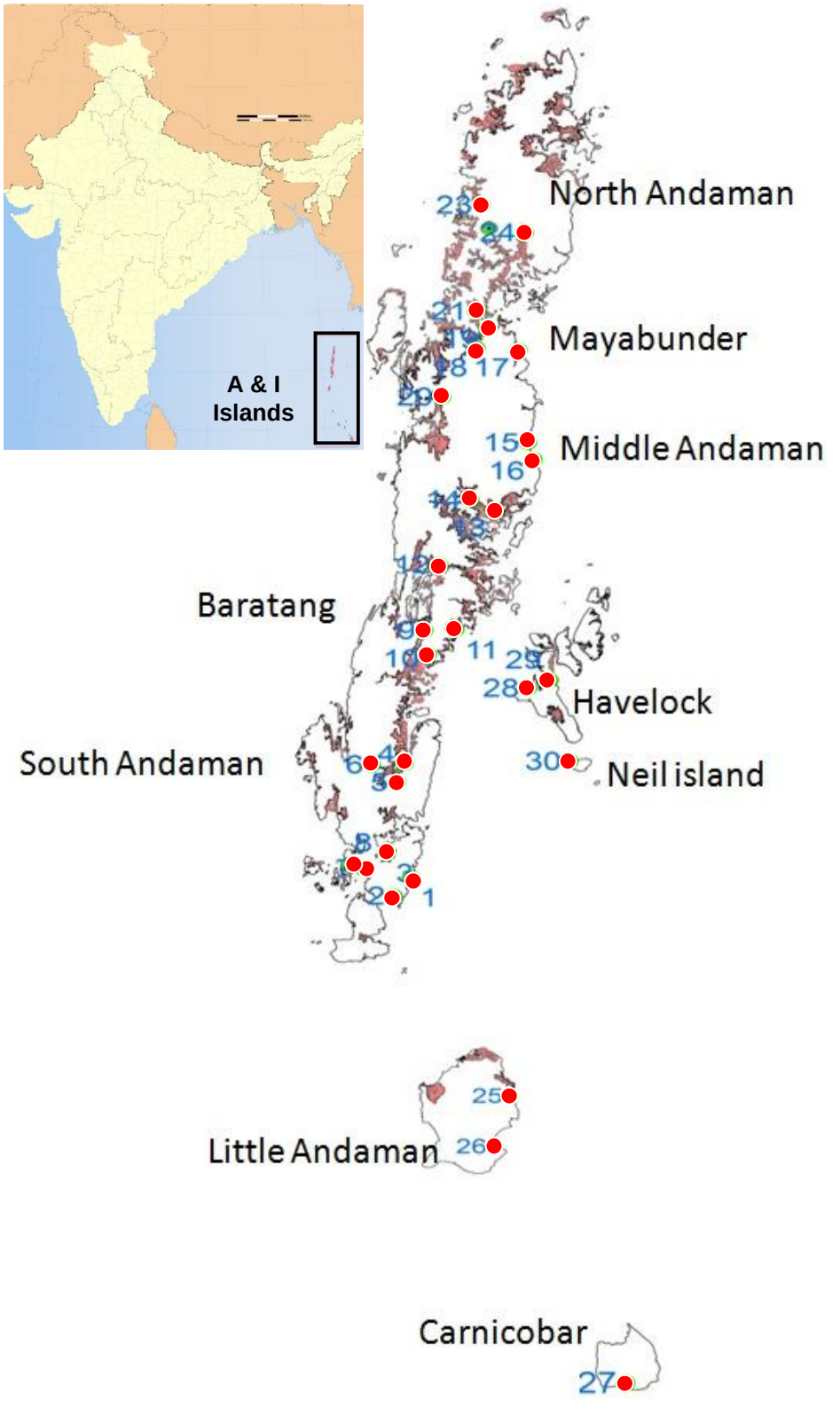

Figure 1. Sampling site in Andaman and Nicobar islands (ANI), Bengali bay, India. 1. Burmanallah, 2. Chediyatapu, 3. Sippighat, 4. Shaolbay creek, 5. Wrightmyo creek, 6. Jirkatang, 7. Manglutan, 8. Wandoor, 9. Middle strait, 10. Wrafter creek, 11. Baludera, 12. Kadamtala creek, 13. Yerrata creek, 14. Shayamkund creek, 15. Dhaninallah creek, 16. Pachwati creek, 17. Karmatang creek, 18. Tugapur creek, 19. Austin creek, 20. Chainpur creek, 21. Mohanpur creek, 22. Parangara creek, 23. Kishorinagar creek, 24. Kalighat creek, 25. V.K.pur creek, 26. Hut bay, 27. Kimous bay, 28. Radhanagar, 29. Govindnagar, 30. Neil island

Table 1. Distribution of rare mangrove species in ANI

Division	Site	Species recorded (values within bracket indicate number of individual trees recorded)
South Andaman	Burmanallah	*Sonneratia ovata* (7), *Cynometra irripa* (4) *Lumnitzera racemosa* (5), *Bruguiera cylindrica* (13), *Sonneratia alba* (13)
	Chediyatapu	*Sonneratia alba* (31), *Sonneratia ovata* (15), *Rhizophora* hybrids (2), *Bruguiera cylindrica* (8), *Cynometra ramiflora* (1)
	Sippighat	*Bruguiera cylindrica* (16), *Sonneratia alba* (7), *Acanthus ebracteatus* (small patches)
	Shaolbay creek	*Sonneratia ovata* (17), *Rhizophora* hybrids (1), *Bruguiera cylindrica* (18), *Acanthus volubilis* (small patches), *Acrostichum speciosum* (small patches), *Cynometra iripa* (5), *Sonneratia alba* (31), *Acanthus ebracteatus* (small patches)
	Wrightmyo creek	*Bruguiera cylindrica* (13), *Acrostichum speciosum, Sonneratia alba* (19), *Cynometra iripa* (3)
	Jirkatang	*Acanthus volubilis* (Small patches), *Acrostichum speciosum* (small patches), *Bruguiera cylindrica* (17), *Cynometra iripa* (4), *Sonneratia alba* (12)
	Manglutan	*Sonneratia ovata* (4), *Bruguiera cylindrica* (11), *Sonneratia alba* (7)
	Wandoor	*Sonneratia ovata* (2), *Bruguiera cylindrica* (7), *Sonneratia alba* (7)
Baratang	Middle strait	*Bruguiera cylindrica* (57), *Sonneratia alba* (29), *Cynometra iripa* (8)
	Wrafter creek	*Xylocarpus mekongensis* (6), *Bruguiera cylindrica* (87), *Sonneratia alba* (32), *Cynometra iripa* (6)
	Baludera	*Xylocarpus mekongensis* (1), *Bruguiera cylindrica* (5)
Middle Andaman	Kadamtala creek	*Rhizophora* hybrids (13), *Sonneratia ovata* (1), *Sonneratia alba* (16), *Cynometra iripa* (11), *Bruguiera cylindrica* (16)
	Yerrata creek	*Rhizophora* hybrids (5), *Lumnitzera racemosa* (34), *Xylocarpus mekongensis* (41), *Bruguiera cylindrica* (24), *Sonneratia alba* (14), *Cynometra iripa* (12)
	Shayamkund creek	*Brownlowia tersa* (small patches), *Bruguiera cylindrica* (21), *Xylocarpus mekongensis* (3), *Sonneratia alba* (15), *Cynometra iripa* (16)
	Dhaninallah creek	*Sonneratia griffithii* (34), *Xylocarpus mekongensis* (7), *Lumnitzera racemosa* (4), *Bruguiera cylindrica* (7), *Sonneratia alba* (21), *Cynometra iripa* (9)
	Pachwati creek	*Sonneratia griffithii* (7), *Sonneratia alba* (3), *Cynometra iripa* (7)
Mayabunder	Karmatang creek	*Bruguiera cylindrica* (17), *Lumnitzera racemosa* (29), *Xylocarpus mekongensis* (5), *Cynometra iripa* (7)
	Tugapur creek	*Xylocarpus mekongensis* (3), *Bruguiera cylindrica* (16), *Cynometra iripa* (4), *Sonneratia alba* (5)
	Austin creek	*Rhizophora* hybrids (16), *Cynometra iripa* (7), *Bruguiera cylindrica* (14), *Sonneratia alba* (7)
	Chainpur creek	*Xylocarpus mekongensis* (4), *Cynometra iripa* (9), *Bruguiera cylindrica* (17),
	Mohanpur creek	*Xylocarpus mekongensis* (7), *Cynometra iripa* (13), *Bruguiera cylindrica* (18), *Sonneratia alba* (14), *Sonneratia griffithii* (1)
Diglipur	Parangara creek	*Xylocarpus mekongensis* (13), *Cynometra iripa* (5), *Bruguiera cylindrica* (14), *Sonneratia griffithii* (13),
	Kishorinagar creek	*Cynometra iripa* (9), *Bruguiera cylindrica* (11), *Sonneratia alba* (7)
	Kalighat creek	*Sonneratia griffithii* (8), *Cynometra iripa* (4), *Bruguiera cylindrica* (11), *Sonneratia alba* (9)
Little Andaman	V.K. Pur creek	*Sonneratia alba* (11), *Sonneratia caseolaris* (17), *Cynometra iripa* (16), *Bruguiera cylindrica* (14)
	Hut bay	*Sonneratia griffithii* (1),
Carnicobar	Kimous bay	*Rhizophora* hybrids (4), *Lumnitzera racemosa* (5)
Havelock	Radha nagar	*Sonneratia ovata* (7), *Bruguiera cylindrica* (4)
	Govindnagar	*Bruguiera cylindrica* (13), *Sonneratia alba* (18), *Rhizophora hybrids* (11)
	Neil island	*Rhizophora* hybrids (6)

Table 2. Species status based on percentage frequency

Species	Number individuals recorded	Number of sites in which species occurred	Total number of sites	Percentage of frequency	Status
Acanthus volubilis	Small patches	2	30	6.67	Rare
Acanthus ebracteatus	Small patches	2	30	6.67	Rare
Acrostichum speciosum	Small patches	3	30	10	Rare
Bruguiera cylindrica	469	26	30	86.7	Abundant
Cynometra iripa	159	20	30	66.7	Frequent
Cynomtera ramiflora	1	1	30	3.33	Rare
Lumnitzera racemosa	77	5	30	16.7	Rare
Rhizophora hybrids	58	8	30	26.7	Rare
Sonneratia alba	328	22	30	73.3	Frequent
Sonneratia griffithii	64	6	30	20	Rare
Sonneratia ovata	53	7	30	23.3	Rare
Xylocrpus mekongensis	90	10	30	33.3	Common
Brownlowia tersa	Small patches	1	30	3.33	Rare
Sonneratia caseolaris	17	1	30	3.33	Rare

Note: Abundant (a): if the species is present in 81-100% of sampling points; Frequent (f): if the species is present in 61-80% of sampling points; Common (c): if the species is present in 31-60% of sampling points; Rare (r): if the species is present in 1-30% of sampling points

RESULTS AND DISCUSSION

The results of present study confirm the occurrence of 10 out of the 15 rare mangroves reported earlier. Remaining five species namely *Aegialitis rotundifolia, Bruguiera sexangula, Ceriops decandra, Kandelia candel* and *Sonneratia apetala* were not recorded in this study. Contrary to earlier reports in this study *Avicennia alba* was not recorded and *Sonneratia caseolaris* was recorded in only one site; both species are reported as frequent in ANI by Kathiresan (2008). *Acanthus volubilis, Brownlowia tersa and Sonneratia ovata* are reported after their first report, i.e. Parkinson (1923) and Dam Roy et al. (2009). In the discussion below, we highlighted the diagnostic features of each mangrove species and their distribution in ANI.

Acanthus volubilis Wall. is the only climber known to occur in mangroves and considered as true mangrove species (Duke 2006; Polidoro et al. 2010). *A. volubilis* was first reported from ANI by Parkinson (1923) after that it was included in the mangrove species list by several authors (Thothatri 1962; Mall et al. 1987; Dagar et al.1991; Debnath 2004; Mandel and Naskar 2008). But, Mall et al. (1987) mentioned that he included this species based on Parkinson (1923) report and he has not encountered in any sites. Once *A. volubilis* was considered as an extinct species in India, but recently it has been recorded again with its very limited population from Sunderbans (Mandel and Naskar 2008). Kathiresan (2008) did not included this species in his report. Dam Roy et al. (2009) reported this species from ANI, but description and photographs given for *A. volubilis* reveal that the only character of the observed specimen used to identify the species is spineless leaves and stem; however, this can be a feature of *A. ilicifolius* as well (Jayatissa et al. 2002). Moreover herbarium deposited by Thothathri (1962) in BSI, Regional centre at Port Blair also resembles the same. Thus *A. volubilis* reported here after its first report (i.e. Parkinson 1923). In this study *A. volubilis* was reported at two sites i.e. Shoalbay creek and Jirkatang in South Andaman. In both sites, it was observed in small patches along with *Acrostichum aureum* and *Acrostichum speciosum* on the landward edge. *A. volubilis* was easily identified by its smooth (without stem axial spines) and twining with delicate sprawling stems, spineless leaves, terminal inflorescences and white flowers without bracteoles (Figure 2.A-2.D).

In India *Acanthus ebracteatus* Vahl. is known to occur in Andaman and Nicobar Islands and Kerala (Kathiresan 2008). But the details about their status and distribution are inadequate, because the taxonomical discrimination between the *A. ebracteatus* and *A. ilicifolius* are still not clear (Kathiresan 2010). For instances, Remadevi and Binojkumar (2000) argued that many specimen identified and indexed as *A. ilicifolius* in Indian herbarium are actually *A. ebracteatus*. In contrast, Anupama and Sivadasan (2004) questioned the identification made by Remadevi and Binojkumar (2000). In this study *A. ebracteatus* was recorded at two sites i.e Shaolbay creek and Sippighat in South Andaman. Generally *A. ebracteatus* is identified by its white colored flowers, but some ecological variants of *A. ilicifolius* exhibit white colored flowers with unarmed leaves and stems (Jayatissa et al. 2002). Hence, identification based on flowers may cause misidentification in the field. During the present study, it was found that position of inflorescences and direction of stem axial spines at nodes helps the rapid differentiation of *A. ilicifolius* from *A. ebracteatus* apart from flower color and presence of bracteoles. *A. ebracteatus* is distinguished from other *Acanthus* spp by its highly serrated leaves, white colored flowers, absence of bracteoles, stem with auxiliary spines facing downwards and terminal inflorescences (Figure 2.E-2.J). But in *A. Ilicifolius'* leaves and stems are either armed or unarmed, flower color is blue or white (rarely white), inflorescences are both axial and terminal and stem with auxiliary spines facing upwards (Figure 2.K-2.N)

Species of *Acrostichum* are usually called mangrove ferns. In ANI *Acrostichum aureum* L. is a common species, in contrast, *Acrostichum speciosum* Willd. is rare. In the present survey *A. speciosum* was recorded at three sites i.e Shoalbay creek, Wrightmyo creek, and Jirkatang. In all the sites, *A. speciosum* was observed at the mangrove understory, and just at the margins of high intertidal zones. These areas are frequently inundated by tides and are usually shady. It was also observed on the landward edges along with *A. aureum* in Shoalbay creek. In fields, *A. aureum* and *A. speciosum* are easily distinguished based on frond shape and texture. The frond of *A. speciosum* narrows gradually to a pointed tip and papery (Figure 2.O, 2.Q), while that of *A. aureum* has a broadly rounded end and thickly coriaceous fronds (Figure 2.R). Recently Dam Roy et al. (2009) reported this species in Wandoor and Burmanallah, but description and photographs given for *A. speciosum* reveal that the only character of the observed specimen used to identify the species was pointed leaf tip; however, this can be a feature of *Stenochlaena palustris* as well (Giesen et al. 2006). *S. palustris* differ from *A. speciosum* by its serrated leaflet margin and parallel venation (Figure 2.S).

Bruguiera cylindrica (L.) Bl. was mentioned as a rare species by Dagar et al. (1991) and Kathiresan (2008). But in the present study it was observed in 26 sites and total 469 individual were recorded. So it is noteworthy that *B. cylindrica* is now abundant in Andaman Islands. It is small tree generally found inside the mangroves and occasionally forms pure stands that appear similar in appearance to those of *B. parviflora*. *B. cylindrica* is distinguished from other *Bruguiera* species by its small flowers, three flowered inflorescences and calyx with fully reflexed calyx lobes (Figure 2.T-2.V). In field it is easily distinguished from *B. parviflora* by its dark green leaves, folded when mature and reflexed calyx lobes, whereas *B. parviflora* possess small yellowish green leaves, long ribbed calyx with small adpressed lobes and thin propagule (Figure 2.W-2.Y).

Brownlowia tersa (L.) Kosterm. is generally found on the soft mud of intertidal estuarine banks and can be recognized in the field by its greyish brown branches, lanceolate leaves with dull silvery under surface, yellowish pink color flowers (Figure 3.A-3.C) and pear-shaped woody fruits with two valved carpels (Kathiresan 2010). It

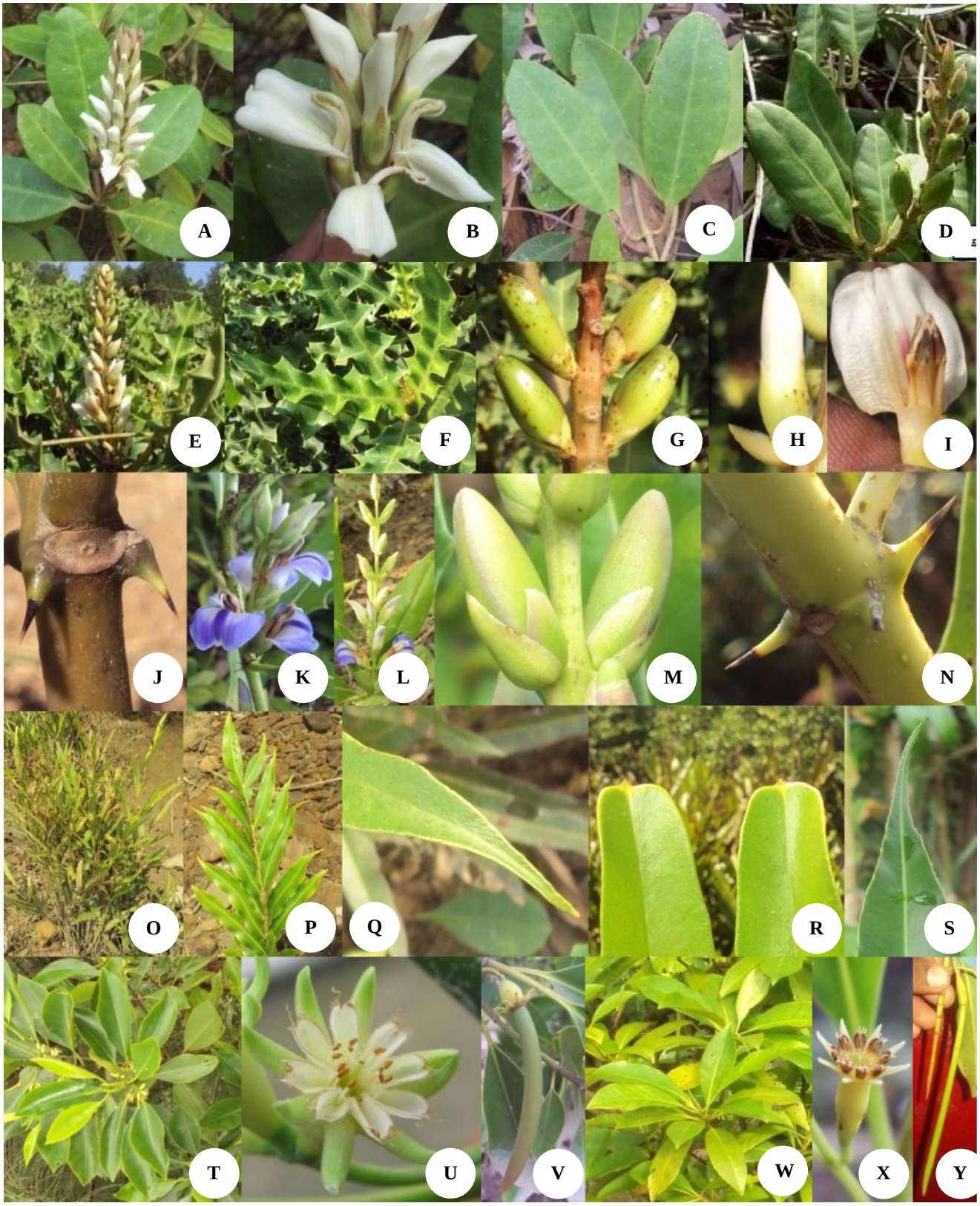

Figure 2. (A) Terminal inflorescences (B) white flower with bract (C) smooth leaves and (D) fruits of *Acanthus volubilis* (E) terminal inflorescences (F) highly serrated leaves (G) fruits (H) mature bud without bracteoles (I) white flower and (J) downward facing stem axial spines of *Acanthus ebracteatus* (K) terminal and (L) axillary inflorescences with purple flowers (M) bud with bract and bracteoles and (N) upward facing stem axial spines of *Acanthus ilicifolius* (O) habitat (P) sterile leaves with narrowly pointed leaflets and (Q) pointed tip of *Acrostichum speciosum* (R) blunt leaf tip of *Acrostichum aureum* (S) serrated margin of leaflet of *Stenochlaena palustris* (T) dark green leaves (U) flowers and propagule of *Bruguiera cylindrica* with reflexed calyx lobes (W) yellowish green leaves (X) flowers and (Y) propagule of *Bruguiera parviflora* with long calyx tube.

Figure 3. (A) Habitat (B) flowers and (C) leaves with slivery grey underside *of Brownlowia tersa* (D) Leaves (E) flowers and (F) fruits of *Cynometra iripa* (G) Leaves and (H) fruits of *Cynometra ramiflora* (I)axillary Inflorescences (J) white flowers with small stamens and (K) fruits of *Lumnitzera racemosa* (L) red flowers of *Lumnitzera littorea* with long stamens; (M) mature bud with smooth green bract (N) broad leaves (O) presence of stamens in two distinct whorls in *Rhizophora* hybrids.

is common in West Bengal and Odisa; but rare in ANI and Godavari estuary of Andhra Pradesh. Hajra et al. (1999) have also mentioned that *B. tersa* was reported, some 80 years ago, to be found abundant near large creeks of Middle Andaman like Dhanikhari creek, but is now rare there. In the present, it was recorded from Shyamkund area in Middle Andaman along the landward edges of mangroves with *Acanthus* sp and *Acrostichum* sp. It is one of the near threatened species (Kathiresan 2010).

Two species of genus *Cynometra* i.e. *Cynometra iripa* Kostel. and *Cynometra ramiflora* Linn. are commonly called as wrinkle pod mangroves. Both species were known to occur in ANI and are rare (Dagar et al. 1991; Kathiresan 2008). In the present survey, 159 mature trees of *Cynometra iripa* were recorded from 20 locations and *C. ramiflora* was recorded only from one site (Chediyatapu). In the field, *Cynometra* species is easily recognized by its off-centered mid-veins on leaves (Figure 3.D and 3.G). *C. iripa* and *C. ramiflora* are differentiated based on the position of beaks in the pods. *C. iripa* has prominent lateral beak because the style is bent in it (Figure 3.E-3.F), whereas *C. ramiflora* has sub-terminal beak (Figure 3.H)

because it has straight style. Ovary is densely hairy in *C. iripa* (Figure 3.E) and smooth in *C. ramiflora.* These two species not easily differentiates without fruiting and flowering.

Lumnitzera racemosa Wild. is easily identified by its white flowers, light green succulent narrowly elliptic leaves and dark roughly fissured stem. It is distinguished from *L. littorea* by its axillaries racemes of flowers with white petals and stamens shorter than petals (Figure 3.I- 3.K) whereas *L. littorea* exhibit terminal racemes of flowers with red petals and stamens longer than the petal (Figure 3.L). We have recorded this species in 4 sites in Andaman Islands and one site in Carnicobar. Total 77 mature individuals were recorded.

In ANI *Rhizophora* hybrid was first recorded by Singh et al. (1987). He recorded this hybrid taxon from Havelock Island and described it as *Rhizophora x lamarckii* present in the mixed stands of *R. apiculata* and *R. mucronata*, but *R. x lamarckii* is a hybrid between *R. apiculata* and *R. stylosa*. Due to nomenclature uncertainty between *R. x lamarckii* and *R. x annamalayana (*Lo, 2003*)*, in the present study this taxon has been described as *Rhizophora* hybrid. *Rhizophora* hybrids are easily identified by their height, a large number of flowers with smooth bract (Figure 3.M-3.O) and rare occurrence of propagules. In this study, *Rhizophora* hybrids have been observed in 8 sites *viz.* Havelock, Neil, Chediyatapu, Shoalbay creek, Austin creek, Yerrata creek, Kadamtala creek in Andaman islands and Kimous bay in Carnicobar island, total 58 mature individual were recorded. Except in Havelock the occurrence of *Rhizophora* hybrids in other places have been reported first time in this study. In Austin creek, Kadamthala creek, Shoalbay creek and Yerrata creek *Rhizophora* hybrids were present in the mixed stands of *R. apiculata* and *R. mucronata;* in other places hybrids are present along with *R. apiculata*, *R. mucronata* and *R. stylosa*. So, it may be concluded that both *R. x lamarckii* (*R. apiculata x R. stylosa*) and *R. x annamalayana* (*R. apiculata x R. mucronata*) might be present in ANI. As natural hybrids play a very important role in evolution of novel gene combinations and in the process of speciation, it is important to conserve the natural hybrids of the genus *Rhizophora*. Moreover, *Rhizophora* hybrids rarely produce seeds, making their propagation very difficult. One of the unique features of Indian *Rhizophora* hybrids is the presence of stamens in two distinct whorls i.e. outer longer stamens and inner smaller stamens (Ragavan et al. 2011).

In contrast to Dagar et al. (1991) and Kathiresan (2008), in this study, *Sonneratia alba* J. Smith. was observed in 22 sites; altogether with 328 individuals were recorded, whereas *Sonneratia caseolaris* (L.) Engl. was recorded only in V.K. pur creek, Little Andaman. It was found from this study that taxonomical distinction between *S. caseolaris* and *S. alba* was not clear in ANI; for instance, Dagar et al. (1991) mentioned that *S. caseolaris* was most common in Andaman islands and exhibit rough bark. But based on the present study, it was found that rough bark is the feature of *S. alba* and *S. alba* is common in Andaman islands, whereas in *S. caseolaris* bark is smooth and grey in color and it is rare in ANI. *S. alba* is distinguished from *S. caseolaris* by its drop shaped leaves with rounded leaf tip, broad mucronate, flowers with white petals and stamens, cub shaped calyx with lobes tinged red inside, rough fissured bark, conical pneumatophores and sickle shaped seeds (Figure 4.A-4.D). However, we observed great deal of morphological variation amongst populations of *S. alba* in Andaman islands. *S. caseolaris* is identified by its willow tree like appearance, leaves are elliptic in shape with pointed mucro, smooth or lightly fissured flaky bark, flowers with ribbon like red petals, numerous red stamens (rarely white), flattened calyx and irregular seeds (Figure 4.E-4.I). *S. alba* and *S. caseolaris* are ecologically two different entities. *S. alba* is a pioneering species in the mangrove habitat, intolerant of long periods of exposure to fresh water, usually occur in downstream of tidal creeks and offshore island embayments. *S. caseolaris* occur only in upstream areas dominated with river or freshwater inputs. *S. caseolaris* individuals were recorded at V.K.Pur creek (little Andaman) in upstream of the creek with *Barringtonia racemosa* (fresh water mangrove).

Sonneratia ovata Backer. was first reported in ANI by Dam Roy et al. (2009) from Havelock islands. During the present survey *S. ovata* were recorded in seven sites *viz.* Havelock, Burmanallah, Chediyatapu, Kadamtala, Shoalbay creek, Manglutan and Wandoor. This species is not reported in any other part of India. *S. ovata* is easily distinguished from other *Sonneratia* species by its enveloped calyx lobes with its fruits, fissured bark and rounded leaf (Figure 4.J-4.M). *S. ovata* is one of the near threatened species (Polidoro et al. 2010). In all the sites we located this species just above the high tide mark along with *Ceriops* sp., *Excoecaria agallocha* and *Bruguiera cylindrica*. Total 53 mature individuals were recorded.

In India *Sonneratia griffithii* Kurz is known to occur rarely on the muddy banks of estuarine mouths under tidal inundation in Sundarbans, Odisa and Andaman islands (Kathiresan 2010). *S. griffithii* was first reported from ANI by Parker (1925). After that there are no reports of the species from ANI. No herbarium specimen is also available in ANI. In this study, *S. griffithii* was recorded at 6 sites, *viz.* Dhaninallah creek, Parangara creek, Panchwati, Kalighat creek, Mohanpur and Hut bay. Total 64 individuals were recorded in this study. *S. griffithii* is distinguished from other species of *Sonneratia* by its obovate leaves, large solitary white flowers with white stamens, absence of petals and larger globose fruits with a depression at the apex and short style (Figure 4.N-4.Q). Another important key character to distinguish *S. griffithii* is the shape of buds. Shape of the bud is smooth and rounded in *S. griffithii*. *S. griffithii* is rare and is a critically endangered species (Kathiresan 2010; Polidoro et al. 2010). Among the 30 countries in the Indian Ocean region, *S. griffithii* has been reported only from Malaysia, Thailand, Myanmar and India (Kathiresan and Rajendran 2005) and is locally extinct in a number of areas throughout its range

Three species of genus *Xylocarpus* i.e., *Xylocarpus granatum* Koenig, *Xylocarpus mekongensis* Pierre and *Xylocarpus moluccensis* (Lamk.) M. Roem was known to occur in Andaman islands (Hajra et al. 1999; Debnath 2004; Dagar et al. 1991). In this study, the former two species were observed. Based on critical field observations

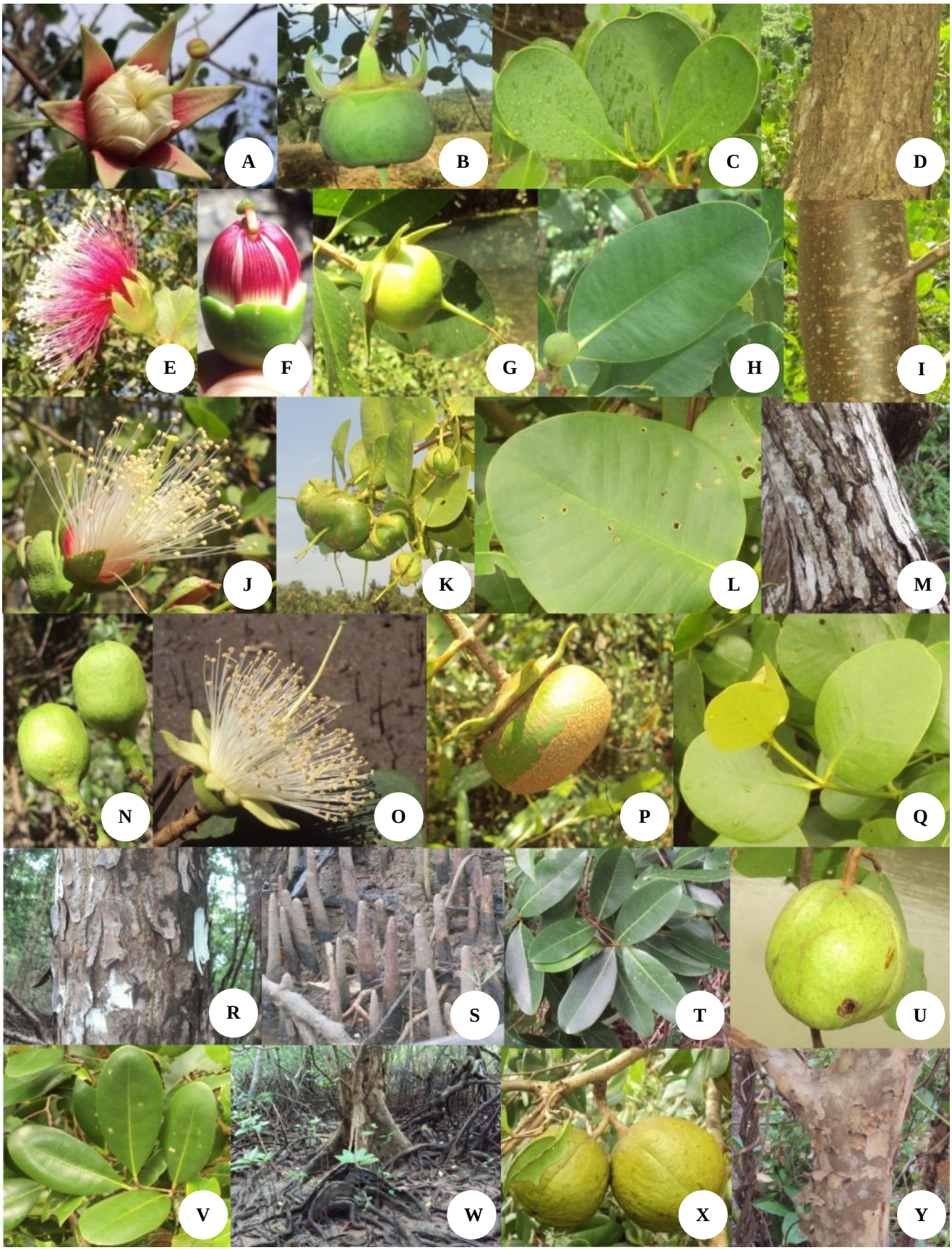

Figure 4. (A) flowers, (B) fruits (C) leaves and (D)bark of *Sonneratia alba,* (E) flowers (F)red petal (G) fruits (H) leaves and (I) smooth bark of *Sonneratia caseolaris* (J) flowers, (K) fruits (L) leaves (M) bark of of *Sonneratia ovata* (N) mature bud (O) flower (P) fruit and (Q) leaves of *Sonneratia griffithii*; (R) peeling bark, (S) pneumatophores, (T) leaves and (U) fruits of *Xylocarpus mekongensis* (V) leaves (W)buttresses and planks root (X) fruits and (Y) bark of *Xylocarpus granatum*.

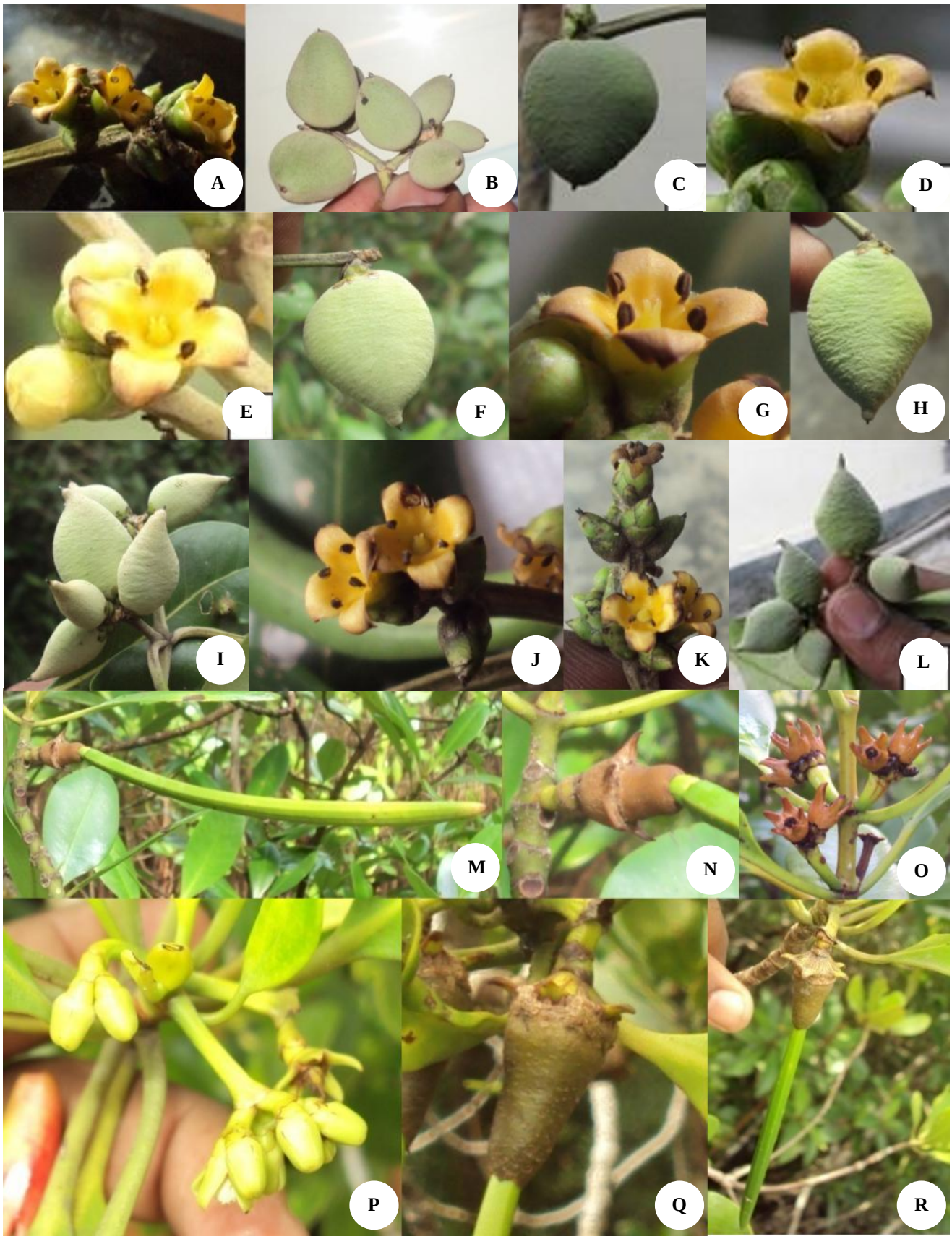

Figure 5. Variation in *Avicennia marina* (A-D) flowers with style length equal to base of the stamen and fruits without beak; (E-H) flowers with style length equal to base of anther and fruits with small beak; (I-L) flowers with small style and fruits with prominent beak (M) upright propagule (N) downward facing calyx lobes and (O) short peduncle of *Ceriops decanra* (photos taken in Pichavaram (P) long peduncle (Q) reflexed calyx lobes and (R) hanging propagules of *Ceriops tagal.*

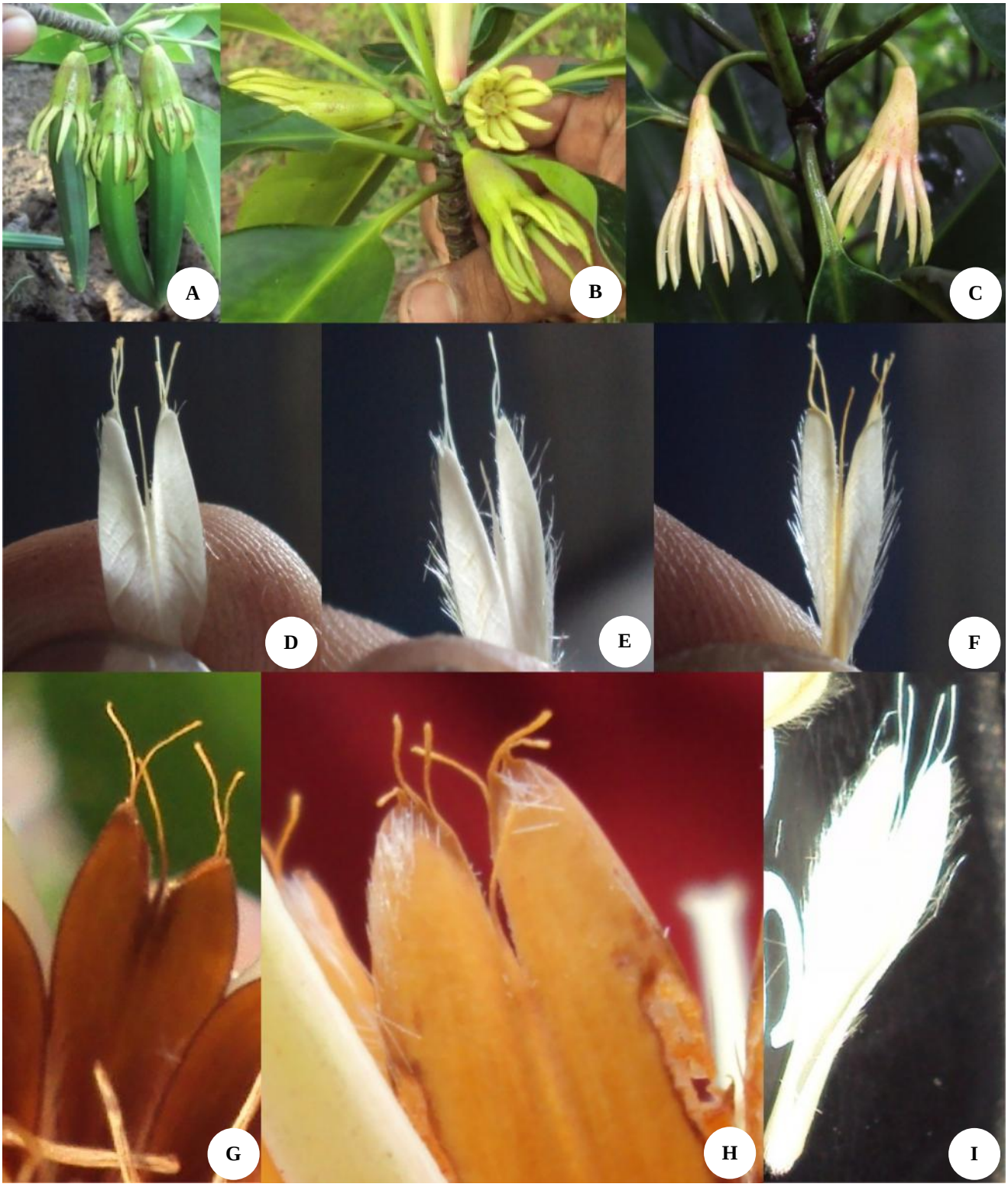

Figure 6. Variation in *Bruguiera gymnorrhiza* (A,B) green color calyx (C) pinkish white calyx (D) petal with petal spine equal to petal lobe (E) petal spine shorter than petal lobe (F) petal spine longer that petal lobe (G) petal apex with two bristles (H) three bristles (I) two bristles with small stub.

and literatures analysis (Giesen et al. 2006; Duke 2006) it is understood that *X. moluccensis*, *X. gangeticus* and *X. parvifolius* are synonyms of *X. mekongensis*. *X. granatum* is the most common in ANI and is easily identified by its buttressed stem with plank roots, light brown bark with thin flakes and large fruits with pyramidal seeds (Figure 4.V-4.Y). *X. mekongensis* is easily identified by its peg like pneumatophores, dark brown bark peeling in long thick narrow strips and small fruits (Figure 4.R-4.U). *X. mekongensis* was observed in 10 sites *viz.* Chainpur creek, Yerrata creek, Tugapur creek, Shyamkund

creek, Parangara creek, Dhaninallah creek, Wrafter creek, Karmatang creek, Mohanpur creek and Baludera ; total 90 individuals were recorded. In Yerrata creek alone, 41 individuals were recorded along with *Bruguiera* spp and *Lumnitzera* spp. In the rest of the sites, we located only few individuals were found along the banks of the creek with *Rhizophora* sp and *X. granatum*.

Kathiresan (2008) and Mandel and Naskar (2008) noted the occurrence *Avicennia alba* Bl. in ANI without any taxonomical notes. Generally, *A. alba* is identified by its elongated and pointed propagules and spicate inflorescences unique within the genus, but in this study, marked variation have been observed amongst populations of *Avicennia marina* in the fruit beak, style length and its position relative to anther. We observed three kind of *A. marina* based on the beak i.e. fruits without beak, intermediate beak and prominent beak (Figure 5.A-5.L). This observation suggest the occurrence of varietal species amongst the populations of *A. marina* and identification of *A. alba* based on the prominent stylar beak is not reliable without consideration of other characters. So, it is stressed here that *A. alba* is not present in ANI. Moreover *A. alba* is not reported in most of the previous studies too (Dagar et al. 1991; Debnath 2004; Dam Roy et al. 2009; Mall et al. 1987).

Rest of the rare mangrove species i.e. *Aegialitis rotundifolia* Roxb., *Sonneratia apetala* Buch.-Ham**.** *Ceriops decandra* (Griff.) Ding Hou, *Kandelia candel* (L.) Druce and *Bruguiera sexangula* (Lour.) Poir were not observed in this study. Though *Sonneratia apetala* was reported by Dagar et al. (1991) from Chediyatapu west, Burmanalla and New wandoor, in this study *S. apetala* could not be found in above mentioned sites, instead, *S. alba was* recorded. According to Dagar et al. (1991) *S. alba* was rare in ANI but in the present study, it was found recorded from most of the sites. This observation revealed the incorrect identification of *S. apetala* in the past, due to lack of extensive taxonomical studies. Moreover the above mentioned three species (*Aegialitis rotundifolia*, *Kandelia candel*, *Sonnertia apetala*,) were not recorded in recent times by other researchers too, such as Debnath (2004) and Dam Roy et al. (2009).

Without flowering and fruiting, species i.e. *Ceriops decandra* and *Bruguiera sexangula* cannot be differentiated from *Ceripos tagal* and *Bruguiera gymnorrhiza*, respectively. *C. decandra* is easily distinguished from *C. tagal* by its short peduncle, calyx lobe facing downwards, sharply ridged short hypocotyl warty towards apex and hypocotyls always in upright position (Figure 5.M-5.O). *C. tagal* possesses long peduncle, long propagules with yellow color collar and calyx lobes facing upwards (Figure 5.P-5.R). *C. tagal* is most common in Andaman group of islands. Mall et al. (1987), Singh (2003) and Dam Roy et al. (2009) did not report *C. decandra*.

B. sexangula from ANI was reported by Singh et al. (1987) and no further collections are available (Debnath 2004). Mall et al. (1987) and Singh and Garge (1993) observed only a few individuals of *B. sexangula* from Burmanallah area in South Andaman. The reports of *B. sexangula* from ANI by previous authors appeared doubtful as they followed the calyx color as key character to distinguish *B. sexangula* and *B. gymnorrhiza (*red/pink for *B. gymnorrhiza* and yellow for *B. sexangula).* Dagar et al. (1991) mentioned that calyx color of *B. sexangula* is initially green and turns yellow when mature. According to Duke (2006) the presence and absence of petal spine and number of petal bristles at the apex of the petal lobe are the key characters to distinguish *Bruguiera* species. Generally in *B. sexangula* petal spine is shorter than the petal lobe and petal bristles are absent or minute (Duke 2006). Sheue et al. (2005) have characterized *B. gymnorrhiza* with petal spine greater than the petal lobe and the petal bristles vary from 2-3. In the present study three groups of *B. gymnorrhiza* have been recorded based on the length of petal spine i.e., petal spine equal to petal lobe, petal spine shorter than the petal lobe and petal spine greater than the petal lobe (Figure 6.D-6.I). This observation shows unreliability of petal spine and bristles as key to identification of *Bruguiera* species. This further indicates that there could be two forms of *B. gymnorrhiza*. Moreover, different colors of calyx were observed in *B. gymnorrhiza* (Figure 6.A-6.C). As it is very difficult to distinguish *C. decandra* and *B. sexangula* from *C. tagal* and *B. gymnorrhiza*, respectively, it is inferred that former species might have been misidentified due to lack of extensive taxonomical studies in the past.

CONCLUSION

All the mangrove species discussed in this study are threatened in India and rare in much of its range. In contrast to earlier report, two species i.e *Sonneratia alba Cynometra iripa* were found to be frequent. *Bruguiera cylindrica* and *Xylocarpus mekongensis were* found to be abundant and common respectively, in ANI. At present, all these species are at serious risk as no systematic attempt has been made to conserve them. Hence immediate and effective conservation measures should be taken for their protection and propagation for recovery. In order to confirm the existence of other doubtful species and to avoid misidentification periodical surveys are required on the distribution and occurrence of mangrove species in ANI.

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REFERENCES

Anupama C, Sivadasan M. 2004. Mangroves of Kerala, India. Rheedea 14: 9-46

Banerjee LK, Sastry ARK, Nayar MP. 1989. Mangroves in India Identification Manual. Botanical Survey of India, Calcutta, India

Blasco. 1977. Outline of ecology, botany and forestry of mangals of the Indian subcontinent. In: Chapman VJ (ed.). Wet Coastal Ecosystem. Elsevier. Amisterdam.

Dagar JC, Mongia AD, Bandhyopadhyay AK. 1991. Mangroves of Andaman and Nicobar Islands, Oxford and IBH, New Delhi.

Dam Roy S, Krishnan P, George G, Kaliyamoorthy M, Goutham Bharathi MP. 2009. Mangroves of Andaman and Nicobar Islands. CARI, Port Blair.

Debnath HS. 2004. Mangroves of Andaman and Nicobar islands; Taxonomy and Ecology (A community profile). Bishen Singh Mahendra Pal Singh, Dehradun.

Duke NC, Bunt JS. 1979. The genus *Rhizophora* (Rhizophoraceae) in North-eastern Australia. Aust J Bot 29: 657-678.

Duke NC, Jackes BR. 1987. A systematic revision of the mangrove genus *Sonneratia* (Sonneratiaceae) in Australasia. Blumea 32: 277-302.

Duke NC. 1991. A systematic revision of the mangrove genus *Avicennia* (Avicenniaceae) in Australasia. Aust Syst Bot 4: 299-324.

Duke NC. 2006. Australia's mangroves: the authoritative guide to Australia's mangrove plants. The University of Queensland and Norman C. Duke, Brisbane.

FAO. 2003. Status and trends in mangrove area extent worldwide. In: Wilkie ML, Fortuna S, eds; Forest Resources Assessment Working Paper No. 63. Rome: Forest Resources Division, FAO. Available: http://www.fao. org/docrep/007/j1533e/j1533e00. [Accessed on August 1, 2009].

FAO. 2007. The World's Mangroves 1980-2005, FAO Forestry Paper 153. Forest Resources Division, FAO, Rome.

Flather CH, Sieg CH. 2007. Species rarity: Definition, causes, and classification. In: Raphael M, Molina R (eds). Conservation of Rare or Little-Known Species. Island Press, Portland.

Giesen W, Wulffraat S, Zieren M, Scholten L. 2006. Mangrove guidebook for Southeast Asia. FAO and Wetlands International. RAP Publication, Bangkok, Thailand.

Hajra PK, Rao PSN, Mudgal V. 1999. Flora of Andaman and Nicobar Islands Vol. 2. Botanical Survey of India, Calcutta.

Jayatissa LP, Dahdouh-Guebas F, Koedam N. 2002. A review of the floral composition and distribution of mangroves in Sri Lanka. Bot J Linn Soc 138: 29-43.

Kathiresan K, Rajendran N. 2005. Mangrove ecosystems of the Indian Ocean region. Indian J Mar Sci 34**:** 104-113.

Kathiresan K. 2000. Mangrove and associate plant species. Flora and Fauna in mangrove ecosystems: A manual for Identification. http://ocw.unu.edu/

Kathiresan K. 2002. Manual on identification of mangroves and associate plant species. All India Co-ordinated Project on "Survey and Inventorization of Coastal and Marine Biodiversity (East Coast)". http://ocw.unu.edu/

Kathiresan K. 2004. Biodiversity in mangrove ecosystems of India: Status, Challenges and Strategies. ENVIS For Bull 4: 11-23.

Kathiresan K. 2008. Biodiversity of Mangrove Ecosystems. Proceedings of Mangrove Workshop. GEER Foundation, Gujarat, India.

Kathiresan K. 2010. Importance of mangrove forest. J Coast Environ 1: 11-26.

Mall LP, Singh VP, Pathak SM, Garge A, Jat MS, Laskari M. 1987. Ecological studies of mangrove forest ecosystem of Andaman and Nicobar Islands. Final technical report. MAB project No.F 20/3/79 ENV. School studies in Botany. Vikaram University, Ujjain 456010. India.

Mandal RN, Naskar KR. 2008. Diversity and classification of Indian mangroves: a review. Trop Ecol 49: 131-146.

Parker N. 1925. The genus *Sonneratia*. Indian Forester 2: 505

Parkinson CE. 1923. A Forest Flora of the Andaman Islands. Bishen Singh and Mahendrapal Singh, Dehradun

Polidoro BA, Carpenter KE, Collins L, Duke NC, Ellison AM, Ellision JC, Farnsworth EJ, Fernando ES, Kathiresan K, Koedam NE, Livingstone SR, Miyagi T, Moore GE, Vien Ngoc Nam, Ong JE, Primavera JH, Salmo SG, Sanciangco JC, Sukardjo S, Wang Y, Yong JWH. 2010. The loss of species: Mangrove extinction risk and geographic areas of global concern. PLoS ONE 5(4): 1-10.

Ragavan P, Saxena M, Coomar T, Saxena A. 2011. Preliminary study on Natural hybrids of genus *Rhizophora* in India. ISME/GLOMIS Elec J 9: 13-19.

Remadevi S, Binoj Kumar MS. 2000. *Acanthus ebracteatus* Vahl - An addition to the flora of Mainland of India. J Econ Taxon Bot 24 (1): 241-242

Sahni KC. 1957. Mangrove Forests in the Andaman & Nicobar. Mangrove Symposium 16-19 Oct. 1957 Culcutta, India.

Sheue CR, Yong JWH, Yang YP. 2005. The *Bruguiera* (Rhizophoraceae) Species in the Mangroves of Singapore, especially on the New Record and the Rediscovery. Taiwania 50: 251-260.

Singh VP, Garge A. 1993. Ecology of Mangrove Swamps of the Andaman Islands. International Book Distributors, Dehradun, India.

Singh VP, Mall LP, George A, Pathak SM. 1987. A new record of some mangrove species from Andaman and Nicobar Islands and their distribution. Indian For 113 (3): 214.

Singh VP. 2003. Biodiversity, community pattern and status of Indian mangroves. In: Alsharhan AS, Fowler A, Goudie AS, Abdellatif EM, Wood WW (eds.) Desertification in the Third Millennium. Proceedings of an International Conference, Dubai. Taylor & Francis, New York.

Thothathri K. 1962. Contribution to the flora of Andaman and Nicobar Islands. Bull Bot Surv India 4: 281-296.

Tomlinson PB. 1986. The botany of mangroves. Cambridge University Press, Cambridge.

Wang BS, Liang SC, Zhang WY, Zan QJ. 2003. Mangrove flora of the world. Acta Bot Sin 45: 644-653.

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Endophytic fungi associated with endogenous *Boswellia sacra*

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ABSTRACT

El-Nagerabi SAF, Elshafie AE, AlKhanjari SS. 2014. Endophytic fungi associated with endogenous Boswellia sacra*. Biodiversitas 15: 24-30.* Endophytic fungi associated with leaves and stem tissues of *Boswellia sacra* growing in Dhofar Mountains of Oman were investigated from May 2008 through October 2011. The biological diversity, tissue-preference and seasonal variations of fungi were evaluated. Forty-three species and 3 varieties of fungi were recovered as new records from this plant. Of these isolates, 35 species are new reports to the mycoflora of Oman, whereas 12 species were added to the list of fungal flora of the Arabian Peninsula. The genus *Alternaria* (12 species) is the most prevalent genus recovered from 12.5-83.3% of the screened leaves and stem samples, followed by *Aspergillus* (5 species, 3 varieties, 6.9-86.1%), Mycelia sterilia (76.4%), *Rhizopus stolonifer* (62.5%), *Drechslera* (3 species, 40.3-54.2%), *Cladosporium* (3 species, 20.8-52.8%), *Curvularia lunata* (38.8%), *Chaetomium* (2 species, 15.3-26.3%), *Penicillim* spp. (9.8-27.8%), *Fusarium* (9 species, 6.9-27.8%), *Ulocladium consortiale* (27.8%), *Mucor hiemalis* (19.5%), and the remaining species (*Scytalidium thermophilum*, *Phoma solani*, *Taeniolella exilis*, and *Botryodiplodia theobromae*) exhibited very low levels of incidence (4.2-11.1%). Endophytic colonization of the leaf tissues was greater (43 species, 3 varieties) comparable to stem tissues (25 species). This indicates heterogeneity and tissue-preference, with no evidence of seasonal variation. Therefore, the isolation of many fungal species and sterile mycelia supports the biodiversity of the endophytic fungi invading *B. sacra* and the high possibility of isolating more fungal species using advanced molecular techniques

Key words: Dhofar Mountains, endophytes, fungal community, Oman, tissue-preference

INTRODUCTION

Mountain ecosystems are of great interests to the world, covering 24% of the earth surface and supporting 12% of the world population as water source and inhabited by diverse flora and fauna (Anon 2008). In Oman, Dhofar Mountains are distinguished ecosystem with different climatic conditions and diverse vegetation. They have faced rapid development which resulted in noticeable climatic changes and vegetation deterioration. These changes are affecting the flora, fauna and microorganisms including fungi and bacteria which survive on higher plants (Carlile et al. 2001).

Boswellia sacra Flueck. (Frankincense, Olibanum) (synonyms: *B. carteri*, *B. undulata*, *B. crenata*) belongs to the Burceraceae family, which includes several species growing in the Arabian Peninsula, India and East Africa (Camarda et al. 2007; Hasson et al. 2011). *B. sacra* from Dhofar Mountains are currently and ecologically relevant species showing symptoms of decline due to anthropic factors and possibly global warming (Liu et al. 2010; Raffaelli 2010). It provides several good services as timber, fodder, nectar and gum which are useful in traditional medicines, religious ritual and income regeneration (Eshete et al. 2012). Frankincense (gum, olibanum) is useful in pharmaceutical industry, flavoring, beverage, liqueurs, cosmetics, detergents, creams and as perfumery (Lemenih and Teketay 2003a,b; Eshete et al. 2012). Anticancer, anti-inflammatory, immunomodulatory, antimicrobial and anti-viral activities of several *Boswellia* species in addition to being a rich source of non-volatile triterpenoic constituents have been reported (Bűchele et al. 2003; Mothana and Lindequist 2005; Akihisa et al. 2006; Banno et al. 2006; Mothana et al. 2007; 2009; Hasson et al. 2011).

Epiphytic or endophytic fungi spend some part of their life cycle on or inside leaf tissues without negative impact (Farr et al. 1989; Elamo et al. 1999; Strobel 2002; Devarajan et al. 2002; Gamboa and Bayman 2006; Arnold 2007; Huang et al. 2008; Liu et al. 2010; Jalgaonwala et al. 2011). Numerous fungi have been isolated from different tissues of leaves and stems of terrestrial and aquatic plants as epiphytes or endophytes (Huang et al. 2008). Some of these endophytes might promote growth and ecological adaptability of the host by enhancing plant tolerance to environmental stress and resistance to phytopathogens and/or herbivores (Clay and Schardl 2002; Waller et al. 2005; Barrow et al. 2007; Liu et al. 2010; Sun et al. 2011). Therefore, the deterioration of beneficial endophytes could lead to the development of new disease problems (Mmbaga and Sauve 2009).

Numerous fungi have been isolated from unexplored sites, habitats, and substrates of extreme environmental conditions (Ilyas et al. 2009), however, there are many plant species from which endophytes have not yet been

isolated (Strobel 2002; Huang et al. 2008). The variations of endophytes/epiphytes diversity are due to generic variations among plants and the environmental conditions (Elamo et al. 1999). In Oman, little research has been carried out on coprophilous fungi (Gene et al. 1993; Elshafie 2005), aflatoxins and mycotoxigenic moulds (Elshafie and Al-Shally 1998; Elshafie et al. 1999; 2002), nematophagous fungi (Elshafie et al. 2003, 2005), endophytes (El-Nagerabi et al. 2013) and some plant diseases (Al-Bahry et al. 2005; Elshafie and Ba-Omer 2001). Nonetheless, there is no published study on the biodiversity of the fungal flora of the wild and cultivated plants of Dhofar Mountains, Oman. Endophytic fungi which are associated with wild and cultivated plant in Oman have not yet been extensively explored (El-Nagerabi et al. 2013).

Endophytes are among the poorly understood groups of fungi (Gazis and Chaverri 2010). It is quite promising to explore interesting and diverse fungal species among these plants. In the present investigation, we examined the diversity of the endophytic fungi colonizing *B. sacra*, collected from Dhofar Mountains during the growing season between May 2008 and October2011; the fungal communities in the leaf and stem tissues were evaluated for their tissue-preference and seasonal variation.

MATERIALS AND METHODS

Sampling site

This study was carried out in Dhofar Mountains, Oman which is located at the South of the Arabian Gulf, bordered by Yemen on the South, the Arabian Sea on the Southeast, Iran on the Northeast, the United Arab Emirates on the Northwest, and Saudi Arabia on the West. It is located between latitude of 21°00'N-29°00'N and longitude of 51°00' E-59°40' E (Figure 1). The climate is hot-dry in the interior, hot-humid in the coastal area and humid in the south with summer monsoon rain. The average temperature is about 26°C with annual precipitation of less than 100 mm (AlKhanjari 2005). Dhofar mountain range is located in a coastal region known as "Nejd" covered by drought deciduous broadleaf anogeissus forest typical for the cloud oasis of the Dhofar Governorate in Oman (Miller and Morris 1988; Kurschner et al. 2004; Hildebrant et al. 2006). The site is 500 m above the sea level and about 25 km away from the coast with 113-115 mm precipitation at the coast and a temperature of between 24-26°C, while they are 252 mm and 21°C near the mountain crest of 880 m elevation. The wet season, which is known as "*Khareef*" in Arabic, is in summer from mid-June through mid-September when moist air from the Indian Ocean is pushed against the coastal mountains range, leading to orographic clouds and drizzle (Hildebrandt et al. 2006). During the rest of the year, desert climate prevails, beside, "*Khareef*" rain, precipitation is rare and erratic, mainly from cyclones occurring about once in each three years (Brook and Cohen 2000).

Plant material

Duplicate samples of healthy green leaves and stems of *Boswellia sacra* were collected from Dhofar Mountains, Oman. The selected plant was identified at the Department of Biological Sciences and Chemistry, College of Arts and

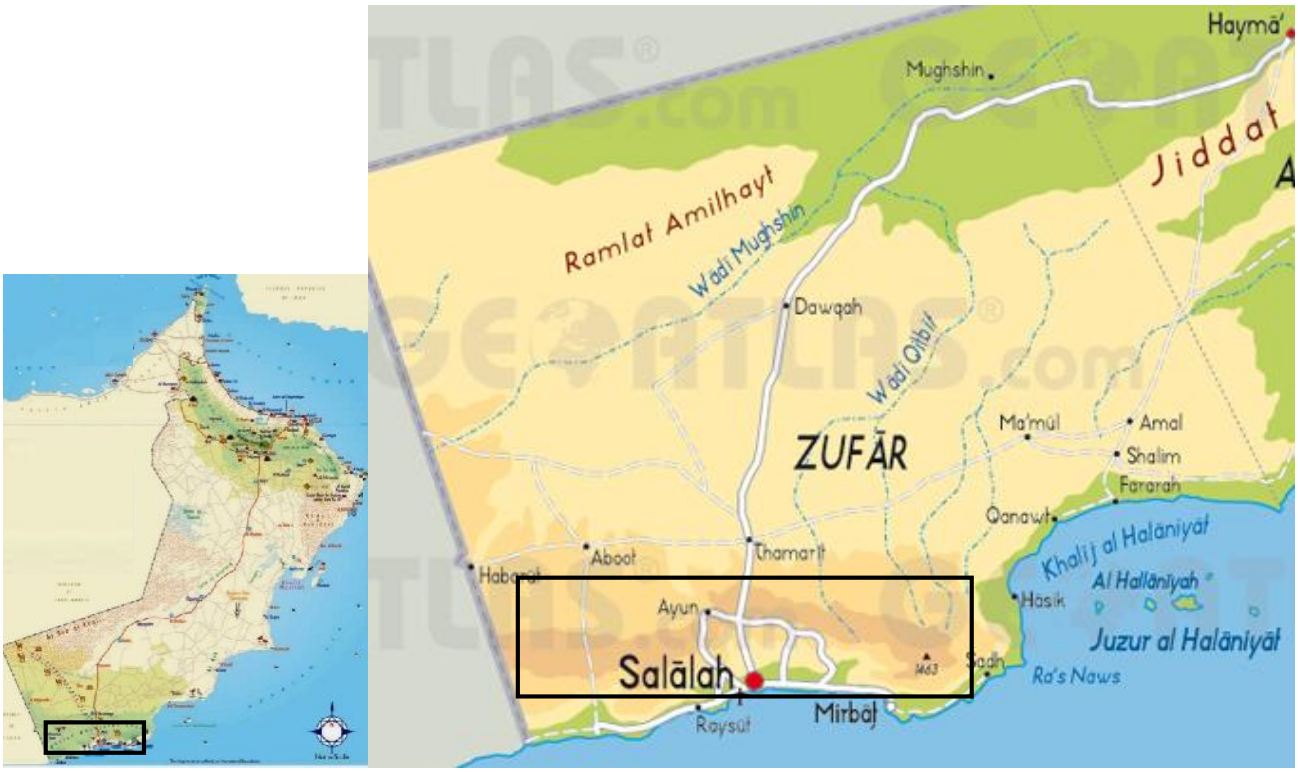

Figure 1. Sampling site in Dhofar (Zufar) Mountains, Oman.

Sciences, University of Nizwa, and Department of Biology, College of Science, Sultan Qaboos University, Oman. Samples were collected at different times and seasons between 2008 and 2011. The samples were collected in sterile polyethylene bags and stored for less than a week in refrigerator at 5°C before testing.

Isolation of endophytic fungi

The tissues of the selected plant parts were cut into small pieces of approximately 1.0 × 0.5 cm in diameter and washed with several changes of sterile distilled water. The pieces were surface disinfected with 70% ethanol for 1 min followed by 5% sodium hypochlorite for 5 min (Gazis and Chaverri 2010; Liu et al. 2010). The disinfected pieces were aseptically inoculated on Potato Dextrose Agar (PDA, Potato, 200 g; dextrose, 20 g; agar 15 g; distilled water, 1L) supplemented with 0.05 mg/ml chloramphenicol to suppress the bacterial growth, and enable the mycelia development on the plant tissues. The inoculated plates were incubated at ambient temperature (27-29°C) for 7-10 days until the mycelium was apparent on the growth media. The developing fungal colonies were then inoculated on Petri dishes containing Malt Extract Agar (MEA) for preparation of pure colonies, identification and presservation as dry herbarium materials. Duplicates of the isolated fungi were deposited at the herbarium of Department of Biological Sciences and Chemistry, College of Arts and Sciences, University of Nizwa, and Department of Biology, College of Science, Sultan Qaboos University, Oman.

Identification of the isolated fungi

The fungal isolates were identified using macroscopic features based upon colony morphology on the growth media and microscopic observations of mycelia, asexual conidia and sexual spores according to different taxonomic books, monographs and taxonomic papers (Barnett 1955; Raper and Fennell 1965; Pitt 1979; Ellis 1971, 1976; Sutton 1980; Webster 1980; Nelson et al. 1983; Barnett and Hunter 1998, 2003).

Data analysis

The number of times each fungal species was isolated (NCI = Number of Cases Isolation) was calculated according to the formula used in our previous study (El-Nagerabi et al. 2013) as the number of the samples from which the fungus was isolated, whereas the occurrence remarks (OR) as a total number of the samples from which a given species was isolated compared to the total number used for the isolation of the fungi. The number of the samples from which a given species was isolated divided by the total number of the collected samples was used to calculate the incidence percentages of the fungal species.

RESULTS AND DISCUSSION

Biodiversity of endophytic fungal consortia/composition of the plant

Forty-three species and three varieties of fungi belonging to 15 genera and sterile mycelia were recovered from green leaves and stems of *Boswellia sacra* (Table 1). Different genera were identified with variable number of species such as *Alternaria* (12 species), which followed by *Fusarium* (9 species), *Aspergillus* (5 species and 3 varieties), *Cladosporium* and *Drechslera* (3 species), *Chaetomium* (2 species) and one species from each of the remaining 9 genera (*Botryodiplodia, Curvularia, Mucor, Penicillium, Phoma, Rhizopus, Scytalidium, Taeniolella, Ulocladium)* along with numerous unidentified species of the genus *Aspergillus, Cladosporium, Fusarium* and *Penicillium*. Of these fungi, *Alternaria* is the most prevalent (12 species, 12.5-83.3%) followed by *Aspergillus* (6.9-86.1%), *Mycelia sterilia* (76.4%), *Rhizopus stolonifer* (62.5%), *Drechslera* (40.3-54.2%), *Cladosporium* (20.8-52.8%), *Curvularia lunata* (38.8%), *Chaetomium* (15.3-26.3%), *Mucor hiemalis* (19.5%), *Penicillium* (9.8-27.8%), *Fusarium* (6.9-27.8%), *Ulocladium consortiale* (27.8%), whereas the remaining species (*Scytalidium thermophilum, Phoma solani, Taeniolella exilis* and *Botryodiplodia theobromae*) displayed low levels of occurrence (4.2-11.1%) (Table 1). Since this is the first study on the mycoflora of *B. sacra*, therefore all of the isolated fungi (43 species and 3 varieties) are new endophytes to the tissues of this plant, whereas 35 species are new records to the mycoflora of Oman and 12 species are new fungal flora to Arabian Peninsula (Table 1).

The plant tissues, specially leaves and stems are excellent reservoirs for several types of microorganisms including endophytic fungi (Petrini 1991; Bokhary et al. 2000). Endophytic fungi were continuously isolated from the tissues of the most parts of terrestrial and aquatic plants (Devarajan et al. 2002; Huang et al. 2008). They are important and quantifiable component of fungal community affecting plants biodiversity and structures (Krings et al. 2007; Huang et al. 2008). Several studies of endophytic fungi from tropical and temperate forests support the high estimate of species diversity (Kumar and Hyde 2004; Santamaria and Bayman 2005; Santamaria and Diez 2005; Sänchez-Märquez et al. 2007). Almost all the terrestrial plants studies have observed mitosporic, ascomycetes fungi and sterile forms as endophytes (Bills 1996; Devarajan et al. 2002). In present study, pigmented dematiaceous hyphomycetes and ascomycetes colonized the leaf and stem tissues of *B. sacra* (Table 1). Some of these ubiquitous fungi including the species of *Alternaria alternata, A. angustiovoide, A. brassicicola, Cladosporium, Helminthosporium, Chaetomium, Drechslera, Aspergillus, Fusarium, Penicillium, Phoma, Ulocladium,* and *Camarosporium* were isolated in similar study from many other plants (Huang et al. 2008; Sun et al. 2011). The dark mycelia of some of these fungi benefit their host through absorption of more UV radiation comparable to white mycelia (Sun et al. 2011). Therefore, these fungi might enhance the growth and improve ecological adaptation of the host plants by enhancing plant tolerance to environmental stresses and resistance to phytopathogens and/or herbivores (Clay and Schardl 2002; Waller et al. 2005; Barrow et al. 2007; Liu et al. 2010; Sun et al. 2011). It was concluded that the pigmented dark fungal mycelia increase the host resistance to microbes and hydrolytic

enzymes (Carlos et al. 2008; Sun et al. 2011).

Various fungal taxa were isolated as endophytes from the leaf tissues of single species of tropical plant (Petrini 1991). Some of these fungi are either pathogenic or saprophytic which obtained their nutrition from leaf exudates, insect secretion or from organic matters deposited on the leaf surface (Last and Deighton 1965; Bokhary et al. 2000). The variation of foliar endophytes/ epiphytes is due to genetic differences among trees and the variations in the environmental conditions (Elamo et al. 1999). Although large numbers of endophytes were obtained, few species dominate the community (Petrini et al. 1992). Some species of *Alternaria, Colletotrichum* and *Fusarium* have been reported as endophytes for many plants (Liu et al. 2010). *Phoma, Cladosporium*, and *Fusarium* are frequently reported to occur as endophytes in terrestrial plants of the tropics (Brown et al. 1998). In Japan, *Alternaria* spp., *Cladosporium* spp., *Stemphyllium* spp., and *Pleospora* sp. were dominant endophytes of *Salicornia europaea* (Sun et al. 2011). *Alternaria alternata*, *Cladosporium cladosporioides* and *Penicillium chrysogenum* are the most common endophytes isolated from halophytes of the Red Sea Coast of Egypt (El-Morsy 2000). *Aspergillus niger* was the dominant endophytic fungus in mangrove and legumes (Dorothy and Kandikere 2009). Dematiaceous fungi universally inhabit different ecological zones and play important ecological role for the survival of the plants. Many species of the genus *Aspergillus* such as *A. fumigatus*, and *A. niger* in addition to species of *Penicillium* and *Fusarium* are adapted to different plant tissues (Ilyas et al. 2009). The colonization and isolation rates of the endophytic fungi isolated from 29 traditional Chinese medicinal and herbal plants ranged from36.7-100% and 0.45-1.75%, respectively (Huang et al. 2008). In the present investigations, some species of these endophytes such as *Alternaria alternata* (83.3%), *Aspergillus niger* (86.1%), *A. fumigatus* (25%), *Cladosporium cladosporioides* (20.8%), *Fusarium* spp. (6.9-27.8%), *Penicillium* spp. (9.8-27.8%), and *Phoma solani* (9.8%) were similarly recovered from the leaves and stems of *B. sacra* whereas the remaining species were reported for the first time as endophytes to this plant (Table 1).

Sterile mycelia consist of various morphological fungal types without any true spores. These fungi are considerably prevalent in endophytic investigations (Lacap et al. 2003). In similar studies of 29 medicinal plants, sterile mycelia had the highest relative frequency (27.2%) comparable to other endophytes (Huang et al. 2008). In the present study, 55 sterile mycelia were isolated from most of the tested samples and had the highest level of incidence (76.4%) and occurrence remark (Table 1). These mycelia revealed different macroscopic and microscopic features and do not form reproductive structures when incubated for long period of time to enhance sporulation as concluded in similar studies (Carlos et al. 2008; Sun et al. 2011).

Endophytic fungal community among different tissues

Many plants tissues are colonized by a characteristic population of microorganisms (Bowerman and Goos 1991). Endophytic fungi frequently demonstrate single host specificity at the plant species level, but this specificity could be influenced by seasonal changes of the climatic factors (Cohen 2004; Huang et al. 2008; Sun et al. 2011). Partial heterogeneity or geographic were used to indicate the endophytic fungal segregation impacted by environmental differences (Yahr et al. 2006). Recent study showed that endophytes are not host specific (Jalgaonwala et al. 2011) and could colonize multiple host species of the same plant family within the same habitat, and their distribution can be similar in closely related plant species (Huang et al. 2008). Single endophyte or strains of the same fungus can be isolated from different parts or tissues of the same host differ in their ability to utilize different substrates (Jalgaonwala et al. 2011). There are more species of endophytes from branches than leaves (Collado et al. 2000; Liu et al. 2010). In the study of *Suaeda corniculata*, 11 fungal species were isolated from the stem and 15 species were recovered from the leaves, whereas in *S. microphylla*, totally, 13 fungal species were isolated from the leaves and 18 species were recovered from the stems (Sun et al. 2011). These variations in endophytes colonization of branches and leaves could be caused by the difference of substrate and nutrients of the host tissues (Rodriguez 1994; Rodriguez et al. 2009; Sun et al. 2011). Endophytes which invade mature or senescent organs are less host-selective due to decreasing defense capabilities of aging plant tissues which associated with an increased nutrient supply for saprophytic taxa (Peršoh et al. 2010). Thus, the composition of fungal communities in aging leaves seems to be predominately resulted from contagious spread and depend on the spectrum of nearby sporulating fungal taxa. In the present study (Table 1), the leaves of *Boswellia sacra* were colonized by large number of endophytic species (43 species, 3 varieties) in comparison with stems (25 species). This may be attributed to differences in the structural and nutritional composition of the leaves and stems of this plant as concluded in similar studies (Rodriguez 1994; Rodriguez et al. 2009; Sun et al. 2011). The most frequent endophytic fungal taxa from 29 medicinal plants had a nearly ubiquitous presence in leaves and the stem of these plants (Huang et al. 2008). Some species of *Alternaria, Colletotrichum* and *Fusarium* have been reported as endophytes for many plants (Liu et al. 2010). *Phoma, Cladosporium*, and *Fusarium* are frequently reported to occur as endophytes in terrestrial plants of the tropics (Brown et al. 1998). The species of the genus *Alternaria, Cladosporium, Stemphyllium*, and *Pleospora* were dominant endophytes of *Salicornia europaea* in Japan (Sun et al. 2011). *Alternaria alternata, Cladosporium cladosporioides* and *Penicillium chrysogenum* are the most common endophytes isolated from halophytes of the Red Sea Coast of Egypt (El-Morsy 2000). *Aspergillus niger* was the dominant endophytic fungus in mangrove and legumes (Dorothy and Kandikere 2009). It evident that dematiaceous fungi universally inhabit plants in different ecological zones and of important ecological role for the survival of the plants. Generally many species of the genus *Aspergillus* such as *A. fumigatus*, and *A. niger* in addition to species of *Penicillium* and *Fusarium* are adapted to different plant tissues (Ilyas et al. 2009). In the present

Table 1. Number of cases isolation (NCI, out of 36 samples) and occurrence remarks (OR) incidence percentages (I%) of endophytic fungi isolated from different tissues of *B. Sacra*

Isolates	Isolate type	NCI				
		Leaves	OR	Stems	OR	I%
Alternaria alternata	β	36	H	24	H	83.3
Alternaria brassicicola	β õω	30	H	14	M	61.1
Alternaria chartarum	β õ	16	M	-	-	22.2
Alternaria cheiranthi	β õω	11	M	-	-	15.3
Alternaria chlamydospora	β õω	27	H	7	L	47.2
Alternaria citri	β õω	23	H	14	M	51.4
Alternaria dianthi	β õω	32	H	-	-	44.4
Alternaria pluriseptata	β õω	31	H	9	M	55.6
Alternaria radicina	β õω	9	M	-	-	12.5
Alternaria raphani	βõ	33	H	12	M	62.5
Alternaria tenuis	βõ	27	H	-	-	37.5
Alternaria tenuissima	βõ	14	M	16	M	41.6
Aspergillus spp.		26	H	2	R	38.9
*Aspergillus flavus*var.*flavus*	β	21	H	4	R	34.7
Aspergillus flavus var. *columnaris*	β	14	M	-	-	19.4
Aspergillus fumigatus	β	15	M	3	R	25
Aspergillus nidulans	β	9	M	2	R	15.3
Aspergillus niger	β	36	H	26	H	86.1
Aspergillus terreus	β	11	M	-	-	15.3
Aspergillus terreus var. *terreus*	β	5	R	-	-	6.9
Botryodiplodia theobromae	βõ	3	R	-	-	4.1
Chaetomium globosum	βõ	11	M	-	-	15.3
Chaetomium spirale	βõ	15	M	4	R	26.3
*Cladosporium*spp.		18	M	3	R	29.1
Cladosporium cladosporioides	βõ	15	M	-	-	20.8
Cladosporium oxysporum	βõ	23	H	15	M	52.8
Cladosporium tenuissimum	βõ	21	H	-	-	29.1
Curvularia lunata	βõ	13	M	15	M	38.9
Drechslera australiensis	βõ	28	H	11	M	54.2
Drechslera hawaiiensis	βõ	28	H	5	R	45.9
Drechslera spicifera	β	20	H	9	M	40.3
Fusarium spp.		8	L	1	R	12.5
Fusarium chlaydosporum	βõ	20	H	-	-	27.8
Fusarium dimerum	βõ	7	L	-	-	9.8
Fusarium equiseti	βõ	15	M	2	R	23.7
Fusarium oxysporum	βõ	5	R	-	-	6.9
Fusarium pallidoroseum	βõ	8	L	-4	R	16.7
Fusarium pluriferatum	β õω	5	R	-	-	6.9
Fusarium poae	βõ	16	M	2	R	25
Fusarium semitectum	βõ	6	L	-	-	8.3
Fusarium solani	βõ	7	L	4	R	15.3
Mucor hiemalis	βõ	14	M	-	-	19.5
*Penicilliums*pp.		14	M	6	L	27.8
Penicillium auratiogriseum	β õω	7	L	-	-	9.8
Phoma solani	β õω	6	L	1	R	9.8
Rhizopus stolonifer	β	34	H	11	M	62.5
Scytalidium thermophilum	β õω	6	L	2	R	11.1
Taeniolella exilis	β õω	6	L	-	-	8.3
Ulocladium consortiale	βõ	17	M	3	R	27.8
Sterile mycelia		36	H	19	H	76.4

Note: β: New record for *B. sacra*, Õ: New record to the mycoflora of Oman, ω: New record to Arabian Peninsula, OR: Occurrence remarks, out of 36 samples, H: High, more than 18 samples, M: Moderate, between 9-18 samples, L: Low, between 6-8 samples, R: Rare, less than 6 samples.

study, some of these fungi were isolated from the leaves; other species were encountered on the stems, whereas the remaining fungi were prevailed on both tissues (Table 1). This variation in endophytes on different tissues types might suggest the tissue-preference of dominant individual fungus (Wilder and Müller 1984) or reflects their compatibility to colonize specific tissues (Rodriguez 1994; Rodriguez et al. 2009).

Seasonal diversity of endophytic fungi

Little is known about the temporal changes in the endophytic fungal community. Endophytic fungi recovered from the selected plant are similar during summer (March-July) and winter (September-January). Almost the same species of fungi were recovered from the tissues of the plant, and there were no evident variations of the fungal flora with the seasons (El-Nagerabi et al. 2013). These fungal species colonize the tissues of the plant consistently during the growing season. This is may be due to the continuous growth of the mycelia within the tissues and production of new spores to invade new tissues (Sun et al. 2011). However, the abundance of endophytes varied among sampling times and did not increase over time. On the other hand, precipitation may influence the incidence of endophytes (Sahashi et al. 2000; Göre and Bucak 2007). More fungal endophytes developed in plant tissues in spring comparable to autumn and the higher rainfall in spring may enhance evidence dispersal of the fungal spores (Göre and Bucak 2007). It has been concluded that smaller and the more scattered the plant fragments sampled the higher the probability of approaching real diversity values of endophytic fungal communities (Gamboa and Bayman 2006). Endophytes which colonize healthy plant tissues are either remain dormant or produce more extensive but symptomless infection (Devarajan et al. 2002). In the present study, there is no evidence of seasonal variation in the endophytic fungi associated with the leaves and stems tissues of *Boswellia sacra* as suggested by many authors (Sun et al. 2011).

CONCLUSION

This investigation evaluated the diversity of endophytic fungi inhabiting *B. sacra* plant. From this study, 43 species and 3 varieties and sterile mycelia of fungi were isolated from the leaves and the stems of this plant. Some of these fungi are new records to this plant, to the mycoflora of Oman and the Arabian Peninsula. There is evident tissue-preference of the endophytes isolated from leaves and stems as expressed by

the incidence and occurrence remark of these fungi which is not associated with any seasonal fluctuation. This study is based mainly on macroscopic and microscopic characterization of the isolated fungi which does not allow the identification of abundantly isolated sterile mycelia. In the future studies, we should adopt many molecular methods which help in identification of non-sporulating fungal isolates.

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REFERENCES

Akihisa T, Tabata K, Banno N, Tokuda H, Nishimura R, Nakamura Y. 2006. Cancer chemopreventive effects and cytotoxic activities of the triterpene acid from the resin of *Boswellia carteri*. Biol Pharm Bull 29: 1976-1979.

AlBahry SN, Elshafie AE, Deadman M. 2005. First report of *Ganoderma colossum* on *Ficus altisima* and *Delonix regia* in Oman. Pl Pathol 54: 245.

AlKhanjari SS. 2005. Exploration and estimation of morphological and genetic diversity of wheat (*Triticum* spp.) landraces in Oman. Kassel University Press GmbH, Germany.

Anon. 2008. Mountains of the world, ecology, conservation and sustainable development. Sultan Qaboos University Press, Muscat, Sultanate of Oman.

Arnold AE. 2007. Understanding the diversity of foliar endophytic fungi: progress, challenges, and frontiers. Fungi Biol Rev 21: 51-66.

Banno N, Akihisa T, Yasukawa K, Tokuda H, Tabata K, Nakamura Y. 2006. Anti-inflammatory activities of the triterpene acids from the resin of *Boswellia carteri*. J Ethnopharmacol 107: 249-253

Barnett HL, Hunter BB. 1998. Illustrated genera of imperfect fungi. 4th ed. Prentice-hall, Inc, New York, USA.

Barnett HL, Hunter BB. 2003. Illustrated genera of imperfect fungi. 4th ed. Burgess Publishing Company Minneapolis, USA.

Barnett HL. 1955. Illustrated genera of imperfect fungi. 2nd ed. Burgess Publishing Company, Minneapolis, USA.

Barrow J, Lucero M, Reyes-Vera I, Havstad K. 2007. Endosymbiosis fungi structurally integrated with leaves reveals a lichenous condition of C4 grasses. In vitro Cell Dev Biol Pl 43 (1): 65-70.

Bills GF. 1996. Isolation and analysis of endophytic fungi communities from woody plants. In: Redlin SC, Carris L (eds). Endophytic fungi in grasses and woody plants: Systematics, ecology and evolution. APS Press, Minnesota.

Bokhary HA, Al-Sohaibany S, Al-Sadoon QH, Parvez S. 2000. Fungi associated with *Calotropis procera* and *Capparis spinosa* leaves. J King Saud Univ 12: 11-23.

Bowerman L, Goos RD. 1991. Fungi associated with living leaves of *Nymphaea odorata*. Mycologia 83: 513-516.

Brook GA, Shen SW. 2000. Rainfall in Oman and the United Arab Emirates: Cyclicity, influence of the Southern Oscillation and what the future may hold. Arab World Geogr 3: 78-96.

Brown KB, Hyde KD, Guest DI. 1998. Preliminary studies on endophytic fungal communities of *Musa acuminata* species complex in Hong Kong and Australia. Fugal Divers 1: 27-51.

Büchele B, Zugmaier W, Simmet T. 2003. Analysis of pentacyclic-triterpenic acids from frankincense gum resins and related pharmaceuticals by high performance liquid chromatography. Identification of lupeolic acid, a novel pentacyclic-triterpene. J Chromatogr B 791: 21-30.

Camarda L, Dayton T, Di Stefano V, Pitonzo R, Schillaci D. 2007. Chemical composition and antimicrobial activity of some oelegum resin essential oils from *Boswellia* spp. (Burseraceae). Ann Chem 97: 837-844.

Carlile MJ, Watkinson CS, Gooday GW. 2001. The fungi. 2nd ed. Academic Press, London.

Carlos PT, Marcelo BS, Joshua DN, Luiz RT. 2008. Melanin as a virulence factor of *Paracoccidioides brasiliensis* and other dimorphic pathogenic fungi, a mini review. Mycopathologia 165: 331-339.

Clay K, Schardl C. 2002. Evolutionary origins of ecological consequences of endophyte symbiosis with grasses. Amer Natur 160: s99-s127.

Cohen SD. 2004. Endophytic-host selectivity of *Disculaum brinella* on *Quercus alba* and *Quercus rubra* characterized by infection, pathogenicity and mycelial compatibility. Eur J Pl Pathol 110: 713-721.

Collado J, Platas G, Peleaz F. 2000. Host specificity in fungal endophytic populations of *Quercus ilex* and *Quercus faginea* from central Spain. Nova Hedwigia 71: 421-430.

Devarajan PT, Suryanarayanan TS, Geetha V. 2002.Endophytic fungi associated with the tropical seagrass *Halophila ovalis* (Hydrocharitaceae). Indian J Mar Sci 3: 73-74.

Dorothy DA, Kandikere RS. 2009. Assemblage and diversity of fungal associated with mangrove wild legume *Canavalia cathartica*. Trop Subtrop Agroecosyst 10: 225-235.

Elamo P, Helander MH, Saloniemi I, Neuvonen S. 1999. Birch family and environmental conditions affect endophytic fungi in leave. Oecologia 118: 151-156.

Ellis MB. 1971. Dematiaceous hyphomycetes. Commonwealth Mycological Institute, Kew.

Ellis MB. 1976. More Dematiaceous hyphomycetes. Commonwealth Mycological Institute, Kew.

El-Morsy EM. 2000. Fungi isolated from the endorhizosphere of halophytic plants from Red Sea Coast of Egypt. Fungal Divers 5: 43-54.

El-Nagerabi SAF, Elshafie AE, Alkhanjari SS. 2013. Endophytic fungi associated with *Ziziphus* species and new records from mountainous area of Oman. Biodiversitas 14 (1): 10-16.

Elshafie AE, Al-Bahry SN, Ba-Omar T. 2003. Nematophagous fungi isolated from soil in Oman. Sydowia 55: 18-32.

Elshafie AE, Al-Lawatia T, Al-Bahry SN. 1999. Fungi associated with black tea and tea quality in the Sultanate of Oman. Mycopathologia 14: 89-93.

Elshafie AE, Al-Mueine R, Al-Bahry SN, AlKindi AY. 2005. Nematophagous and non-nematophagous fungi belonging to the genera *Arthrobotrys* and *Dactylella* from soils in Oman. Kuwait J Sci Eng 32: 57-72.

Elshafie AE, Al-Rashdi T. A, Al-Bahry SN, Bakheit CS. 2002. Fungi and aflatoxins associated with spices in the Sultanate of Oman. Mycopathologia 155: 155-160.

Elshafie AE, A-Shally NS. 1998. Mycoflora and mycotoxigenicmoulds of pistachio nuts for human consumption in the Sultanate of Oman. Sci Technol 3: 1-6.

Elshafie AE, Ba-Omar T. 2001.First report of *Albizia lebbck* dieback caused by *Scyalidium dimidiatum* in Oman. Mycopathologia 154: 37-40.

Elshafie AE. 2005. *Coprophilous mycobiota* of Oman (summary). Mycotaxon 93: 355-357.

Eshete A, Teketay D, Lemenih M, Bongers F. 2012. Effects of resin tapping and tree size on the purity, germination and storage behavior of *Boswellia papyrifera* (Del.) Hochst. seeds from Metema District, northwestern Ethiopia. For Ecol Manag 269: 31-36.

Farr DF, Bills GF, Chamuris GP, Rossmans AY. 1989. Fungi on plants and plant products in the United States. APS Press, the American Phytopathological Society, St. Paul, Minnesota.

Gamboa M, Bayman P. 2006. Communities in endophytic fungi in leaves of a tropical timber tree (*Guarea guidonia*: Meliaceae). Biotropica 33: 352-350.

Gazis R, Chaverri P. 2010. Diversity of fungal endophytes in leaves and stems of wild rubber trees (*Hevea brasiliensis*) in Peru. Fungal Ecol 3: 240-254.

Gene J, Elshafie AE, Guarro J. 1993. Two new coprophilous Pezizales from the Sultanate of Oman. Mycotaxon 46: 275-284.

Göre ME, Bucak C. 2007.Geographical and seasonal influence on the distribution of fungal endophytes in *Laurus nobilis*. For Pathol 37: 281-288.

Hasson SS, Al-Balushi MS, Sallam TA, Idris MA, Habbal O, Al-Jabri AA. 2011. *In vitro* antibacterial activity of three medicinal plants-*Boswellia* (Luban) species. Asian Pacific J Trop Biomed1: S178-S182.

Hildebrandt A, Elfatih A, Eltahir B. 2006. Forest on the edge: Seasonal cloud forest in Oman creates its own ecological niche. Geophys Res Lett 33: 1-4.

Huang WY, Cai YZ, Hyde KD, Corke H, Sun M. 2008. Biodiversity of endophytic fungi associated with 29 traditional Chinese medicinal plants. Fungal Divers 33: 61-75.

Ilyas M, Kanti A, Jamal Y, Hertina, Agusta A. 2009. Biodiversity of endophytic fungi associated with *Uncaria gambier* Roxb. (Rubiaceae) from west Sumatra. Biodiversitas 10: 23-28.

Jalgaonwala RE, Mohite BVM, Mahajan RT. 2011. A review: natural products from plant associated endophytic fungi. J Microbiol Biotechnol 1: 21-32.

Krings M, Taylor TN, Hass H, Kerp H, Dotzler N, Hermsen FJ. 2007. Fungal endophytes in a 400-million-yr-old land plant: infection pathways, spatial distribution, and host responses. New Phytol 174: 648-657.

Kumar DSS, Hyde KD. 2004. Biodiversity and tissue-recurrence of endophytic fungi from *Tripterygium wilfordii*. Fungal Divers 17: 69-90.

Kurschner H, Hein P, Kilian N, Hubaishan MA. 2004. The Hybanthodurae-Anogeissetumdhofaricae ass. Nova-Phytosociology, structure and ecology of an endemic South Arabian forest community. Phytocoenologia 34: 569-612.

Lacap DC, Hyde KD, Liew ECY. 2003. An evaluation of the fungal morphotype concept based on rhibosomal DNA sequences. Fungal Divers 12: 53-66.

Last FT, Deighton FC. 1965. The non-parasitic mycoflora on the surface of living leaves. Trans Br Mycol Soc 48: 83-89.

Lemenih M, Teketay D. 2003a. Frankincense and myrrh resources of Ethiopia: I distribution, production, opportunities for dry land development and research needs. SINET: Ethiopian J Sci 26: 63-72.

Lemenih M, Teketay D. 2003b. Frankincense and myrrh resources of Ethiopia: 11 medicinal and industrial uses. SINET: Ethiopian J Sci 26: 161-172.

Liu C, Liu T, Yuan F, Gu Y. 2010. Isolating endophytic fungi from evergreen plants and determining their antifungal activities. Africa J Microbiol Res 4: 2243-2248.

Miller GM, Morris M. 1988. Plants of Dhofar the southern region of Oman traditional, economic and medical uses. Office of Conservation of the Environment, Muscat, Sultanate of Oman [separate English and Arabic editions].

Mmbaga MT, Sauve RJ. 2009. Epiphytic microbial communities on foliage of fungicide treated and non-treated flowering dogwoods. Biol Contr 49: 97-104.

Mothana RA, Lindequist U, Gruenert R, Bednarski PJ. 2009. Studies of the *in vitro* anticancer, antimicrobial and antioxidant potentials of selected Yemeni medicinal plants from the island Soqotra. BMC Comp Altern Med 9: 7.

Mothana RAA, Gruenert R, Lindequist U, Bednarski PJ. 2007. Study of the anticancer potential of Yemeni plants used in folk medicine. Pharmazie 62: 305-307.

Mothana RAA, Lindequist U. 2005. Antimicrobial activity of some medicinal plants of the island Soqotra. J Ethnopharmacol 96: 177-181.

Nelson PE, Toussou, TA, Marasas WFO. 1983. *Fusarium* species. An illustrated manual for identification. The Pennsylvania State University Press, University Park and London.

Peršoh D, Melcher M, Flessa F, Rambold G. 2010. First fungal community analyses of endophytic ascomycetes associated with *Viscum album* ssp. *austriacum* and its host *Pinus sylvestris*. Fungal Biol 114 (7): 585-596.

Petrin O. 1991. Fungal endophytes of tree leaves. In: Andrews JA, Hirano SS (eds) Microbial ecology of leaves. Springer, New York.

Petrini O, Sieber TN, Toti L, Viret O. 1992.Ecology, metabolites production and substrate utilization in endophyticfungi. Nat Toxins 1: 185-196.

Pitt JI. 1979.The genus*Penicillium* and its teleomorphic states *Eupenicillium* and *Talaromyces*. Academic Press, New York.

Raffaelli M. 2010. The Frankincense tree (*Boswellia sacra*, Burseraceae) from Oman: ITS and ISSR analyses of genetic diversity and implications for conservation. Genet Res Crop Evol 57: 1041-1052.

Raper KB, Fennell DI. 1965. The genus *Aspergillus.* Williams and Wilkins, Baltimore.

Rodrigues KF. 1994. The foliar endophytes of the Amazonian palm Eutrepeoleracea. Mycologia 86: 376-385.

Rodriguez RJ, White JF, Arnold AE, Redman RS. 2009. Fungalendophytes: diversity and functional roles. New Phytol 182: 314-330.

Sahashi N, Miyasawa Y, Kubono T, Ito S. 2000. Colonization of beech leaves by two endophytic fungi in northern Japan. For Pathol 30: 77-86.

Sänchez-Märquez S, Bill GF, Zabalgogeazcoa I. 2007.The endophytic mycobiota of the grass *Dactylis glomerata*.Fungal Divers 27:171-195.

Santamaria J, Bayman P. 2005. Fungal epiphytes and endophytes of coffee leaves (*Coffeaarabica*). Microbial Ecol 50: 1-8.

Santamaria O, Diez JJ. 2005. Fungi in leaves, twigs and stem bark of *Populus tremula* from northern Spain. For Pathol 35: 95-104.

Strobel GA. 2002. Rainforest endophytes and bioactive products.Crit Rev Biotechnol 22: 315-333.

Sun Y, Wang Q, Lu XD, Okane I, Kakishika M. 2011. Endophytic fungi associated with two *Sauaeda* species growing in alkaline soil in China. Mycosphere2: 239-248.

Sutton BC. 1980. The Coelomycetes. Commonwealth Mycological Institute, London.

Waller F, Achatz B, Baltruschat H, Fodor J, Becker K, Fischer M, Heier T, Hűchelhoven R, Neumann C, von Wettstein D, Franken P, Kogel KH. 2005. The endophytic fungus *Piriformospora indica* reprograms barley to salt-stress tolerance, disease resistance, and higher yield. Proc Nat Acad Sci 102: 13386-13391.

Webster J. 1980. Introduction to fungi.2nd ed. Cambridge University Press, Cambridge.

Wilder B, Müller E. 1984. Untersuchungen fiber endophytischepilze yon *Arctostaphylos uvaursi* (L) Sprengel (Ericaceae). Botanica Helvetica 94: 307-337.

Yahr R, Vilgalys R, DePriest PT. 2006. Geographic variation in algal partners *of Cladonia subtenuis* (Cladoniaceae) highlights the dynamic nature of lichen symbiosis. New Phytol 171: 847-860

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How plant diversity features change across ecological species groups? A case study of a temperate deciduous forest in northern Iran

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ABSTRACT

Bazdid Vahdati F, Saeidi Mehrvarz Sh, Naqinezhad A, Gholizadeh H. 2014. How plant diversity features change across ecological species groups? A case study of a temperate deciduous forest in northern Iran. Biodiversitas 15: 31-38. Species diversity is one of the most important indices for evaluating the stability and productivity of forest ecosystems. The aim of this research was to recognize ecological species groups and to determine the relationship between environmental variables and the distribution of ecological species groups. For this purpose, 25 400-m^2 relevés were sampled using the Braun-Blanquet method. Vegetation was classified using modified Two-Way Indicator Species Analysis (TWINSPAN) and resulted in three ecological species groups. Different species diversity indices were applied to quantify diversity of these species groups. ANOVA and Duncan's tests indicated that all species and environmental variables except altitude changed significantly across the species groups. The results also showed that the group located in the northern aspect and on low slopes had the highest diversity indices compared with groups located in dry aspects and on high slopes. In reality, abundant precipitation (northern aspect) and soil enrichment (low slopes) are principal factors that provide suitable conditions for plant growth and species diversity. Thus, the study of diversity changes in ecological species groups can result in an ecologically precise perspective for managing forest ecosystems.

Key words: Ata-Kuh, ecological species groups, Hyrcanian forests, Iran, plant diversity

INTRODUCTION

The assessment of forest biodiversity has become an important issue for studying ecosystems and their conservation (Aubert et al. 2003). Biodiversity preservation is considered to be a key management objective which is essential for the stability of forest ecosystems (Torras and Saura 2008). Forest biodiversity is considered at different levels, including genetic variation within species (genetic diversity), the variety of species in a community or area (species diversity), and the variety of habitat types within a landscape (ecosystem diversity) (Zhang et al. 2012). Complex interactions can occur within and amongst these levels. This complexity allows organisms to adapt to continually changing environmental conditions and to maintain ecosystem functions. Applying the ecological species group and indicator species in each group, through measures such as presence and absence or relative coverage of each group, will help identify species-environment relationships (Barnes et al. 1982). Moreover, the data of ecological species groups can be used to evaluate site conditions and vegetation classification.

The humid conditions on the northern slopes of the Alborz Mountains result in a Hyrcanian deciduous closed forest along the southern shores of the Caspian Sea (Zohary 1973). Because of their diverse topographic conditions, Hyrcanian forests can be considered hot spots of plant biodiversity (Eshaghi Rad and Banj Shafiei 2010). Generally, these forests are characterized by three elevational belts, lowland (50-500 m), submountain (501-1000 m), and mountain (1001-2200 m) (Zohary 1973; Naqinezhad et al. 2008; Hamzeh'ee et al. 2008; Siadati et al. 2010). The transition zone (i.e. submountain forests) in the eastern parts of the Hyrcanian forests are dominated by stands of *Quercus castaneifolia* and *Carpinus betulus* (Akhani et al. 2010). Despite changes in land use and the exploitation of natural resources, the lowland/submountain zones still contains few intact patches.

To date, some studies of plant species diversity and ecological species groups have been carried out in the Hyrcanian forests (e.g. Nazarian et al. 2004; Pourbabaei et al. 2006; Esmailzadeh and Hosseini 2007; Hamzeh'ee et al. 2008; Naqinezhad et al. 2008; Eshaghi Rad et al. 2009; Abedi and Pourbabaei 2010; Eshaghii Rad and Banj Shafiei 2010; Hashemi 2010; Kialashaki and Shabani 2010; Pourbabaei and Haghgooy 2012; Naqinezhad et al. 2012; Naqinezhad and Zarehzadeh 2013; Naqinezhad et al. 2013; Pourbabaei and Abedi 2013). However, no research has been carried out in the lowland/submountain Ata-Kuh forest to identify ecological species groups and to find their relationships with environmental variables and biodiversity indices. It is obvious that effective conservation of the remaining Hyrcanian forests requires an understanding of

the ecosystem processes controlling species composition and biodiversity (Naqinezhad et al. 2013).

The objectives of this study were: (i) delimiting the main ecological species groups based on TWINSPAN classification, (ii) evaluating species diversity indices among the ecological species groups, and (iii) finding the relationship between topographic factors (altitude, slope and aspect) and ecological species groups in order to determine the main factors affecting the separation of ecological species groups and diversity indices.

MATERIALS AND METHODS

Study site

Ata-Kuh forest with an area of 700 ha is situated 10 km southeastern of Lahijan (Guilan Province), between 37º 09′ 28.4″ and 37º 09′ 23.4″ N and between 50º 05′ 06.9″ and 50º 06′ 04.1″ E (Figure 1). The altitude ranges between 250 and 680 m. The study area is located on the northern slope of the Alborz Mountains. In this area, the major geological formations are composed of Cretaceous basaltic rocks, Triassic granite rocks, and Carboniferous metamorphic phyllitic and schistic rocks (Darvishzadeh 1991). The most important soil types in Ata-Kuh forest are brownish and loamy.

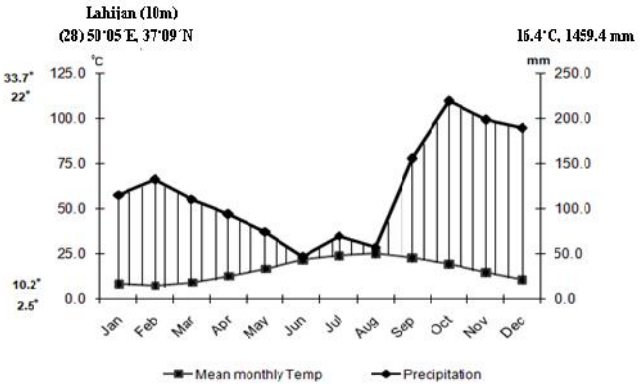

Figure 2. Climatological diagram from Lahijan station (1982-2010).

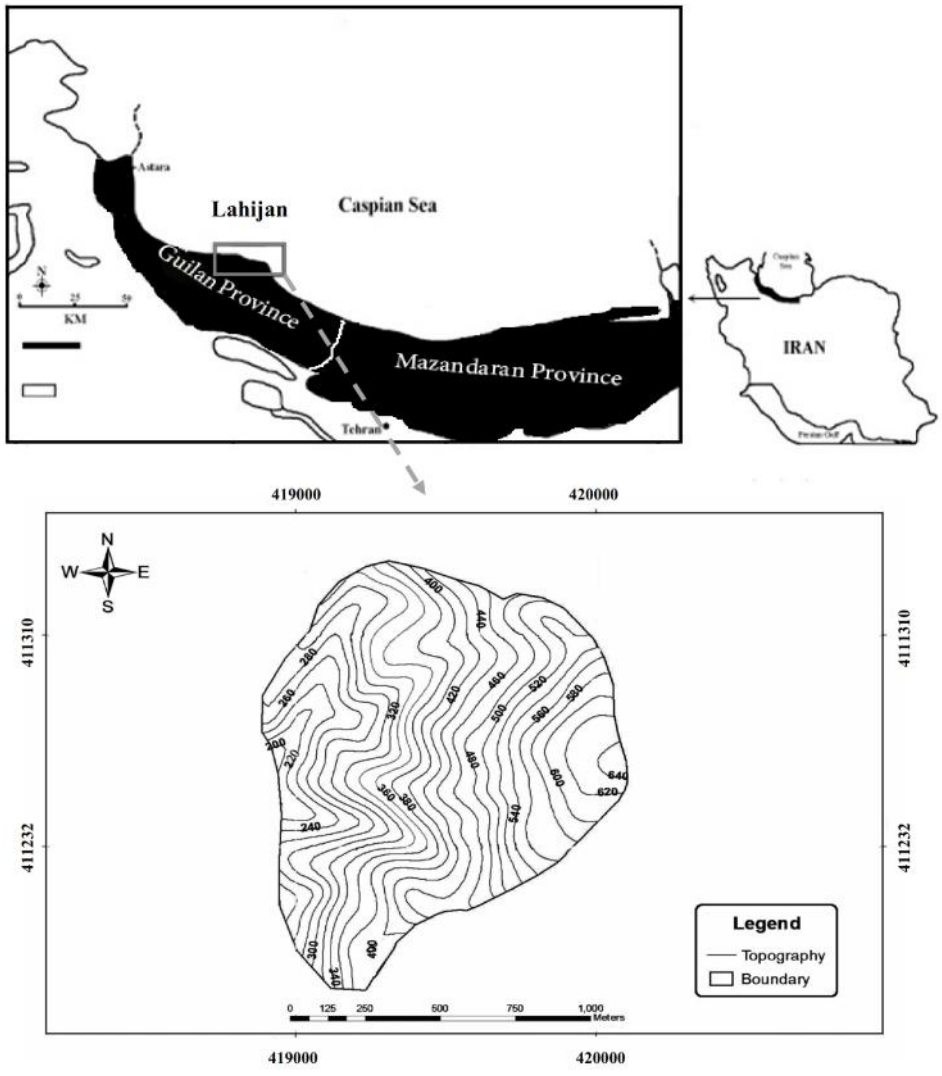

Figure 1. The topographic map of Ata-Kuh forest showing position of the area in Iran.

According to the available data from the nearest climatological station (Lahijan station), for a period of 28 years from 1982 to 2010, the average annual temperature was 16.5˚ C. Mean maximum temperature in the hottest months (July and August) and mean lowest temperature in the coldest months (January and February) were 22˚C and 10.2˚C, respectively. The average total annual precipitation and average annual temperature are 1459.4 mm and 16.47˚ C, respectively (Figure 2). The climate of the area is estimated to be temperate oceanic climate (sub-Mediterranean variant), according to the recent bioclimatic classification of Iran (Djamali et al. 2011).

Vegetation sampling

The vegetation was collected phytosociologically during growing seasons from March 2010 to March 2011 according to Braun-Blanquet approach (Braun-Blanquet 1964; Mueller-Dombois and Ellenberg 1974) and using the seven-degree scale (r, +, 1…5). Only floristically and

environmentally homogeneous areas were selected. According to the Braun-Blanquet method, a homogenous area is subjectively chosen and is necessary for relevés sampling. A total of 25 relevés with an area of 400 m^2 were sampled. Topographic variables (altitude, slope, and aspect) were measured using GPS (Garmin, model Geko), Suunto clinometers and Suunto compass in each relevé, respectively. Slope of the area was divided into three floors: low sloping (0-15 %), moderate sloping (15-30 %) and high sloping (more than 30 %) and geographical aspect quantitated by using Cos (45-Aspect) +1. It's value varies between zero to 2 (Beers et al. 1966).

Nomenclature for vascular plants was based on (Rechinger 1963-2010; Assadi et al. 1988-2011). Moreover, the ferns were identified using Khoshravesh et al. (2009).

Data analysis

The phytosociological data were analyzed using the modified TWINSPAN method (Hill 1979; Roleček et al. 2009) embedded in the JUICE 7.0 program (Tichý 2002). TWINSPAN analysis is one of the most popular classification methods used in plant community ecology (Lepš and Šmilauer 1999). In this method, relevés are compared based on presence or absence of species. Pseudospecies cut levels were set to seven and the values of cut levels to 1, 2, 3, 4, 5, 6, 7. Tow relevés were selected as a minimum group size for division. The fidelity of species to clusters and diagnostic species for vegetation units was determined using the phi-coefficient, based on presence/absence data (Chytrý et al. 2002; Tichý and Chytrý 2006). Also, threshold value of *phi* = 0.25 was selected (Illyés et al. 2007).

In order to evaluate plant species diversity, various indices may be used. In this study, we applied the Shannon Wiener (H′) and Simpson (1-D) diversity indices, Smith and Wilson evenness index, and species richness. Shannon-Wiener diversity index, which takes into account both species abundance and species richness, was used because of increased sensitivity to rare species and because it is the most commonly used index (Kent and Coker 1992). In addition, the Simpson index (1-D) was used due to more sensitivity to the most frequent plant species (Krebs 1999). These indices were calculated after transformation of the Braun-Blanquet scale values to percentage cover: r= 0.1%; 1= 2.5%; 2=15.0%; 3=37.5%; 4=62.5%; 5=87.5% (Pyšek et al. 2004).

Shannon-Wiener H':

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

Simpson 1-D:

$$1\text{-}D = 1 - \sum_{i=1}^{s} (P)_i^2$$

Where:

p_i: the relative cover of *i*th species

S: the total number of species in the sampling relevés.

The evenness index expresses how individuals are distributed among the different species. The Smith and Wilson evenness index (E_{var}) was used, because it is independent of species richness and is sensitive to both rare and common species in the community (Krebs 1999).

$$E_{var} = \frac{2}{p \arctan\left\{\sum_{i=1}^{s}\left[\log_e(ni) - \sum_{j=1}^{s}\log_e(nj)/s\right]^2 / S\right\}}$$

Where:

arctangent: measured as an angle in radians,

n_i: the percentage cover of the i_{th} species,

n_j: the percentage cover of the j_{th} species,

S: the total number of species in the sampling relevés.

Numbers of species per relevé was taken as a measure of species richness (S) (Timilsina et al. 2007). Normality of the obtained data was checked using the Kolmogorov-Smirnov test. A one-way ANOVA was used to evaluate differences among groups identified by TWINSPAN, and Duncan's test was used for comparing mean. All diversity indices and statistical analyses were calculated using Ecological Methodology ver. 6.0 (Krebs 1999) and SPSS 16.0 for windows, respectively.

RESULTS AND DISCUSSION

Results

Three distinct groups of species were identified using modified TWINSPAN analysis for the 25 relevés at the first level of analysis (Figure 3, Table 1). Ecological species group I was altitudinally ranged from 250 m to 360 m a.s.l. and located on south-facing slopes. There are 104 species in this ecological species group. The most important diagnostic species of this group was *Parrotia persica* C. A. Mey., a thermophilous Arcto-Tertiary relict species (Akhani et al. 2010). Other herbal diagnostic species were *Solanum nigrum* L., *Ophioglossum vulgatum* L. and *Viola sintenisii* W. Becker. This group has been under degradation owing to agricultural activities and livestock grazing.

Group II was altitudinally ranged from 500 m to 680 m a.s.l. and found on high slopes (more than 30 %) with a southeast aspect. Also, 147 species were recorded in this ecological species group. This ecological species group was characterized with *Fagus orientalis* Lipsky and *Rubus hirtus* Waldst. & Kit. as its dominant species. Other important species were *Crataegus pseudomelanocarpa* Popov ex Lincz., *Primula heterochroma* Stapf, *Viola odorata* L., *Bromus japonicus Thunb. ex* Murray, *Oplismenus undulatifolius* (Ard.) P. Beauv. and *Solanum kieseritzkii* C.A. Mey.

Table 1. Combined synoptic table of percentage frequency (constancy) and fidelity (phi coefficient × 100, upper indices). Only species with phi coefficient ≥0.25 (frequency and fidelity in bold) were considered as diagnostic species for specific vegetation groups.

Group number	**1**	**2**	**3**
Number of relevés	**5**	**9**	**11**
Parrotia persica		**87** $^{68.0}$	.	8
Solanum nigrum		**67** $^{75.6}$	.	.
Ophioglossum vulgatum		**61** $^{54.2}$	.	17
Viola sintenisii		**57** $^{50.4}$	30	42
Fagus orientalis		30	**87** $^{87.8}$	33
Rubus hirtus		33	**81** $^{62.1}$	42
Oplismenus undulatifolius		.	**80** $^{58.9}$	31
Primula heterochroma		.	**60** $^{55.8}$	17
Viola odorata		.	**50** $^{54.6}$	8
Crataegus pseudomelanocarpa		.	**40** $^{55.5}$	.
Carpinus betulus		.	33	**80** $^{77.7}$
Thelypteris palustris		.	.	**71** $^{75.6}$
Crataegus microphylla var. *dolichoocarpa*		.	20	**67** $^{61.9}$
Rhynchocorys maxima		.	10	**58** $^{58.1}$
Stellaria media		.	10	**54** $^{53.0}$
Calystegia sylvestris		33	.	**51** $^{53.0}$
Rumex sanguineus		.	.	**52** $^{56.8}$
Veronica crista-galli		.	.	**44** $^{56.8}$
Diospyros lotus		33	10	**42** $^{50.1}$
Smilax excelsa		33	30	**41** $^{39.6}$
Mespilus germanica		33	30	**38** $^{35.2}$
Viola caspia subsp. *caspia*		.	10	42
Asplenium scolopendrium		33	40	17
Geum urbanum		.	30	42
Bromus japonicus		33	30	42
Fragaria vesca		33	60	33
Poa annua		33	10	50
Hypericum androsaemum		100	20	42
Epimedium pinnatum		67	50	8
Ruscus hyrcanus		.	60	50
Hypericum perforatum		67	.	25
Cystopteris fragilis var. *fragilis*		.	60	50
Salvia glutinosa		.	50	75
Athyrium filix-femina		.	40	42
Pteris cretica		100	70	50
Oxalis corniculata		33	10	33
Willemetia tuberosa		.	.	33 $^{50.0}$
Geum iranicum		33	20	33
Lamium album subsp. *album*		.	.	25
Poa nemoralis		.	.	25
Scilla hohenackeri		.	20	25
Potentilla reptans		.	.	25
Thelypteris limbosperma		33	.	25
Cerastium glomeratum		.	.	25
Veronica persica		.	.	25
Gleditsia caspica		.	.	25
Rubus sanctus×*hirtus*		.	10	17
Juncus acutus		.	.	17
Carex grioletii		.	10	17
Polystichum worronowii		33	20	17
Parietaria officinalis		33	20	17
Euphorbia stricta		.	30	17
Fragaria viridis		67	20	25
Carex divulsa subsp. *divulsa*		.	10	17
Urtica dioica subsp. *dioica*		.	.	17
Pterocarya fraxinifolia		.	.	17
Pimpinella affinis		.	.	17
Luzula forsteri		.	.	17
Sambucus ebulus		.	20	17
Ranunculus arvensis		.	.	17
Dryopteris pallida		.	10	17
Polystichum lonchitis		.	20	17
Rumex pulcher subsp *pulcher*		.	10	17
Pteridium aquilinum		33	.	17
Asplenium trichomanes		.	.	17
Campanula latifolia		33	10	17
Arum maculatum		.	.	8
Albizia julibrissin		.	.	8
Thlaspi umbellatum		.	.	8
Carex digitata		33	.	8
Chelidonium majus		.	.	8
Acer campestre		.	.	8
Carex diluta		.	.	8
Campanula rapunculus subsp. *lambertiana*		.	.	8
Teucrium hyrcanicum		.	.	8
Crocus caspius		.	.	8
Polystichum braunii		33	.	8
Aira elegans		.	.	8
Geranium purpureum		.	.	8
Pyrus communis		.	.	8
Sedum stolonifer		.	.	8
Clinopodium cf. *vulgare*		.	.	8
Poa trivialis		.	.	8
Ilex spinigera		.	.	8
Polygonum lapathifolium subsp *brittingeri*		33	.	8
Phytolacca americana		33	.	8
Prunella vulgaris		.	.	8
Carex remota subsp. *remota*		33	8	.
Torilis leptophylla		.	.	8
Cyperus rotundus		.	.	8
Rubus discolor		33	.	8
Rubus caesius		33	30	8
Dryopteris filix-mas		.	20	8
Rubus sanctus×*dolichocarpus*		.	20	8
Rubus saxatilis		.	20	8
Amaranthus chlorostachys		33	10	8
Conyza candensis		.	10	8
Circaea lutetiana		.	20	8
Dioscorea communis		.	10	8
Mercurialis perennis		.	10	8
Dryopteris affinis		.	10	8
Milium pedicellare		.	10	8
Potentilla adscharica		.	.	8
Nonnea lutea.		.	.	8
Lolium persicum		.	.	8
Ornithogalum sintenisii		.	.	8
Agrimonia eupatoria		.	.	8
Lophochloa Phleoides		.	.	8
Silene apetala		.	.	8
Prunus divaricata		.	.	8
Taraxacum sp.		33	10	8
Viola caspia subsp *sylvestroides*		33	10	8
Matteuccia struthiopteris		.	.	8
Thlaspi hastulatum		33	.	.
Capsella bursa-pastoris		.	10	.
Rubus sanctus×*hyrcanus*		33	10	.
Solanum kiseritzckii		30	.	.
Rubus persicus		.	10	.
Euphorbia squamosa		.	10	.
Scutellaria tournefortii		33	10	.
Ficus carica		33	.	.
Sida rhombifolia		33	.	.
Mentha aquatica		33	.	.
Cyclamen coum var. *caucasicum*		.	10	.
Hedera pastuchovii		33	.	.
Euphorbia amygdaloides		33	.	.
Setaria glauca		33	.	.
Lepidium draba		.	10	.
Cardamine impetiense var. *pectinata*		.	10	.
Polypodium vulgare		.	10	.
Cardamine hirsuta		.	10	.

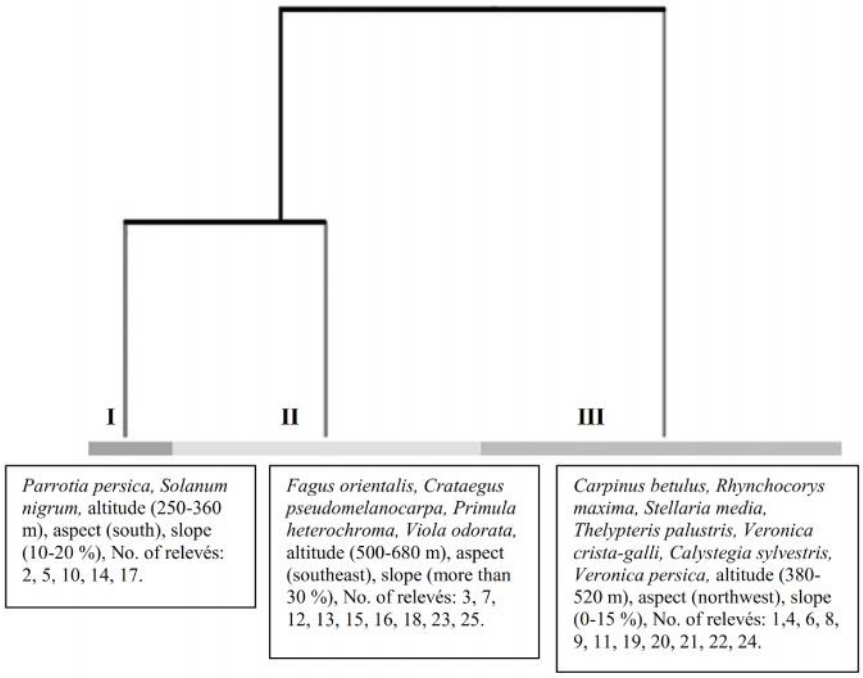

Figure 3. TWINSPAN classification dendrogram for Ata-Kuh forest indicating diagnostic species, ecological factor (altitude, aspect and slope) and number of relevés for each ecological species group in the boxes.

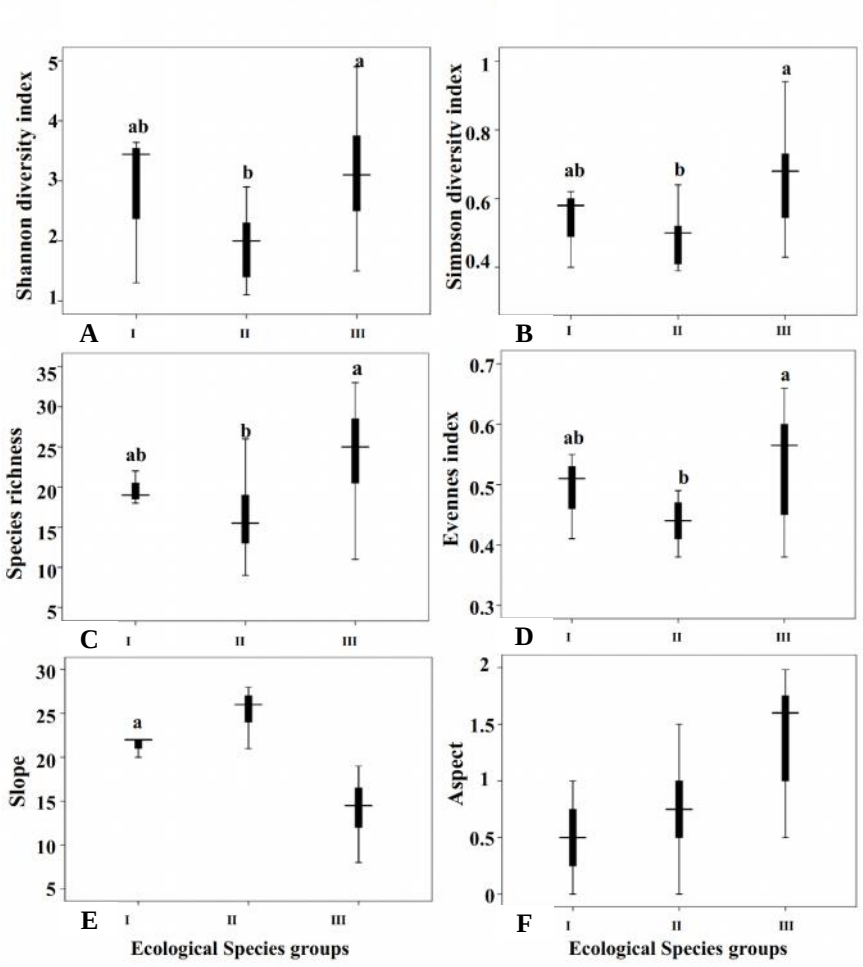

Figure 4. The relationship between ecological species group and (A) Shannon diversity index, (B) Simpson diversity index, (C) Species richness, (D) Evenness index, (E) Slope and (F) Aspect in Ata-Kuh forest.

Ecological group III was observed in the middle elevations (380-520 m a.s.l.), and the habitat was more or less flat (0-15 %) and relatively humid (northwest aspects). 260 species were recorded in this ecological species group. The most important diagnostic woody and liana species were *Carpinus betulus* L., *Diospyros lotus* L., *Crataegus microphylla* K. Koch., *Mespilus germanica* L. and *Smilax excelsa* L. In this group, dominant and diagnostic understory species were *Rhynchocorys maxima* Richter, *Stellaria media* (L.) Cirillo, *Thelypteris palustris* Schott, *Veronica crista-galli* Steven, *Calystegia sylvestris* Roem. & Schult. and *Veronica persica* Poir.

The one-way ANOVA test indicated that there were significant differences between groups in terms of diversity indices and topographic factors in the studied areas ($P < 0.05$) while there were no significant differences between groups in terms of altitude (Table 2). Duncan's test indicated that the highest value of all diversity indices was found in group III, and the lowest values of these indices were in group II.

Shannon-Wiener (H′) and Simpson (1-D) diversity indices were relatively high in the group III compared to other ecological groups (Figure 4.A-B). The lowest and highest values of the species richness index (S) were shown in groups II and III, respectively (Figure 4.C). Moreover, group II had the lowest value of Smith and Wilson's evenness index (E_{var}). In contrast, this index was considerably higher in group III (Figure 4.D).

The value for slope in group III was significantly lower than in the other groups. Groups I and II were located in dry aspects, and there were no significant differences between these two groups in terms of slope and aspect. On the other hand, group III was located in more humid aspects and showed a statistically significant difference with other groups (Figure 4.E-F).

Table 2. Summary statistics (Means ± standard error) and *P*-value from ANOVA of different biodiversity indices and topographic variables in the studied ecological species groups in Ata-Kuh forest. Abbreviation: H′ = Shannon-Wiener diversity index, 1-D = Simpson diversity index, E_{var} = Smith and Wilson evenness index, S = species richness.

Indices and variables	Group I Means (± SE)	Group II Means (± SE)	Group III Means (± SE)	*P*-value
H′	$2.79^{ab} \pm 0.74$	$1.92^{b} \pm 0.17$	$3.11^{a} \pm 0.26$	0.01*
1-D	$0.53^{ab} \pm 0.06$	$0.49^{b} \pm 0.27$	$0.66^{a} \pm 0.04$	0.01*
E_{var}	$0.49^{ab} \pm 0.04$	$0.43^{b} \pm 0.01$	$0.53^{a} \pm 0.02$	0.01*
S	$19.66^{ab} \pm 1.20$	$16.20^{b} \pm 1.54$	$23.91^{a} \pm 1.86$	0.01*
Altitude (m a.s.l.)	551.33±44.87	538.90±21.06	505.83 ± 41.00	0.71ns
Slope (%)	$21.33^{a} \pm 0.66$	$25.30^{a} \pm 0.66$	$14.91^{b} \pm 1.38$	0.00*
Aspect (º)	$0.50^{b} \pm 0.28$	$0.75^{b} \pm 0.13$	$1.43^{a} \pm 0.13$	0.00*

Note: Significant differences showed by different letters (a, b, $P < 0.05$); * significant at 0.05 level, n.s.= no significant.

Discussion

The study of ecological species groups is one method of discerning vegetation-environment relationships. Diversity measures are very effective ways to evaluate both the ecological status and conservation management. Species diversity is also regarded as one of the most central criteria in decisions regarding forest management priorities and posses vital importance for the conservation of natural communities which are increasingly threatened by industrial and urban expansion and forest clearing (Naveh and Whittaker 1980).

Topographic factors were introduced as an important factor of vegetation distribution (Mark et al. 2000). Altitudes, geographical aspect, and slope have also been mentioned as factors affecting diversity (Vujnovic et al. 2002). In the present study, aspect and slope had significant effects on the diversity and distribution of ecological groups, but no direct relationship between the distribution of ecological groups and elevation was observed. This may be due to the rather limited altitudinal distribution of studied relevés in the area. Similar results were achieved in other studies related to the Hyrcanian forest (Esmailzadeh et al. 2012; Pourbabaei et al. 2006). The studied area is part of the Hyrcanian lowland/submountain forests (Frey and Probst 1986). The occurrence of significant roles of slope inclination and aspect on distribution of ecological species groups of the forests were observed in several investigations (e.g. Pourbabaei et al. 2006; Eshaghii Rad and Banj Shafiei 2010; Kialashaki and Shabani 2010; Pourbabaei and Haghgooy 2012).

Ecological species group II, with an indicator woody species of *Fagus orientalis*, located densely in areas with steep slope (more than 30%) and dry aspects, exhibited the lowest amount of diversity indices which is consistent with the study results of Moore and Vankat (1986), Eshaghi Rad et al. (2009) and Kialashaki and Shabani (2010). Pourbabaei and Haghgooy (2012) expressed that *Fagus orientalis* stands were often found on 38.5% slope and with less moisture. Likewise, Mataji and Babaei (2006) and Atalay (2006) stated that this species is common on drier slopes (southwest-and south-facing slopes).

Barbier et al. (2008) stated that light is a major limiting factor of forest vegetation cover and species richness. In the group II, the dense cover of *Fagus orientalis* with its close canopy resulted in a high level of shade on the forest floor. As we thought, low ground-layer vegetation can be affected by high shade. These findings were consistent with the findings of other researchers (Hill 1986; Schoonmaker and Mckee 1988; Fahy and Gormally 1998).

Aspect is considered an important factor in the distribution of ground flora (Olivero and Hix 1998). The aspect influences the distribution of ecological groups, probably through its influence on temperature and moisture (Eshaghii Rad and Banj Shafiei 2010). South-facing slopes receive more solar radiation and less precipitation; thus, these factors lead to higher soil temperatures and produce unsuitable conditions for plant growth. Small and McCarthy (2005) also mentioned that the diversity and species richness of south-facing slopes is less than that of northern slopes. Moreover, slope inclination is regarded as one of the most important abiotic factors controlling the pedogenic process on a local scale (McDaniel et al. 1992; Buol et al. 1997). Slope can control the movement of water and material on a hillside and contribute to the spatial differences of soil properties (Chun-Chih et al. 2004). The negative effects of slope on species diversity in the current investigation were obvious, owing to soil erosion, water drainage, and unfavorable conditions for plant growth (Hall 1983). This was consistent with study results obtained in other parts of the Hyrcanian forest (e.g. Hashemi 2010; Esmailzadeh et al. 2012). Nevertheless, *Solanum kieseritzkii*, a shady species in forests, functioned as the dominant species in group II and, like in other studies (Mataji et al. 2010), tended to grow on high-sloped ground.

Ecological species group III, with an indicator woody species of *Carpinus betulus*, represented high species diversity and was located on low slopes with more moisture. Tanács et al. (2007) stated that oak-hornbeam forests were observed on northern slopes. Kavgaci et al. (2011) expressed that species richness is high in the *Carpinus betulus* dominated forest. They also found that this species appears densely on gently inclined slopes.

Barbier et al. (2008) believed that understory plant species have different optimal light requirements. Furthermore, in spaces between the trees and shrubs, light-demanding species and spiny shrubs such as *Crataegus microphylla* and *Mespilus germanica* have been located.

Many species of this group are light-demanding, and as they receive high amounts of light, the herb layer becomes more abundant. Naaf and Wulf (2007) stated that increases in species richness are mainly due to high light. Abrari Vajari et al. (2012) also found a positive correlation between light and species richness in the Hyrcanian forests. Eshaghi Rad et al. (2009), while studying plant species diversity in deciduous forests of Iran, determined that high levels of light at the forest floor in *Querco-Carpinetum* communities resulted in high density and frequency of ground layer species. Instead, the presence of relatively

dense tree species provides suitable habitat conditions for growing shade-demanding plants.

North aspect and low slope were topographic factors which had a positive effect on species diversity. Atalay (2006) also mentioned that biodiversity richness of the north-facing slopes is more than that of the southern slopes. This is in agreement with results obtained in other forest areas (e.g. Kooch et al. 2009; Abedi and Pourbabaei 2010; Hashemi 2010). We observed higher species diversity in lower slopes (group III) in comparison with higher slopes (groups I and II) (Abedi and Pourbabaei 2010). The high species diversity at lower slopes could also be attributed to soil conditions. As Salehi et al. (2007) stated, slope and aspect influence vegetation and soil conditions. Also, Chun-Chih et al. (2004) found that soils accumulate soluble ions from the summit and deposit them on the footslope, where leaching is weaker and soil enrichment is stronger. Macarthur (1965) reported that an increase in productivity may cause a gradual increase in species richness. Nevertheless, soil properties produce favorable conditions for plant growth at this site.

One reason for the higher diversity in group III with *Carpinus betulus* as the dominant species could be due to the higher decomposition rate of *Carpinus betulus* compared to *Fagus orientalis* and thus nutrient availability, tree growth, and long-term site productivity (Cornelissen 1996; Toutain 1987; Prescott et al. 2000).

CONCLUSION

From the current investigation it can be concluded that in comparison with groups I and II, group III had higher diversity indices because of more suitable topographic conditions (i.e. north aspect and higher humidity and slopes less than 15%) in this group. It seems that other topographic, soil and physiographic factors such as land form, parent materials and soil physico-chemical properties also affect vegetation and diversity indices in this area; hence more attention should be paid to soil and anthropogenic factors in future studies. These results also suggest that diversity evaluation can be considered as a complement to the assessment of vegetation, if the main objective of forest managers is to maintain or even increase plant biodiversity in a forest ecosystem.

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REFERENCES

Abedi A, Pourbabaei H. 2010. Plant diversity in natural forest of Guilan Rural Heritage Museum in Iran. Biodiversitas 11 (4): 182-186.

Abrari Vajari K, Jalilvand H, Pourmajidian MR, Espahbodi K, Moshki A. 2012. Effect of canopy gap size and ecological factors on species diversity and beech seedlings in managed beech stands in Hyrcanian forests. J. For Res 23 (2): 217−222.

Akhani H, Djamali M, Ghorbanalizadeh A, Ramezani E. 2010. Plant biodiversity of Hyrcanian relict forests, N, Iran: An overview of the flora, vegetation, palaeoecology and conservation. Pak J Bot 42: 231-258.

Assadi M, Maassoumi AA, Khatamsaz M, Mozaffarian V. 1988-2011. Flora of Iran. Research Institute of Forests and Rangelands Publication, Tehran, Iran.

Atalay I. 2006. The Effects of Mountainous Areas on Biodiversity: A Case Study from the Northern Anatolian Mountains and the Taurus Mountains. Grazer Schriften der Geographie und Raumforschung 41: 17-26.

Aubert M, Alard D, Bureau F. 2003. Diversity of plant assemblages in managed temperate forests: a case study in Normandy (France). For Ecol Manag 175: 321-337.

Barbier S, Gosselin F, Balandier P. 2008. Influence of tree species on understory vegetation diversity and mechanisms involved — A critical review for temperate and boreal forests. For. Ecol. Manag. 254(1): 1-15

Barnes BV, Pregitzer KS, Spies TA, Spooner VH. 1982. Ecological forest site classification. J For 80: 493-498.

Beers TW, Dress PE, Wensel LC. 1966. Aspect transformation in site productivity research. J For 80: 493-498.

Braun-Blanquet J. 1964. Pflanzensoziologie; Grundzüge der Vegetationskunde. Springer Verlag, Wien, New York.

Buol SW, Hole FD, McCracken RJ, Southard RJ. 1997. Soil genesis and classification. Iowa State University Press, Ames IA.

Chun-Chih T, Zueng-Sang C, Chang-Fu H. 2004. Relationships between soil properties and slope position in a lowland rain forest of southern Taiwan. Geoderma 12: 131-142.

Chytrý M, Tichy L, Holt J, Botta-Dukàt Z. 2002. Determination of diagnostic species with statistical fidelity measures. J Veg Sci 13: 79-90.

Cornelissen JHC. 1996. An experimental comparison of leaf decomposition rates in a wide range of temperate plant species and types. J Ecol 84: 573-582.

Darvishzadeh A. 1991. Geology of Iran. Amir Kabir Publications, Iran.

Djamali M, Akhani H, Khoshravesh R, Andrieu-Ponel V, Ponel P, Brewer S. 2011. Application of the global bioclimatic classification to Iran: implications for understanding the modern vegetation and biogeography. Ecol Medit 37 (1): 91-114.

Eshaghi Rad J, Manthey M, Mataji A. 2009. Comparison of plant species diversity with different plant communities in deciduous forests. Int J Environ Sci Tech 6 (3): 389-394.

Eshaghi Rad J, Banj Shafiei A. 2010. The distribution of ecological species groups in Fagetum communities of Caspian forests: determination of effective environ-mental factors. Flora 205: 721-727.

Esmailzadeh O, Hosseini SM. 2007. The relationships between ecological species groups with plant diversity index in Afratakhteh forest. J Environ Stud 43 (2): 21-30.

Esmailzadeh O, Hosseini SM, Asadi H, Ghadiripour P, Ahmadi A. 2012. Plant biodiversity in relation to physiographical factors in Afratakhteh Yew (*Taxus baccata* L.) habitat, NE Iran. J Plant Biol 4(12): 1-12.

Fahy O, Gormally M. 1998. A comparison of plant and carabid beetle communities in Irish oak woodland with a nearby conifer plantation and clearfelled site. For Ecol Manag 110: 263-273.

Frey W, Probst W. 1986. A synopsis of the vegetation of Iran. In: Kürschner H (eds) Contributions to the vegetation of Southwest Asia. Dr. Ludwig Reichert Verlag, Wiesbaden 1-43.

Hall GF. 1983. Pedology and geomorphology. In: Wilding LP, Smeck NE, Hall GF (eds) Pedogenesis and Soil Taxonomy; I. Concepts and Interactions, Elsevier, New York.

Hamzeh'ee B, Naqinezhad A, Attar F, Ghahreman A, Assadi M, Prieditis N. 2008. Phytosociological survey of remnant *Alnus glutinosa* ssp. *barbata* communities in the lowland Caspian forests of northern Iran. Phytocoenologia 38: 117-132.

Hashemi SA. 2010. Evaluation plant species diversity and physiographical factors in natural broad leaf forest. Amer J Environ Sci 6 (1): 20-25.
Hill MO .1979. TWINSPAN: a Fortran program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Cornell ecology programs series. Cornell University, Ithaca, New York.
Illyés E, Chytrý M, Botta-Dukàt Z, Jandt U, Škodovà I, Janišovà M, Willner W, Hàjek O. 2007. Semi-dry grasslands along a climatic gradient across Central Europe: vegetation classification with validation. J Veg Sci 18: 835-846.
Kavgaci A, Čarni A, Tecimen HB, Özalp G. 2011. Diversity of floodplain forests in the Igneada region (NW Thrace-Turkey). Hacquetia 10 (1): 73-93.
Kent M, Cocker P. 1992. Vegetation description and analysis: A practical approach. Belhaven Press, London.
Khoshravesh R, Akhani H, Eskandari M, Greuter W. 2009. Ferns and fern allies of Iran. Rostaniha 10: 1-132.
Kialashaki A, Shabani S. 2010. Investigation plant species diversity in the ecological species groups in the Aghozchal Forest (Case study, Part IV 3 series 46 Kojour Basin). J. Sci Tech Nat Res 5(1): 29-38.
Kooch Y, Jalilvand H, Bahmnyar MA, Pormajidian MR. 2009. Comparison of wood species diversity indices with respect to characteristics of natural lowland forest stands in Chalous. Iranian J Biol 22 (1): 183-192.
Krebs CJ. 1999. Ecological methodology. Harper and Row, New York.
Lepš J, Šmilauer P. 1999. Multivariate analysis of ecological data. Faculty of Biological Sciences, University of South Bohemia, České Budéjovice.
MacArthur RH. 1965. Patterns of species diversity. Biol Rev 40: 510.
Mark AF, Dickinson KJ, Hofstde RG. 2000. Alpine vegetation, plant distribution, life form, and environments a humid New Zealand region. Arctic-Antarctic Alp Res 32: 240-254.
Mataji A, Babai S. 2006. Investigation on plant associations and physiographical situation to draw plant association profile in north of Iran (Case study, Kheiroudkenar Forest-Noshahr). Iranian J For Poplar Res 14 (3): 268-358.
Mataji A, Moarefvand P, Babaie Kafaki S, Madanipour Kermanshahi M. 2010. Understory vegetation as environmental factors indicator in forest ecosystems. Int J Environ Sci Technol 7: 629-638.
McDaniel PA, Bathke GR, Boul SW, Cassel DK, Falen AL. 1992. Secondary manganese/iron ratios as pedochemical indicators of field-scale through flow water movement. Soil Sci Soc Am J 56: 1211-1217.
Moore MR, Vankat JL. 1986. Responses of the herb layer to the gap dynamics of a mature beech-maple forest. Am Midl Nat 115: 336-347.
Mueller-Dombois D, Ellenberg H. 1974. Aims and methods of vegetation ecology. John Wiley & Sons, New York.
Naaf T, Wulf M. 2007. Effects of gap size, light and herbivory on the herb layer vegetation in European beech forest gaps. For Ecol Manag 244: 141-149.
Naqinezhad A, Hamzeh'ee B, Attar F. 2008. Vegetation-environment relationships in the alderwood communities of Caspian lowlands, N. Iran (toward an ecological classification). Flora 203: 567-577.
Naqinezhad A, Bahari SH, Gholizadeh H, Esmaeili R, Hamzeh'ee B, Djamali M, Moradi H. 2012. A phytosociological survey of two lowland Caspian (Hyrcanian) remnant forests, Northern Iran, for validation of some forest syntaxa. Phytol Balcan 18 (2): 173-186.
Naqinezhad A, Zarehzadeh S. 2013. Phytosociological survey of Noor and Sisangan lowland Hyrcanian forests, Mazandaran province. J Plant Biol 5 (16): 103-121.
Naqinezhad A, Zare-Maivan H, Gholizadeh H, Hodgson JG. 2013. Understory vegetation as an indicator of soil characteristics in the Hyrcanian area, N. Iran. Flora 208: 3-12.
Naveh Z, Whittaker RH. 1980. Structural and floristic diversity of shrublands and woodlands in northern Israel and other Mediterranean areas. Plant Ecol 41 (3): 171-190.
Nazarian H, Ghahreman A, Atri M, Assadi M. 2004. An introduction to the forest associations of Elika ecoton area, N. Iran. Pak J Bot 36: 641-657.
Olivero AM, Hix DM. 1998. Influence of aspect and stand age on ground flora of southeastern Ohio forest ecosystems. Plant Ecol 139: 177-187.
Pourbabaei H, Faghir M, Poor-rostam A. 2006. Determination of plant ecological groups in the beech forest of Siyahkal, Eastern Guilan, Iran. Ecol Environ Conserv 12 (1): 9-15.
Pourbabaei H, Haghgooy T. 2012. Plant species diversity in the ecological species groups in the Kandelat Forest Park, Guilan, North of Iran. Biodiversitas 13 (1): 7-12.
Pourbabaei H, Abedi R. 2013. Plant species groups in chestnut (*Castanea sativa* Mill.) sites, Hyrcanian forests of Iran. Ecologia Balkanica 5: 37-47.
Prescott CE, Maynard DG, Laiho R. 2000. Humus in northern forests: friend or foe? For Ecol Manag 133: 23-36.
Pyšek P, Chocholoušková Z, Pyšek A, Jarošik V, Chytrý M, Tichý L. 2004. Trends in species diversity and composition of urban vegetation over three decades. J Veg Sci 15: 781-788.
Rechinger KH. 1963-2010. Flora Iranica. Academics Druck-Verlagsanstalt, Graz.
Roleček J, Tichý L, Zelený D, Chytrý M. 2009. Modified TWINSPAN classification in which the hierarchy respects cluster heterogeneity. J Veg Sci 20: 596-602.
Salehi A, Zahedi G, Burslem D, Swaine M. 2007. Relationships between tree species composition properties and topographic factors in a temperate deciduous forest in northern Iran. Asian J Plant Sci 6 (3): 455-462.
Schoonmaker P, Mckee A. 1988. Species composition and diversity during secondary succession of coniferous forests in the western Cascade Mountains of Oregon. For Sci 34: 960-979.
Siadati S, Moradi H, Attar F, EtemadV, Hamzeh'ee B, Naqinezhad A. 2010. Botanical diversity of Hyrcanian forests; a case study of a transect in the Kheyrud protected lowland mountain forests in northern Iran. Phytotaxa 7: 1-18.
Small CJ, McCarthy BC. 2005. Relationship of understory diversity to soil nitrogen, topographic variation, and stand age in an eastern oak forest, USA. For Ecol Manag 217: 229-243.
Tanács E, Samu A, Bárány-kevei I. 2007. Forest structure studies in Aggtelek National Park (Hungary). Acta Climatologica et Chorologica Universitatis Szegediensis 40-41: 123-133.
Tichý L. 2002. JUICE, software for vegetation classification. J Veg Sci 13: 451-453.
Tichý L, Chytrý M. 2006. Statistical determination of diagnostic species for site groups of unequal size. J Veg Sci 17: 809-818.
Timilsina N, Ross MS, Heinen JT. 2007). A community analysis of Sal (*Shorea robusta*) forests in the western Terai of Nepal. For Ecol Manag 241: 223-234.
Torras O, Saura S. 2008. Effects of silvicultural treatments on forest biodiversity indicators in the Mediterranean. For Ecol Manag 255: 3322-3330.
Toutain F. 1987. Activité biologique des sols, modalité et lithodépendance. Biol Fertil Soils 3: 31-38.
Vujnovic K, Wein RW, Dale MRT. 2002. Predicting plant species diversity in response to disturbance magnitude in grassland remnants of central Alberta. Can J Bot 80: 504-511.
Zhang JT, Fan L, Li M. 2012. Functional diversity in plant communities: theory and analysis methods. Afr J Biotechnol 11 (5): 1014-1022.
Zohary M. 1973. Geobotanical foundations of the Middle East. Fischer Verlag, Stuttgart, Amsterdam.

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A comparative study on plant diversity in alder (*Alnus subcordata*) stands of natural and plantation areas

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ABSTRACT

*Rezaei-Taleshi SA. 2014. A comparative study on plant diversity in alder (*Alnus subcordata*) stands of natural and plantation areas. Biodiversitas 15: 39-47.* Diversity index is the useful criteria for evaluating sustainability of forest ecosystems. Current study carried out in Alder (*Alnus subcordata* C.A. Meyer) stands that located in north forests of Iran. The aim of the study is express the plant diversity indices and positive role of the trees both natural and plantation forms. Data of Alder trees and associated species were recorded in sample plots which lay down in study area randomly. The abundance, density, percentage of frequency of each species was calculated by standard methods. The results of analysis revealed that, 47 species (21 trees and shrubs species and 26 herbaceous species) were abundant in 80 sample plots both in natural and plantations Alder stands. Whilst the results showed that the number of species in natural area (44 species) was more than plantation stands (37 species). Comparison of species distribution in different physiographical situation showed that some species such as *Alnus subcordata*, *Parrotia persica*, *Rubus hyrcanus* and *Prunus* sp. recorded in spread rang of physiographic variables as elevation, slopes and aspects. The biodiversity criteria as Shannon H' and Simpsons D and 1/D indexes showed that they were more in natural stands than plantation areas.

Key words: Alder, *Alnus subcordata*, forest, north of Iran, plant diversity

INTRODUCTION

Plant diversity indexes are useful for indicating the forest sustainability. The relationship between biodiversity and ecosystem function has been a central issue in ecological and environmental sciences during the last decade. Greater diversity leads to greater productivity in plant communities, greater nutrient retention in ecosystems and greater ecosystem stability (Tilman et al. 1996, 1997; Hector et al. 1999). Diversity is of theoretical interest because it can be related to stability, maturity, productivity, evolutionary time, predation pressure and spatial heterogeneity (Hill 1973). It is also of vital importance for conservation of natural communities which are increasingly threatened by industrial and urban expansions and forest clearing (Naveh and Whittaker 1980). Some aspects of biodiversity consisted to estimating species niches, calibrating indicator value for species, mapping distribution of individual species and modeling potential distribution of species and plant communities (Kim 1986; Kim and Kim 1988; Abrary 1994; Chytry and Rafajova 2003). This data can be used for variety of other purpose such as determining changes in vegetation, the environmental factor and vegetation distribution (Moustafa and Zaghloul 1995; Regato-Pajares and Elenna-Rossello 1995) which can use some analysis criteria such as Shannon's index (Pielou 1975; Magurran 1988). Generally, biodiversity measurement typically focuses on the species level and species diversity is one of the most important indices which are used for the evaluation of ecosystems at different scales (Ardakani 2004).

Alder is the name of a genus of flowering plants (*Alnus*) belonging to the birch family (Betulaceae). The genus comprises about 30 species of monoecious trees, distributed throughout the North Temperate Zone. Alders trees are sturdy and fast-growing, even in acidic and damaged sites. The alder is primarily a pioneer and opportunist species, and is capable of direct colonization of even the rawest of soil material. The species acts as a pioneer on hydrosphere, being capable of colonizing at very early stages in the primary succession if good seed is available (McVean 1956a,b). Species of *Alnus subcordata* C.A. Meyer is native to temperate regions in North forests of Iran. The Hyrcanian vegetation zone is a green belt stretching over the northern slopes of Alborz mountain ranges (also spelled as Alburz or Elburz) and covers the southern coasts of the Caspian Sea. The specific environmental conditions in these forests have been led to occurrence of different forest communities (Sagheb-Talebi 2004). In the temperate vegetation zone, natural and old growth forests still exist and can be regarded as highly valuable habitats in terms of biodiversity. Temperate forests are extremely variable ecosystems and maintain a high diversity (Dudley 1992). However, the objectives of current manuscript are evaluation and comparing biodiversity criteria in natural and man-made Alder stands and express the role of the trees communities in sustainable management of Iranian temperate forests.

MATERIALS AND METHODS

Study site

This research carried out in even aged pure Alder stands in Sari forest region (north forest of Iran). Geographical positions is latitude from 36° 16′ 32″ N, and longitude 53° 09′ 05″ E with altitude about 950 meter from free sea level (m.asl). In geology point of view, sediments of survey area is including to calcareous, siltstone, argillite with Lomashals and some Conglomerate stones. The survey area covered by brown forest soils. The soil texture emphasized by parent materials (eg. existence of Marl, calcareous, siltstone and argilice). The soil texture are semi heavy texture (clay loam) to heavy (clay) with 30 to 60 percent clay. Average precipitations of region also is 900mm. Mean temperature of entire area is about 14.6◦C and absolute minimum and maximum temperature ranged-6.5 to 40◦C. Mean humidity in survey areas were measured from 60 to 85%. Dominant plant community is Rusco-fagetum and important tree species in survey area are *Fagus orientalis, Carpinus betulus, Alnus subcordata, Diospyrus lotus, Parrotia persica* and *Acer insigne.*

Procedures

Randomize systematic design was used for sampling and collecting data in natural and plantation Alder stands. The pure alder stands were identified based on information of Sari Natural Resources Service (SNRS). Trough frequent visits, natural and plantation stands of Alder were marked on contour line (25_m) map (scale 1: 50000). Based on Alder stands existence, eighth altitude zone consider by 200 m interval from 0 to 1700 m.asl. According to minimum number of stands in each altitude zone, 10 stands and 10 sampling plots were selected randomly. These selected stands distributed homogenously in whole study area which 40 sample plots from natural stands and remaining 40 sample plots were representing plantation stands. Each sample plot was circular in shape, with an area of about 500 m^2 and in nested form with macro and sub plots. Macro-plots were representing the whole plot with radius of 12.61 m. While sub-plots (micro-plots) was about 50 m^2 area which located at center of macro plot. Data collection in Macro-plots were measured of geographical position (latitude and longitude) by GPS (Garmin), altitude (m.asl) by altimeter, aspect (azimuth), or direction of slop by compass, slop of aspect (in percent) by Abny level or slop-meter, age of plantations and natural stands (by information of SNRS), land forms (flat, hills, flood plain, terrace, bench including lower slop etc.), dominant tree and herbaceous species, regeneration type (natural/plantation), crown covers (percent of crown of trees on ground as shade or percent of browsing area), percent of understory (percent of ground plant cover) and Diameter at Breast Height (DBH) of alders and other trees and shrubs (by caliper or meter bund). Also regeneration and number of seedlings of trees/shrubs and number of herbaceous species at floor were collected in micro-plots.

Observations on frequency, abundance and density of associated species with Alders for both natural and plantation stands were recorded in sample plots lay down randomly in study area. The plant species including the herbaceous were recorded carefully and their identification was confirmed by flora of Mazandaran province. The abundance, density, percentage of frequency of each species was calculated as per the method of Misra (1968) by using following formulae.

$$\text{Percentage of frequency} = \frac{\text{Number of quadrates in which species occurred}}{\text{Total number of quadrates studied}} \times 100$$

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

$$\text{Abundance} = \frac{\text{Total number of individuals of species in all quadrates}}{\text{Total number of quadrates in which species occurred}}$$

Based on frequency data, species were grouped into five percentage frequency classes (Raunkiers 1937). Frequency percentage: A: 1-20%, B: 21-40%, C: 41-60%, D: 61-80% and E: 81-100%.

Shannon-weaner index and Simpson index were used for the calculation of plant community diversity (Raunkaier 1934; Stromberg 1993). Study of plant diversity was done by calculating plant diversity index (Shannon-Weaner and Simpson formulae) in 80 sample plots.

Shannon-Weaner index:

$$H^1 = -\sum_{i=1}^{m} Pi \times LnPi \ , \ Pi = (\frac{ni}{N})$$

Simpson index:

$$D = \sum \frac{ni(ni-1)}{N(N-1)}$$

Where H^1 is Shannon-Weaner H^1index, *Pi* is the proportional abundance and *Ln Pi* is natural logarithm of proportional abundance ni is the number of individuals and N is the total number of individuals, D is Simpson index (Biodiversity is expressed as 1-D and 1/D). The analysis of similarity which calculated by presents or absent of the species in sample plots was done by using clustering method by software (SPSS Ver. 11.5 and Biodiversity Ver. 2) and related similarity dendrograms were illustrated.

RESULTS AND DISCUSSION

The results in Table 1 revealed that there are 53 trees, shrubs and associated herbaceous species in natural and plantation Alder pure stands (more than 90% of composition of stand occupied by Alder). The trees and shrub species number is 23 and herbaceous species number was 30 in whole study area. The plant diversity information in Alder stands indicated that the number of plant species in plantations area (37) is less than natural stands (50).

Table 1. Number of species in natural and plantation Alder stands.

Form of plant	Natural stands	Plantation stands	Common species (both stands)	Total species
Trees and shrubs	21	14	12	23
Herbaceous species	29	23	22	30
Total species	50	37	34	53

The results of phyto-sociological analysis in sample plots showed in Table 2 revealed that the range of percentage of frequency of species viz. *Fagus orientalis, Carpinus betulus, Viola odrata and Gramineae* sp. was highest i.e. between 41 to 60% in natural stands of study area. Following species had the percentage of frequency between 21 to 40%; *Parrotia persica, Acer* sp., *Quercus castinofolia, Diospyrus lotus, Rubus hyrcanus, Sumbucus ebulus, Carex* sp., *Ruscus hyrcanus, Oplismenus undulatifolius, Pteridium aquilinum, Asprola odrata* and *Euphorbia helioscopia*. The remaining plants had percentage of frequency, which ranged less than 21%. From the same table it was revealed that the abundance value more than one was recorded for plants viz. *Rubus hyrcanus, Viola odrata, Gramineae* sp., *Sumbucus ebulus* and *Carex* sp. All of the remaining species was having abundance value less than one.

The study of density of plant species (Table 2) clearly showed that in natural stands highest density (more than two) was for plants viz. *Rubus hyrcanus, Cyglamen europaeun, Viola odrata, Gramineae* sp., *Urtica dioica, U. alba, Sumbucus ebulus, Poa bolboza, Malva sativa, Hypericum androsaemum, Rumex* sp., *Trifolium* sp., *Carex* sp., *Ruscus hyrcanus, Oplismenus undulatifolius, Pteridium aquilinum, Gundelia tournefortii, Mentha* sp., *Asprola odrata, Euphorbia helioscopia, Polysticum vulgare* and *Artimisia annua*. The remaining plants had density less than 2.

From the Table 3 it was seen that in plantation stands all the plant species (without Alder) were recorded in range of percent of frequency less than 21%. The range of frequency more than 10% in the stands was for plant species viz. *Carpinus betulus, Crataegus ambigua, Gramineae* sp., *Urtica dioica, Sumbucus ebulus, Poa bolboza, Carex* sp. and *Oplismenus undulatifolius.* The abundance value in plantation stands for *Carex* sp. was more than one, while for other plants it was less than one. The value of density also indicated that in plantation stands the species viz. *Gramineae* sp., *Sumbucus ebulus, Trifolium* sp., *Feragaria vesca, Carex* sp., *Ruscus hyrcanus* and *Oplismenus undulatifolius* had density more than four for plant species viz. *Rubus hyrcanus, Crataegus European, Viola odrata, Urtica dioica, Poa bolboza, Rumex* sp., *Feragaria sylvestris, Ilex spinigera, Pteris cretia, Pteridium aquilinum, Gundelia tournefortii, Mentha* sp. and *Polysticum vulgar* had density more than two, while remaining plants had density less than two.

Table 2. Results of phyto-sociological analysis of sample plots in natural and pure Alder stands.

Type of plant	Species name	Freq. (%)	Abund.	Dens.	PFC*
Trees and shrubs	*Acer campestre*	28.75	0.30	1.04	B
	Acer velutoniume	18.75	0.19	1.00	A
	Albizia julibrisin	1.75	0.12	1.00	A
	Alnus subcordata	100.00	7.45	7.45	E
	Boxus hyrcanus	1.25	0.01	1.00	A
	Carpinus betulus	52.50	0.60	1.14	C
	Crataegus ambigua	13.75	0.18	1.27	A
	Crataegus European	11.25	0.11	1.00	A
	Diospyrus lotus	22.50	0.23	1.00	B
	Fagus orientalis	42.50	0.64	1.50	C
	Figus carica	1.25	0.02	1.00	A
	Juglans regia	6.25	0.06	1.00	A
	Mespilus germanica	5.00	0.05	1.00	A
	Parrotia persica	36.25	0.36	1.00	B
	Prunus sp.	10.00	0.14	1.38	A
	Pterocarya fraxinifolia	10.00	0.10	1.00	A
	Quercus castinofolia	26.25	0.26	1.00	B
	Quercus macronteria	5.00	0.05	1.00	A
	Rubus hyrcanus	38.75	1.25	3.23	B
	Salix alba	1.25	0.03	2.00	A
	Zelcova azadrach	1.25	0.01	1.00	A
Herbaceous species	*Artimisia annua*	1.25	0.03	2.00	A
	Asprola odrata	28.75	0.66	2.30	B
	Carex sp.	37.50	1.06	2.83	B
	Convolvulus arvensis	3.50	0.17	3.00	A
	Cyglamen europaeun	5.00	0.16	3.25	A
	Euphorbia helioscopia	40.00	0.98	2.44	B
	Feragaria sylvestris	1.25	0.05	2.52	A
	Feragaria vesca	1.25	0.01	1.00	A
	Geamineae sp.	43.75	2.06	4.71	C
	Gundelia tournefortii	1.25	0.05	4.00	A
	Hypericum androsaemum	17.50	0.43	2.43	A
	Ilex spinigera	5.00	0.05	1.00	A
	Malva sativa	2.50	0.08	3.00	A
	Mentha sp.	11.25	0.29	2.56	A
	Oplismenus undulatifolius	30.00	0.85	2.83	B
	Plantago magor	1.55	0.15	3.00	A
	Poa bolboza	11.25	0.30	2.67	A
	Polysticum vulgare	2.50	0.09	3.50	A
	Primula sp.	12.50	0.21	1.70	A
	Pteridium aquilinum	28.75	0.57	2.00	B
	Pteris cretia	20.00	0.33	1.63	A
	Rumex sp.	1.25	0.03	2.00	A
	Ruscus hyrcanus	30.00	0.69	2.29	B
	Smilax exelsa	7.50	0.10	1.33	A
	Sumbucus ebulus	32.5	1.10	3.38	B
	Trifolium sp.	3.75	0.16	4.33	A
	Urtica alba	2.25	0.09	1.86	A
	Urtica dioica	9.45	0.34	3.12	A
	Viola odrata	12.50	0.41	3.70	A

Note: *: PFC is Percentage Frequency Classes based on Raunkiers 1937 in five classes A:1-20%, B: 21-40%, C: 41-60%, D: 61-80% and E: 81-100%.

Table 3. Results of phyto-sociological analysis of sample plots in plantation and pure Alder stands.

Type of plant	Species name	Freq. (%)	Abund.	Dens.	PFC*
Trees and shrubs	*Alnus subcordata*	100.00	20.65	20.65	E
	Fagus orientalis	2.50	0.03	1.00	A
	Carpinus betulus	10.00	0.11	1.13	A
	Parrotia persica	8.75	0.09	1.00	A
	Figus caricca	2.50	0.03	1.00	A
	Acer velutoniume	1.25	0.01	1.00	A
	Acer campestre	7.50	0.09	1.17	A
	Quercus castinofolia	2.50	0.03	1.00	A
	Pterocarya fraxinifolia	3.75	0.04	1.00	A
	Albizia julibrisin	1.25	0.01	1.00	A
	Diospyrus lotus	3.75	0.04	1.00	A
	Rubus hyrcanus	8.75	0.26	3.00	A
	Crataegus ambigua	10.00	0.10	1.00	A
	Crataegus European	1.25	0.04	3.00	A
Herbaceous species	*Asprola odrata*	1.25	0.03	2.00	A
	Carex sp.	13.75	0.83	6.00	A
	Convolvulus arvensis	7.50	0.11	1.50	A
	Euphorbia helioscopia	2.50	0.04	1.50	A
	Feragaria sylvestris	3.75	0.10	2.67	A
	Feragaria vesca	2.50	0.10	4.00	A
	Gramineae sp.	12.50	0.79	6.30	A
	Gundelia tournefortii	1.25	0.03	2.00	A
	Ilex spinigera	1.25	0.04	3.00	A
	Malva sativa	3.75	0.06	1.67	A
	Mentha sp.	6.25	0.24	3.80	A
	Oplismenus undulatifolius	11.25	0.51	4.56	A
	Plantago magor	2.50	0.03	1.00	A
	Poa bolboza	11.25	0.39	3.44	A
	Polysticum vulgar	2.50	0.06	2.50	A
	Pteridium aquilinum	5.00	0.15	3.00	A
	Pteris cretia	6.25	0.14	2.20	A
	Rumex sp.	5.00	0.13	2.50	A
	Ruscus hyrcanus	3.75	0.19	5.00	A
	Sumbucus ebulus	13.75	0.60	4.36	A
	Trifolium sp.	5.00	0.26	5.25	A
	Urtica alba	2.50	0.06	2.50	A
	Urtica dioica	13.75	0.29	2.09	A

Note: *: PFC is Percentage Frequency Classes based on Raunkiers 1937 in five classes A:1-20%, B: 21-40%, C: 41-60%, D: 61-80% and E: 81-100%.

The list of trees and shrubs in different conditions which noted in sample plots showed in Table 4. The analysis of distribution of trees and shrubs species revealed that the number of trees and shrubs such as *Alnus subcordata*, *Parrotia persica*, *Rubus hyrcanus* and *Prunus* sp. spread in wide range of physiographic variables (elevation, slopes and aspect). The species of *Albizia julibrisin* and *Salix alba* were recorded from low lands (range altitude less than 400 m.asl) and *Quercus macronteria*, *Juglans regia* and *Zelcova azadrach* was in high altitude (range 1200 to 1600 m.asl). Some species *viz Albizia julibrisin* and *Salix alba* growing only in lands with low slopes (slopes range 0 to 15%).

Results of table Figures 1 and 2 were shown that number of herbaceous and trees species in pure plantation stands with frequency more than 20% (B and C Raunkiers groups) was less than natural pure stands. However every species in plantation Alder stands were located in A Raunkiers group. Also results of Figure 3 indicated that number of herbaceous, shrubs and trees species in pure natural stands with frequency more than 30% was more than plantation areas. Whilst Abundant Results in Figure 4 clearly explained that herbaceous, shrubs and trees species abundance in natural Alder stands were less than plantation stands. Also abundance of herbaceous species was more than trees and shrubs. Abundance in trees species was maximum for *Fagus orientalis* after Alder. In herbaceous species the abundance was maximum for *Gramineae* sp. and *Sumbucus ebulus*. In Figure 5 results of density shown that density of Alder in Pure plantation stands is more than natural areas. Despite for *Fagus orientalis* it was adversely resulting.

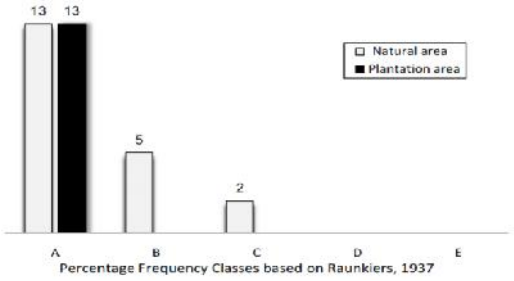

Figure 1. Trees and shrubs variation (based on number of species) in natural and plantation area.

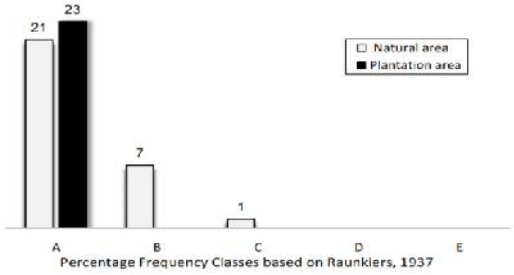

Figure 2. Herbaceous species variation (based on number of species) in natural and plantation area.

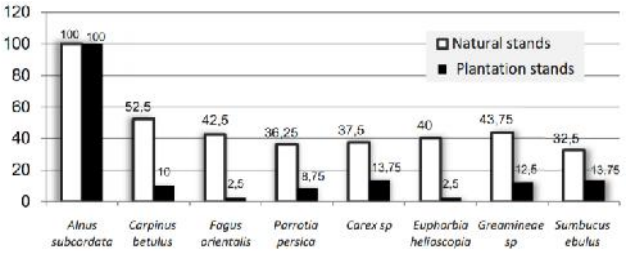

Figure 3. Comparing frequency percent of species that are more than 30 in one of two stands

The results in Table 5 showed the list of important herbaceous species in natural Alder stands. The species *viz. Oplismenus undulatifolius*, *Poa bolboza*, *Carex* sp., *Viola odrata*, *Gramineae* sp., *Urtica dioica*, *Sumbucus ebulus*

Table 4. Important trees and shrubs species in natural Alder stands in north forest of Iran and their presence in different physiographical situation.

Name of species	Elevation (MSL)				Slope (%)				Aspect			
	0- 400	400-800	800-1200	1200-1700	0-15	15-30	30-45	45-60	N	S	E	W
Acer campestre	+	+	+	+	+	+	+	+	+	+	+	-
Acer velutoniume	-	-	+	+	-	-	+	+	+	+	+	-
Albizia julibrisin	+	-	-	-	+	-	-	-	+	-	-	+
Alnus subcordata	+	+	+	+	+	+	+	+	+	+	+	+
Boxus hyrcanus	+	-	-	-	-	+	-	-	-	-	+	-
Carpinus betulus	+	+	+	+	-	+	+	-	+	+	+	+
Crataegus ambigua	-	-	+	+	+	+	+	+	+	+	+	
Crataegus European	-	+	+	+	-	+	+	+	+	+	+	+
Diospyrus lotus	+	+	+	-	+	+	+	+	+	+	+	-
Fagus orientalis	-	+	+	+	-	+	+	+	+	+	+	+
Figus carica	+	-	-	-	+	+	-	-	+	+	+	+
Juglans regia	-	-	-	+	-	-	+	-	+	-	+	-
Mespilus germanica	+	+	+	-	+	+	+	-	+	-	+	+
Parrotia persica	+	+	+	+	+	+	+	-	+	+	+	-
Prunus sp.	+	+	+	+	-	+	+	+	+	+	+	+
Pterocarya fraxinifolia	-	+	+	+	+	+	+	+	+	+	-	-
Quercus castinofolia	+	+	+	-	+	+	+	+	+	+	+	+
Quercus macronteria	-	-	+	+	-	-	+	+	+	-	-	+
Rubus hyrcanus	+	+	+	+	+	+	+	+	+	+	+	+
Salix alba	+	-	-	-	+	-	-	-	+	-	-	-
Zelcova azadrach	-	-	+	+	-	-	+	-	-	-	-	+

Note: + : indicated presence of species in physiographic condition, - : indicated absence of species.

Table 5. Important herbaceous species of natural Alder stands in north forest of Iran and their presence in different physiographical situation.

Name of species	Elevation (MSL)				Slope (%)				Aspect			
	0- 400	400-800	800-1200	1200-1700	0-15	15-30	30-45	45-60	N	S	E	W
Artimisia anua	-	-	+	-	+	-	-	-	-	+	-	-
Asprola odrata	-	+	+	+	-	+	+	+	+	+	+	+
Carex sp.	+	+	+	+	+	+	+	+	+	+	+	+
Convolvulus arvensis	+	+	+	-	+	+	-	-	+	-	+	-
Cyglamen europaeun	+	+	+	+	-	+	-	+	+	-	+	+
Euphorbia helioscopia	+	+	+	+	-	+	+	+	+	+	+	+
Feragaria sylvestris	-	+	+	-	+	+	-	-	+	+	+	+
Feragaria vesca	-	+	-	-	+	+	-	-	-	+	-	-
Gramineae sp.	+	+	+	+	+	+	+	+	+	+	+	+
Gundelia tournefortii	-	-	+	+	+	-	-	-	+	-	+	+
Hypericum androsaemum	+	+	+	+	+	+	+	+	+	+	+	+
ILex spinigera	-	-	+	-	-	-	+	-	-	+	+	+
Malva sativa	+	+	+	+	+	+	+	-	+	-	-	+
Mentha sp.		+	+	+	+	+	+	+	+	+	+	+
Oplismenus undulatifolius	+	+	+	+	+	+	+	+	+	+	+	+
Plantago magor	-	-	+	-	+	-	-	-	+	+	+	+
Poa bolboza	+	+	+	+	+	+	+	+	+	+	+	-
Polysticum vulgar	+	+	+	-	+	+	+	-	+	+	+	-
Primula sp.	+	+	+	+	-	+	+	+	+	+	+	+
Pteridium aquilinum	+	+	+	+	+	+	+	+	+	-	+	-
Pteris cretia	+	+	+	+	-	+	+	+	+	-	+	+
Rumex sp.	+	-	-	-	-	+	-	-	-	+	+	-
Ruscus hyrcanus	+	+	+	+	-	+	+	+	+	+	+	+
Smilax exelsa	+	-	-	-	-	+	+	-	+	+	+	-
Sumbucus ebulus	+	+	+	+	+	+	+	+	+	+	+	+
Trifolium sp.	+	+	+	-	+	+	-	-	+	-	+	+
urtica alba	-	+	+	+	-	-	-	+	+	-	-	+
Urtica dioica	+	+	+	+	+	+	+	+	+	+	+	+
Viola odrata	+	+	+	+	+	+	+	+	+	+	+	+

Note: + : indicated present of species in physiographic condition , - : indicated absence of species.

existed in spread range of physiographic variables as elevations, slopes and aspects. The species of *Gundelia tournefortii*, was only in high altitude range (1200 to 1600 m.asl) and *Smilax exelsa* and *Rumex* sp. were in low altitude (less than 400 m.asl). Some species viz *Artimisia annua*, *Plantago magor* and *Gundelia tournefortii* grew in lands with low slopes (0 to 15%). Species of *Artimisia annua*, *Feragaria vesca* prefer to certain aspect and was reordered only in south aspects.

The analysis of plant diversity in plantation stands showed in table 6 indicated that minimum number of species was in plot number five in location of Naghibdeh with altitude 700 m.asl and maximum species were in plot number seven in location of Karname with altitude 1080 m.asl with five and 16 species respectively.

The number of individual plant showed that the highest number of plants was in plot number seven with 110 plants. The sample plot number 54 located at Bobolkenar with altitude 200 m.asl had minimum individual plants equal to eight.

In natural stands minimum number of species was in plot number 59 at Bobolkenar with altitude 200 m.asl and maximum species were in plot number 45 located at Sadatmaheleh with altitude 1050 m.asl with 10 and 20 species respectively (Table 7).

Average number of individual plants in natural stands also showed that the highest number of plants was in plot number one with 86 plants at Suchelmah area with altitude 950 m.asl. The sample plot number 56 located at Bobolkenar with altitude 250 m.asl had minimum individual plants with 13. The results recorded in Tables 6 and 7 also revealed that list of species in sample plots and diversity indexes (Shannon H' and Simpsons D and 1/D). The highest diversity in plantation stands was found in plot number

49 located at Karnam area with altitude 1550 m.asl and plot number 51 at Babolkenar area with altitude 150 m.asl, while the lowest diversity was in plot number 15 i.e. Ahangarkola location area with altitude 210 m.asl.

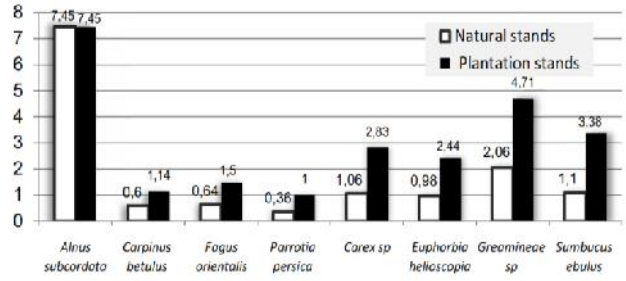

Figure 4. Comparing abundance of species that their frequency percent are more than 30 in one of two stands

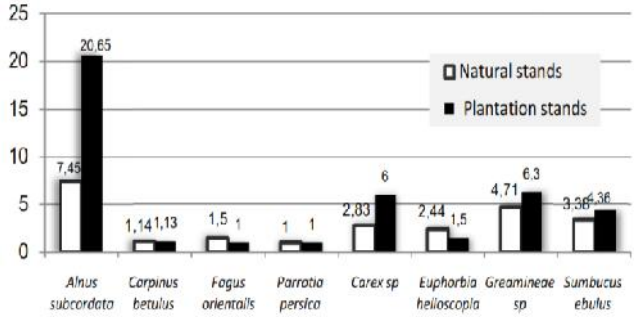

Figure 5. Comparing density of species that their frequency percent are more than 30 in one of two stands

Table 6. Biodiversity criteria of Alder natural stands in north forest of Iran

Plot no.	Number of species	Number of individuals plants	Shannon H' Log Base 10.	Simpsons diversity (D)	Simpsons diversity (1/D)
1	13	86	0.93	0.15	6.87
6	13	28	0.96	0.12	8.04
8	12	57	0.95	0.12	8.31
26	11	42	0.93	0.12	8.61
30	12	14	1.06	0.02	45.50
32	13	17	1.06	0.04	22.67
33	16	29	1.16	0.04	22.56
34	13	23	1.05	0.06	16.87
35	13	23	1.07	0.05	19.46
37	12	20	1.04	0.05	19.00
38	14	16	1.13	0.02	60.00
39	14	20	1.10	0.04	23.75
40	17	26	1.20	0.03	32.50
41	15	32	1.05	0.10	10.33
42	16	26	1.14	0.05	21.67
43	15	30	1.08	0.07	13.59
44	17	30	1.16	0.05	19.77
45	20	33	1.22	0.05	21.12
46	12	16	1.05	0.03	30.00
47	12	18	1.03	0.05	19.13
50	15	27	1.13	0.05	20.65
53	10	21	0.93	0.09	11.05
55	15	21	1.14	0.03	30.00
56	10	13	0.98	0.04	26.00
57	14	18	1.12	0.15	6.87
58	11	20	0.99	0.44	2.30
59	10	16	0.96	0.30	3.39
60	11	21	0.99	0.60	1.67
64	11	23	0.98	0.12	8.31
65	11	21	1.00	0.40	2.49
66	12	27	1.02	0.56	1.78
67	11	19	1.00	0.37	2.73
69	18	34	1.19	0.45	2.21
70	12	27	1.03	0.21	4.67
71	13	27	1.06	0.76	1.32
72	12	27	1.03	0.70	1.43
73	10	23	0.94	0.37	2.68
74	15	33	1.08	0.39	2.59
76	11	27	0.95	0.46	2.15
77	16	38	1.15	0.18	5.56
Mean	13.2	26.72	1.05	0.20	14.2

Table 7. Biodiversity criteria of Alder plantation stands in north forest of Iran

Plot no.	Number of species	Number of individuals plants	Shannon H' Log Base 10.	Simpsons diversity (D)	Simpsons diversity (1/D)
2	7	83	0.53	0.44	2.30
3	7	56	0.63	0.30	3.39
4	8	65	0.40	0.60	1.67
5	5	36	0.48	0.42	2.40
7	16	110	0.90	0.20	4.96
9	8	63	0.58	0.40	2.49
10	5	43	0.40	0.56	1.78
11	9	54	0.63	0.37	2.73
12	13	51	0.62	0.45	2.25
13	8	39	0.53	0.45	2.21
14	6	28	0.69	0.21	4.67
15	7	69	0.26	0.76	1.32
16	6	60	0.30	0.70	1.43
17	9	94	0.64	0.37	2.68
18	9	92	0.63	0.39	2.59
19	7	65	0.49	0.49	2.04
20	8	67	0.53	0.46	2.15
21	6	29	0.72	0.18	5.56
22	8	80	0.38	0.63	1.60
23	8	80	0.39	0.62	1.60
24	11	83	0.60	0.41	2.43
25	10	87	0.62	0.39	2.56
27	10	69	0.72	0.30	3.36
28	7	45	0.77	0.17	5.86
29	7	43	0.79	0.15	6.59
31	10	16	0.95	0.07	15.00
36	10	21	0.96	0.08	13.13
48	8	10	0.88	0.04	22.50
49	9	11	0.93	0.04	27.50
51	15	32	1.10	0.07	15.50
52	9	26	0.89	0.11	9.03
54	6	8	0.75	0.07	14.00
61	10	21	0.90	0.42	2.40
62	10	22	0.87	0.12	8.04
63	9	22	0.90	0.20	4.96
68	8	15	0.82	0.45	2.25
75	10	37	0.77	0.49	2.04
78	8	19	0.84	0.63	1.60
79	6	15	0.65	0.62	1.60
80	6	16	0.68	0.41	2.43
Mean	8.48	47.05	0.68	0.36	5.37

The highest diversity in natural stands was found in plot number 45 at Sadatmahaleh with altitude 1050 m.asl and lowest in plot number 73 at Naghibdeh with altitude 1300 m.asl (Table 7). Overall mean of Shannon H' and Simpsons D and 1/D indexes of survey area revealed that diversity indexes in natural stands was more than plantation stands.

The cluster analyses have done by plants, where present in sample plots and similarity compositions and abundances of stands. It was also illustrated as denderogram. The Figure 6 showed that Bray Curtis cluster analysis in natural stands. The results of cluster analysis revealed that plots number 24 to 30 with 65% similarity and plot number six and 10 to 20 with 60% similarity formed two big categories. In plantation stands plots numbers one to 4, 6 to 10, 12 to 17 and 19 to 23 with 70% similarity consisted of one big category (Figure 7).

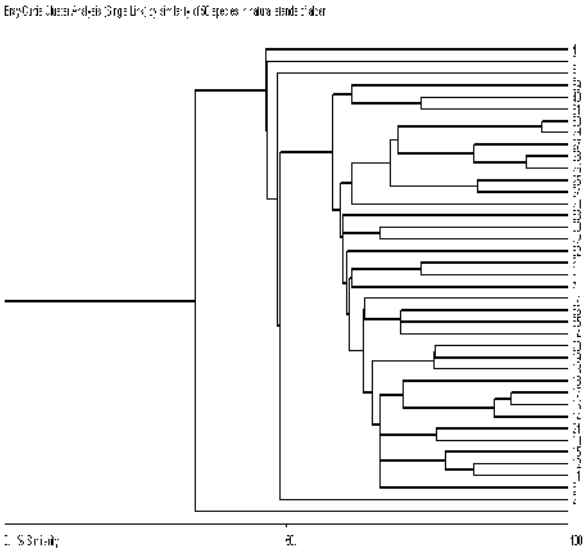

Figure 6. Bray Curtis single link cluster analysis of Alder stands in natural area

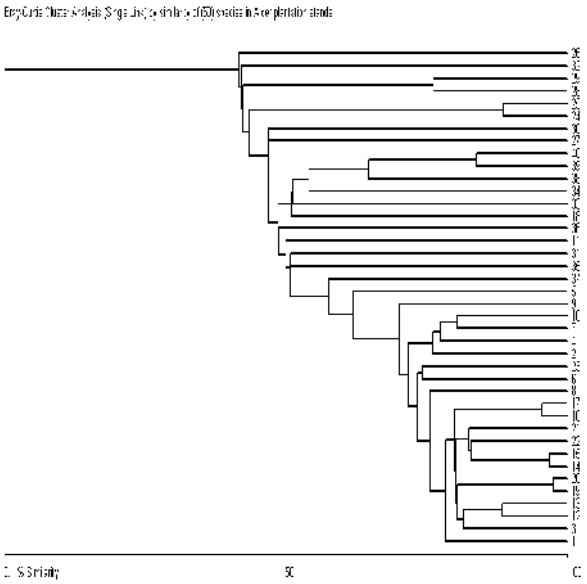

Figure 7. Bray Curtis single link cluster analysis of Alder stands in plantation area

Discussion

The results of plant diversity analysis from survey areas revealed that 53 species were abundant in 80 sample plots. Twenty one trees and shrubs species and 29 herbaceous species noted in natural stands. In plantation stands they were 14 and 23 respectively. As per results, number of species in natural area (50 species) was more than plantation stands (37 species). Also number of herbaceous species in plantation area (23) is less than natural area (29). The effects of trees on the diversity of shrubs and herbs are significant because tree canopies affect the distribution of resources such as light, water-conditions and temperature available to shrubs and herbs (Kessler 2001; Zhang 2003; Nummelin and Zilihona 2004). Moreover according to Knight et al. (2005) the different overstorey tree species create different understorey environments, which affect both components of the herbaceous flora: native species and exotic invaders.

Phyto-sociological analysis of associated plants in pure natural Alder stands of survey area (Table 2) revealed that the species viz. *Fagus orientalis, Carpinus betulus, Viola odrata and Gramineae* sp. were dominant (their range of percentage of frequency were between 41 to 60%). While in plantation stands all the plant species were recorded in range of percent of frequency less than 21%. Based on Raunkiers (1937) and frequency data, species in pure natural Alder stands were grouped into C frequency classes and species in pure plantation Alder stands were grouped whole species into A frequency classes which expressed high variation of plants in natural stands. Some of variation in the richness and abundance of understorey plants among planted forest stands can be attributed to the amount of light available to understorey plants (Cannell 1999). Particularly dense stands can cast so much shade that they appear to literally shade out the understorey vegetation (Humphrey et al. 2002).

The highest range of frequency (more than 10%) in the stands was for plant species viz. *Carpinus betulus, Crataegus ambigua, Gramineae* sp., *Urtica dioica, Sumbucus ebulus, Poa bolboza, Carex* sp. and *Oplismenus undulatifolius.* The number of species with frequency more than 20% (B and C Raunkiers groups) in pure and plantation Alder stands showed that it was less than natural pure stands. The abundant of herbaceous, shrubs and trees species in natural Alder stands was less than plantation. Also the density of Alder in pure plantation stands is more than natural areas. In addition comparisons of mean of Shannon H' and Simpsons D and 1/D indexes of survey area showed that biodiversity criteria in natural stands was more than plantation stands. According to Gibson and Jones (1977) and Barthod (1994), diverse forests can be healthier than monocultures, and thus the trophic dimension of the biodiversity ecosystem functioning relationship needs to be considered. Several reviews indicate that forest monocultures in all climatic regions may experience insect outbreaks that cause considerable damage. Decreased local species diversity is a widespread impact of human activity (Groombridge 1992; Pimm et al. 1995; Vitousek et al. 1997), and may result in decreased primary production (Naeem et al. 1994; Tilman et al. 1996,

1997 and Hector 1999). Plant species could differ in their influence over the physical protection of soil organic matter into aggregates. For example, Jastrow et al. (1998) demonstrated that fine root and mycorrhizal hyphal length (characteristics that vary among plant species) are important in promoting aggregate formation. All of above results demonstrated that tend of natural forest ecosystem to high variation which caused to more sustainability by massive community. It is widely thought that plantation forests are, on average, less favourable as habitat for a wide range of taxa, particularly in the case of even-aged, single-species stands involving exotic species (Hunter 1990; Hartley 2002). In support of this notion, the bird fauna of single-species plantation forests has been reported to be less diverse than that of natural or semi-natural forests (Helle and Mönkkönen 1990; Baguette et al. 1994; Gjerde and Sætersdal 1997; Fischer and Goldney 1998; Twedt et al. 1999).

Comparison of species distribution in different physiographical condition showed that some species such as *Alnus subcordata*, *Parrotia persica*, *Rubus hyrcanus* and *Prunus* sp. recorded in wide range of physiographic variables as elevation, slopes and aspects. Also the species like *Albizia julibrisin* and *Salix alba* recorded from low lands showed range altitude less than 400 m.asl and *Quercus macronteria*, *Juglans regia* and *Zelcova azadrach* were in high altitude range 1200 to 1600 m.asl. Many species had reaction to slopes and existence only in low slope lands, for example *Albizia julibrisin* and *Salix alba* grew in lands with slopes ranged from 0 up to 15 percent. The distribution patterns of vegetation and species diversity were often correlated with patterns of resource variation and resource gradients, which have been well established in vegetation science (Whittaker 1967; Austin 1990; Zhang 2002). Elevation gradient is one key variable that affects the variation of species diversity in communities and is frequently studied. Different plant functional groups may have different resource-use strategies, physiology, and competitive abilities (Lyon and Sagers 2002; Zhang 2002) that caused to distributed in deferent situation of survey areas.

CONCLUSION

Overall in this research obviously indicated that diversity indexes in natural pure stands are higher than plantation pure stands. For sustainable models simulation it is compulsory input some native trees and shrubs species in forest plantation which improves the diversity criteria. It can be utilized for silvicultural practices as plantation activities against degradation of forest ecosystems.

REFERENCES

Abrary K. 1994. Identification of different types of beech (*Fagus orientalis*) forests in different region of Khoske-Ab, Siyakle, Iran. [M.S Thesis]. University of Tarbiat Modarres, Tehran.

Ardakani MR. 2004. Ecology. Tehran University Press, Tehran.

Austin MP. 1990. Community theory and competition in vegetation. In Grace JB, Tilman D. (eds). Perspectives on Plant Competition. Academic Press, New York.

Baguette M, Deceuninck B, Muller Y. 1994. Effects of spruce afforestation on bird community dynamics in a native broad-leaved forest area. Acta Oecologica 15: 275-288.

Bossuyt H, Six J, Hendrix P F. 2005. Protection of soil carbon by microaggregates within earthworm casts. Soil Biol Biochem 37: 251-8.

Cannell MGR. 1999. Environmental impacts of forest monocultures: water use, acidification, wildlife conservation, and carbon storage. New Forests 17: 239-262.

Chytry M, Rafajova M. 2003. Czech national phytosociological database: basic statistic of the available vegetation-plot data. Department of Botany, Masaryk University, Kotlarska, Preslia, Praha 75: 1-15.

Dudley N. 1992. Forests in trouble. A review of the status of temperate forests worldwide. WWF, Gland, Switzerland.

Eshaghi RJ, Manthey M, Mataji A. 2009. Comparison of plant species diversity with different plant communities in deciduous forests. Int J Environ Sci Tech 6 (3): 389-394.

Fisher AM, Goldney DC 1998. Native forest fragments as critical bird habitat in a softwood forest landscape. Austr For 61: 287-295.

Gjerde I, Sætersdal M. 1997. Effects on avian diversity of introducing spruce Picea spp. plantations in the native pine Pinus sylvestris forests of Western Norway. Biol Conserv 79: 241-250.

Groombridge B. 1992. Global biodiversity: status of the Earth's living resources: a report compiled by theWorld Conservation Monitoring Centre. Chapman and Hall, London, UK.

Hartley MJ. 2002. Rationale and methods for conserving biodiversity in plantation forests. For Ecol Manag 155: 81-95.

Hector A, Schmid B, Beierkuhnlein C, Caldeira MC, Diemer M, Dimitrakopoulos PG, Finn JA, Freitas H, Giller PS, Good J, Harris R, Ho¨gberg P, Huss-Danell K, Joshi J, Jumpponen A, Ko¨rner C, Leadley PW, Loreau M, Minns A, Mulder CPH, O'Donovan G, Otway SJ, Pereira JS, Prinz A, Read DJ, Scherer-Lorenzen M, Schulze E-D, Siamantziouras A-S-D, Spehn EM, Terry AC, Troumbis AY, Woodward FI, Yachi S, Lawton JH. 1999. Plant diversity and productivity experiments in European grasslands. Science 286: 1123-1127.

Hector A. 1999. Plant diversity and productivity experiments in European grasslands. Science 286: 1123-1127.

Helle P, Mönkkönen M. 1990. Forest succession and bird communities: theoretical aspects and practical implications. In: Keast A (ed.) Biogeography and Ecology of Forest Bird Communities. SPB Academic Publishing, The Hague.

Hill MO. 1973. Diversity and evenness: A unifying notation and its consequences. Ecology 54 (2): 427-432.

Humphrey JW, Ferris R, Jukes MR, Peace AJ. 2002. The potential contribution of conifers plantations to the UK Biodiversity Action Plan. Bot J Scotland 54: 49-62.

Hunter ML. 1990. Wildlife, Forests, and Forestry: Principles of Managing Forests for Biological diversity. Prentice-Hall, Englewood Cliffs, N.J.

Jastrow JD, Miller RM, Lussenhop J. 1998. Contributions of interacting biological mechanisms to soil aggregate stabilization in restored prairie. Soil Biol Biochem 30: 905-916.

Kessler M. 2001. Patterns of diversity and range size of selected plant groups along an elevational transect in the Bolivian Andes. Biodivers Conserv 10: 1897-1921.

Kim JW. 1986. A phytosociological study of Hokkaido, Japan. Korean J Ecol 12 (2): 109-122.

Kim JW, Kim JH 1988. Phytosociological study on montane forest vegetation at Periphery of Seoul. Korean J Ecol 11 (2): 97-107.

Knight KS, Reich PB. 2005. Opposite relationships between invasibility and native species richness at patch versus landscape scales. Oikos 109 81-88.

Lyon J, Sagers CL. 2002. Correspondence analysis of functional groups in a riparian landscape. Plant Ecol 164: 171-183.

Magurran AE. 1988. Ecological diversity and measurement. Princeton University Press, Princeton.

McVean DN. 1956a. Ecology of *Alnus glutinosa* (L.) Gaertn. III. Seedling establishment. J Ecol 44: 195-218.

McVean DN. 1956b. Ecology of *Alnus glutinosa* (L.) Gaertn. V. Notes on some British alder populations. J Ecol 44: 321-330.

Misra R. 1968. Ecology Workbook. Oxford and IBH Pub. Co., New Delhi.

Moustafa AA, Zaghloul MS. 1996. Environment and vegetation in the montane Saint Catherine area, South Sinai, Egypt. J Environ 34: 331-349.

Naeem S, Thompson LJ, Lawler SP, Lawton JH, Woodfin RM. 1994. Declining biodiversity can alter the performance of ecosystems. Nature 368: 734-737.

Naveh Z, Whittaker RH. 1980. Structural and floristic diversity of shrublands and woodlands in northern Israel and other Mediterranean areas. Plant Ecol 41 (3): 171-190.

Nummelin M, Zilihona IJE. 2004. Spatial variation of arthropod communities in virgin and managed sites in the Kibale Forest, western Uganda. For Ecol Manag 195: 107-114.

Pielou EC. 1975. Ecological Diversity. John Wiley and Sons, New York.

Pimm SL, Russell G, Gittleman JL, Brooks TM. 1995. The future of biodiversity. Nature 269: 347-350.

Raunkiaer C. 1937. Plant Life Forms. Oxford University Press, London.

Regato-Pajares P, Elenna-Rosselo R. 1995. Natural black pine (*Pinus nigra* subsp. *Salzmanii*) forest of Iberian Eastern Mountains: Development of the phytoecological basis for their site evaluation. Ann Sci For 52: 589-606.

Reich PB, Oleksyn J, Modrzynski J, Mrozinski P, Hobbie SE, Eissenstat DM, Chorover J, Chadwick OA, Hale CM, Tjoelker MG. 2005. Linking litter calcium, earthworms and soil properties: a common garden test with 14 tree species. Ecol Lett 8: 811-818.

Sagheb K, Sajedi T, Yazdian F. 2003. Forest of Iran. Research Institute of Forest and Rangelands, Tehran.

Sagheb-Talebi K 2004. Forests of Iran. Research Institute of Forests and Rangelands, Tehran.

Tilman D, Wedin D, Knops J. 1996. Productivity and sustainability influenced by biodiversity in grassland ecosystems. Nature 379: 718-720.

Tilman D, Knops J, Wedin D, Reich P, Ritchie M, Siemann E. 1997. The influence of functional diversity and composition on ecosystem processes. Science 277: 1300-1302.

Twedt DJ, Wilson RR, Henne-Kerr JL, Hamilton RB. 1999. Impact of forest type and management strategy on avian densities in the Mississipi Alluvial Valley, USA. For Ecol Manag 123: 261-274.

Vitousek PM, HA. Mooney, Lubchenco J, Melillo JM. 1997. Human domination of Earth's ecosystems. Science 277: 494-499.

Whittaker RH. 1967. Gradient analysis of vegetation. Biol Rev 42: 207-264.

Zhang J-T. 2002. A study on relations of vegetation, climate and soils in Shanxi province, China. Plant Ecol 162: 23-31.

Zhang J-T. 2003. Applied Ecology. Science Press, Beijing. [Chinese].

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Zelkova carpinifolia reservoir from Hyrcanian Forests, Northern Iran, a new sacrifice of *Ophiostoma novo-ulmi*

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ABSTRACT

Ahmadi A, Kavosi MR, Soltanloo H. 2014. Zelkova carpinifolia *reservoir from Hyrcanian Forests, Northern Iran, a new sacrifice of* Ophiostoma novo-ulmi. *Biodiversitas 15: 48-52. Zelkova carpinifolia* belongs to the *Ulmaceae*. It is the only species from *Zelkova* genus that has been distributed and is native to Iranian forests. This tree species is one of the valuable species that is comprised of endangered plants. Nevertheless, the most of reservoirs of this species have been faced to problems that fungal disease is one of the important and lethal disturbance. This study was conducted to identify the main disturbance which has been resulted in *Z. carpinifolia* decadence in Daland forest reservoir, North of Iran. The study has ensured that *O. novo-ulmi* is the fungal pathogen in this forest reservoir. It can be reminded that this pathogen had been previously found in *Ulmus* genus which has been created devastating event in these noteworthy reservoirs. Some symptoms which were observed in field comprising flagging and wilting of leaves. Bark beetle galleries and occlusion of xylem vessels were the other evidence of fungal disease. In light of laboratory results, the fungi colony was fluffy, light-colored and fast-growing. The different shapes of fungi growth like white fibrous and flower shape or dark petaloid shape were observed. Mean colony diameters of *O. novo-ulmi* were 3.72 ±0.16 mm/day in the dark at 20 °C. Simultaneously, Microscopic analysis of sexual and asexual systems of *O. novo-ulmi* using a light microscope, a stereo microscope, and a scanning electron microscope revealed that it had morphological features of *Sporothix, Pesotum, yeast-like* and *Perithecium synanon* morphology.

Key words: Hyrcanian forest, *Ophiostoma novo-ulmi*, pathogen, symptom, *Zelkova carpinifolia*

INTRODUCTION

Zelkova carpinifolia (Pall.) K. Koch, 1849 species from Elm family (Ulmaceae) has been dispersed in East Anatolia, Caucasus, North and West of Iran. Ten species of *Zelkova* exist worldwide (Chen and Huang, 1999; Jin et al. 2009) but only one of them is native to Iranian forests. It has distribution in Golestan, Guilan, Mazandaran, Azerbaijan, Kurdistan, Khorasan and Tehran provinces of Iran. *Zelkova carpinifolia* with high quality wood and a beautiful canopy in northern forests are valuable. There are few reservoirs of *Z. carpinifolia*. The destruction of lowland forests and overly harvesting of *Zelkova* trees, also new disease, Dutch elm disease has caused rapid extinction of this endangered species in the *Z. carpinifolia* reservoir, in Daland Park, Golestan province, North of Iran.

Ophiostoma novo-ulmi is subspecies of *O. ulmi* that caused second pandemic of Dutch elm disease (DED) and was more aggressive (Brasier 1996; Brasier et al. 2000; Paoletti 2006). *O. novo-ulmi* is separated into two distinct subspecies, *novo-ulmi* and *americana* (Brasier and Kirk 2001; Solla et al. 2008). This fungus creates a vascular wilt disease (Sinclair and Campana 1978; Stipes and Campana 1981; Brasier 1991; Dunn 2000; Jacobi et al. 2007). The pathogens are commonly spread from tree by root grafts and bark beetles (Parker et al. 1941; Stipes et al. 1981; Webber and Gibbs 1989; Jacobi et al. 2007). This fungus belongs to Ophiostomace, Ophiostomatales, Ascomycota (Cannon and Kirk 2007). It is necessary to cited, this fungus is declining *Zelkova* reservoirs by *O. novo-ulmi* with tangible rate which has been already observed on elm trees but today it has infected *Zelkova* trees, another genus of Ulmaceae.

The first comprehensive study about disease on *Zelkova* trees has been reported by Rahnama (2004) that was due to invasive and new strain of *O. novo-ulmi*. This strain is derived from *O. ulmi* that is divided to two subspecies of *O. novo-ulmi* ssp. *novo-ulmi* and *O. novo-ulmi* ssp. *americana*. Unfortunately, this aggressive fungus is infecting other trees. Solla et al. (2005) reported this virulent fungal pathogen caused leaf wilting and subsequent mortality to all three elm species (*Ulmus* spp.) native to Europe and they had the first report in Iberian Peninsula.

The objectives of this study were isolation and identification of pathogen which has infected *Z. carpinifolia* trees in North of Iran, which faced these *Zelkova* trees to extinction event with high rate.

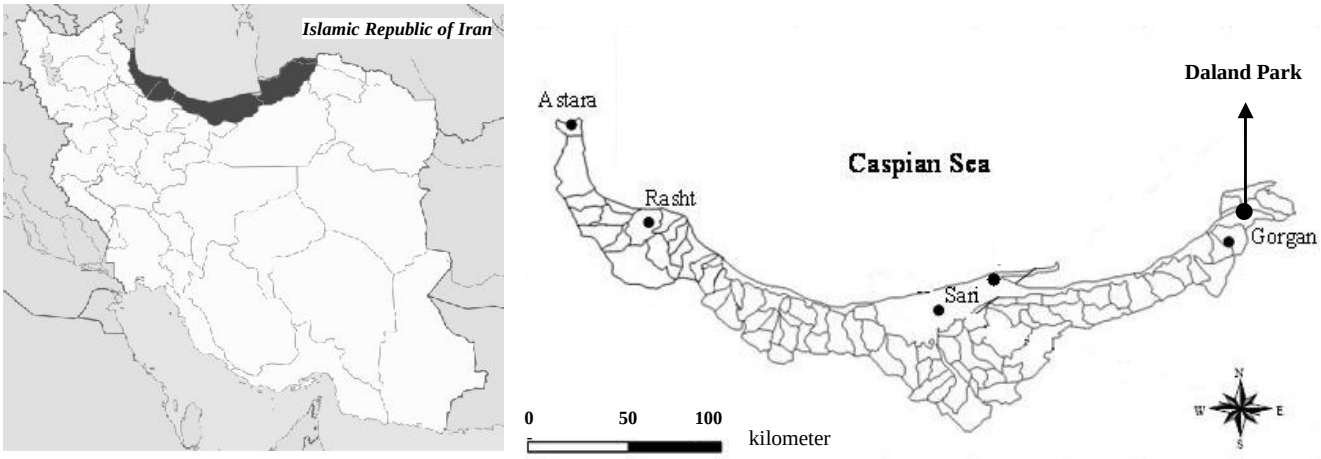


Figure 1. Location of the study site inside Daland park, the part of Hyrcanian forests, Golestan, North of Iran.

MATERIALS AND METHODS

Daland forest reservoir is one of rare reservoir of *Zelkova carpinifolia* which has been located in Golestan province, North of Iran (Figure 1). This reservoir has been encountered with rapid extinction due to fungi infection. Sampling was performed from trees that had symptoms of disease. Disks from stem segments of *Z. carpinifolia* trees were removed which showing characteristic dark spots in cross section. Each tree had symptoms of DED but had evidence of infestation by bark beetles. Stems with necrotic symptoms were transferred to laboratory. Stems were cut into 0.5 cm thickness and after surface sterilizing cultured on WA 2% and were incubated at 20°C for up to three weeks in an incubation chamber.

After growth of fungi, it cultured on potato dextrose agar and malt extract agar media. The strains were isolated. Liquid medium of potato dextrose used for preparing suspension of fungi spore. Some fungi characteristic such as the growth rate, appearance characteristic of fungi, colony and spore were studied and compared with mycology resources (Hunt 1965; De Hoog 1974; Barnett and Hunter 1998; Eriksson et al. 2003).

RESULTS AND DISCUSSION

The preliminary results indicated that limbs, leaves and sometimes entire of *Z. carpinifolia* trees shown symptoms of dieback. This is one of important symptoms which called flagging. It was really sensible in most of trees. In flagging a branch or branches of tree had clearly symptoms of wilting or yellowing of leaves while other branches were healthy (Figure 2). Removing a patch of bark was evident that there was bark beetle which had been created galleries underneath (Figure 3). Bark beetle galleries is one of important symptoms of Dutch elm disease. In cross section of stems, circles of brown dots, browning and infected sapwood was obvious that occurred death of xylem cells because of disturbance in water conducting (Figure 4.A). In Figure (4.B), occlusion of xylem vessels is observable that are due to tyloses.

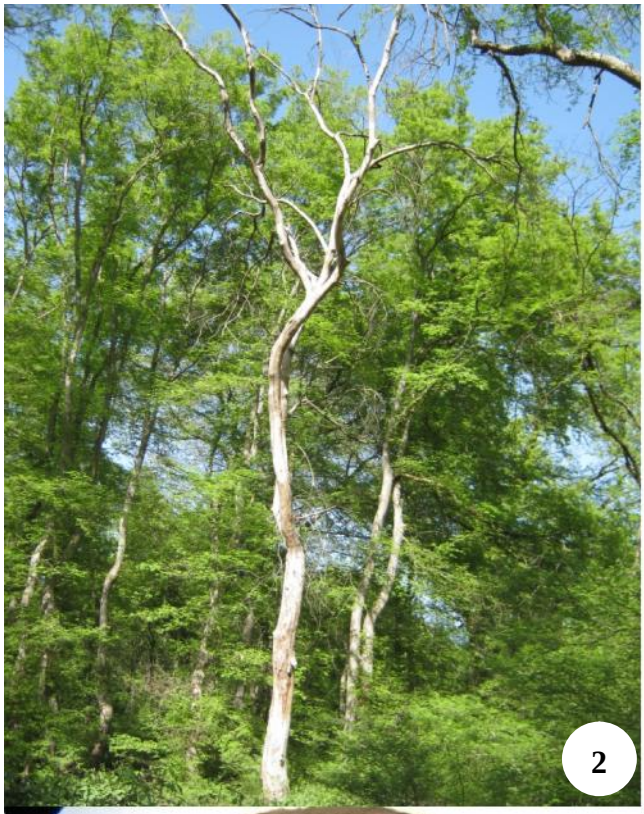
Several fungal isolates were obtained from the stem segments of *Z. carpinifolia*. They grew well in the PDA media. They showed the same morphology and growth pattern. Mycological properties of the fungi including colony shape and color growth were described.

The colony color of isolations incubated at 20°C was first white, gradually creamy to creamy grayish with flower shape in the center of Petri-dish on PDA. 7th days old culture on potato dextrose agar has been shown in figure 5. Colony color on MEA represented that these fungi had colonies with white mycelium when young, turning dark brown as they became older. Colony shape of *O. novo-ulmi* on PDA was white fibrous and in some older colonies, dark petaloid shape were formed at the center of Petri dishes. Mean colony diameters (± standard deviation) for *O. novo-ulmi*, were 3.72 (±0.16) mm/day in the dark at 20 °C.

These results implied that there were sexual and asexual reproduction systems of Sporothix, the phase of spore production, is shown in figure 6. The Conidia were small and oval shape which formed in clusters on short mycelium branches and have size of 2-3×4-6 µm (Figure 7). The conidia produce mycelium via budding and germinating to produce mycelium. These conidia represented asexual reproduction system.

The isolate formed synnemata and droplets of conidia at the apex of the synnemata which denoted in Pesotum phase. In this phase, conidia masses on synnemata were almost yellow and oval shape with size of 1-3×2-5 µm. The conidia were located on the apex of synnemata with 1-2 mm height. The scanning electron micrograph (SEM) of Conidia, synnemata and mycelium are shown in figure 8. In PDA rotating liquid media appeared yeast-like phase which individual cells germinated and the spores had different size. Yeast-like phase can be seen in figure 8.

Perithecium represents sexual system of fungi. In this step, Ascosporic were produced in a black fruiting body called Perithecium (Figure 9). Ascosporic were spherical with long neck Perithecium. Ascosporous were produced in asci which degenerate inside of black fruiting body (Perithecium). The measurements revealed that the neck length was 460 (±175) micrometers and width of basis was 100 (±35).



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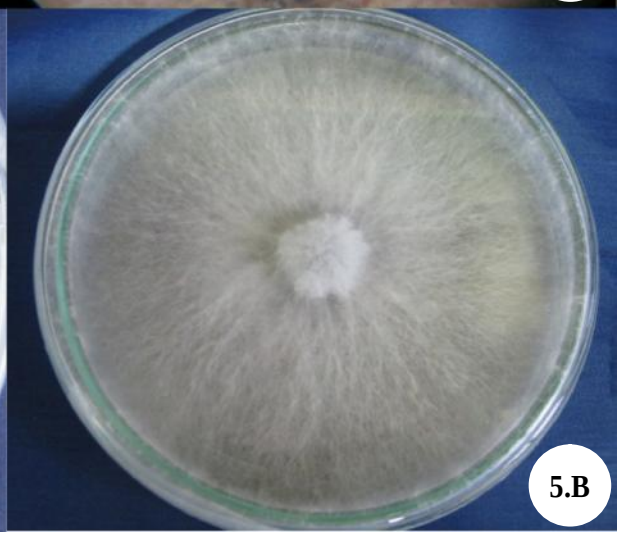
4.B

5.A



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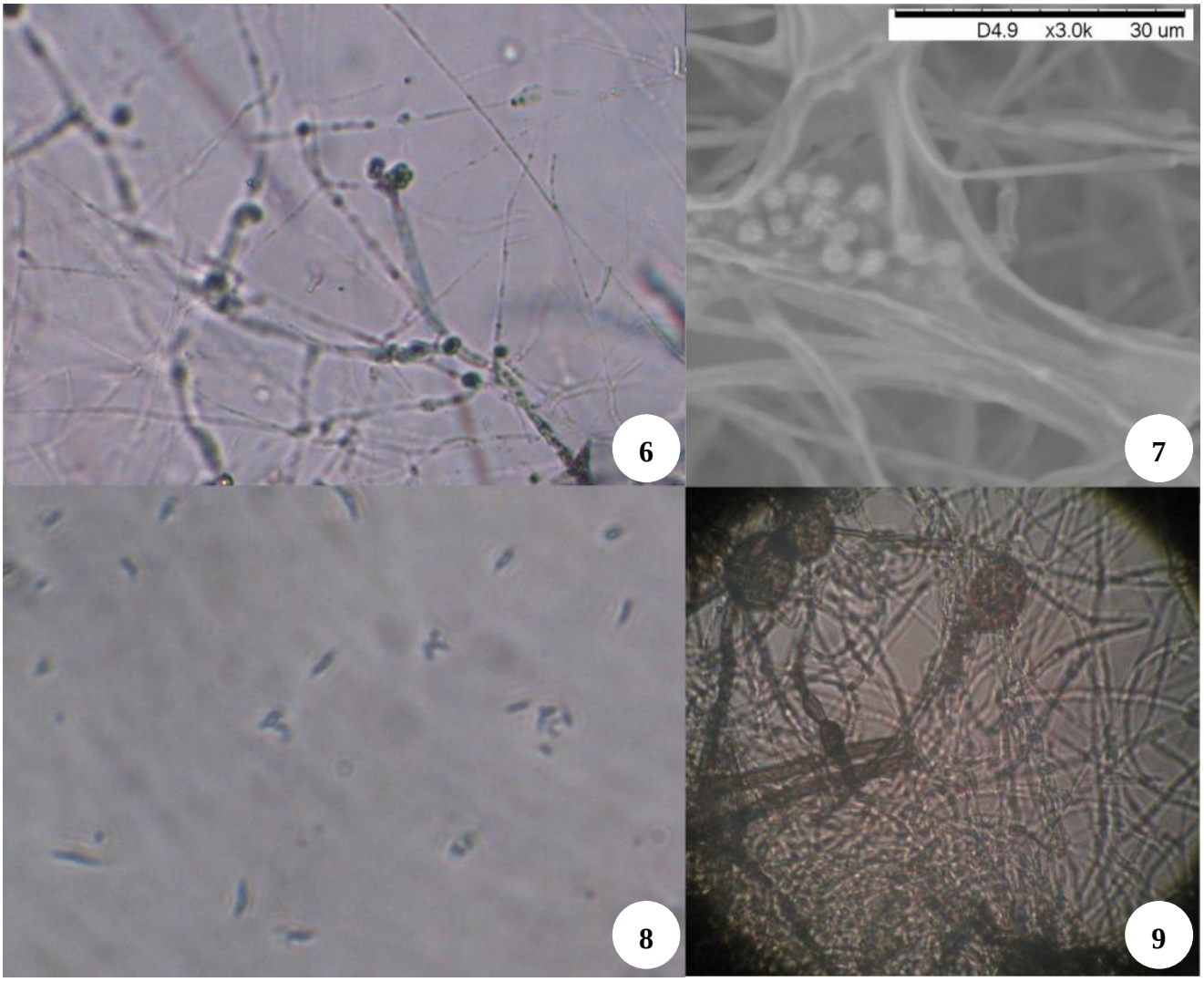

Figure 2. Symptoms of dieback in *Z. carpinifolia* trees
Figure 3. Bark beetle galleries underneath the bark of *Z. carpinifolia*
Figure 4. A and B, Cross section of an *O. novo-ulmi* infected *Z. carpinifolia* branch, showing characteristic dark spots in the wood
Figure 5. A and B, Colony morphology of *O. novo-ulmi* grown at 25°C on PDA (potato dextrose agar) medium
Figure 6. The Sporothrix phase with the small and oval shape conidia in clusters on short mycelium branches
Figure 7. The scanning electron micrograph (SEM) of conidia, synnemata and mycelium (Pesotum phase)
Figure 8. Yeast-like phase with individual cells
Figure 9. The black fruiting bodies (Perithecium) which ascospores were produced in inside them

Discussion

One of terrible declining in *Zelkova carpinifilia* trees is happening. The disease has been a devasting event in the reservoir of *Z. carpinifolia*. Most of researches are working on *ulm* trees and their disease. Despite of informing to all related organization such as natural rescorces and environment organization, they were not serious to solve this problem. This project was a preliminary attempt in determining the cause of *Z. carpinifolia* trees decline. Our forest crouse proved that has been happened and continues epidemic dieback with high rate in most of *Z. carpinifolia* trees in Daland resorvior.

The first symptom which we observed, was flagging and wilting or yellowing of leaves. Browning at the stem segments was another withness of ophiostoma genus, as well. Bark beetle was another field symptom that we suspected the ophiostoma fungi is infecting this reservior of *Z. carpinifolia* which is rare species in Iran and is extincting with high rate. More studies were performed in labratoary for distinguishing the species of *Ophiostoma* genus. Morphological characters comprising growth rate, appearance characteristic of fungi, colony and spore. this fungi were studied and were compared with mycology resources that revealed the fungi pathogen was morphologically similar to *O. novo-ulmi* (Hunt 1965; De Hoog 1974; Barnett and Hunter 1998; Eriksson et al. 2003).

The mycelium of *O. novo-ulmi* on PDA was abundant and fluffy. These fungi produced light-colored, fast-growing colonies. The growth rate of fungi revealed that that these testimonies was related to precence of *O. novo-*

ulmi. The different shapes of fungi growth like white fibrous and dark petaloid shape, were other sign of *O. novo-ulmi*. All the colonies were morphologically typical for *O. novo-ulmi*. Analogous investigations were carried out by Masuya et al. (2009), they reported that the mean growth rates of *O. novo-ulmi* isolates at 20°C were 3.74 (± 0.17) mm/day. The results showed that four types of spore were observed through this research that comprised of sporothrix, pesotum, yeast-like and perithecium. The sporothrix is an asexual state of this species that can produce abundantly in cultures and could be identified easily under the light microscope. This research demonstrated that in sporothrix phase, the observed Conidia were small and were formed at the end of mycelium branches which extend mycelium net trough budding and germinating which agrees with results of Arcy (2000).

The scanning electron micrograph (SEM) of Conidia and synnemata proved the Pesotum phase in experiment. In Pesotum anamorph, synnemata and droplets of conidia at the top of the synnemata were observed that formed oval shape conidia (1-3×2-5 µm) on the apex of synnemata (1-2 mm). It is necessary to note that, these spores may shift from infected trees to healthy trees. It was an interesting fact, that in PDA rotating liquid medium, Yeast-like pahse were observed. Stipes and Compana (1981) reported that this reproduction phase of fungi may interfere in pathogen propagation at xylems. Ascospores and asci in Perithecium, proved the presence of sexual reproduction system in this fungus. Two sexual and asexual reproduction systems were observed in this study.

The occurrence of *O. novo-ulmi* on wounds of *Z. carpinifolia* in this study has expanded the host range of the fungus in Iran. *Zelkova carpinifolia* has not a cosmopolitan distribution and is native to Iran. Its occurrence in *zelkova* trees, a native tree species, expands further the wide host range of this fungus. The fungus has previously been reported from many researches. At the base of our investigations we drew a conclusion; *O. novo ulmi* has been distributed on *Z. carpinifolia*. Maybe it can be associated with other pathogens which extra studies special in this reservoir is necessary. Future studies seems necessary in genetic filed for proving extra information special for determining the subspecies of *O. novo-ulmi* which can be distinguished by genetic Markers (Hoegger et al. 1996).

CONCLUSION

This is the first report of *O. novo-ulmi* presence in Daland reservoir of *Z. carpinifolia*. Todays, researchers have been reported the evidence of hybridization among the subspecies in some countries such as Irland, Germany and Italy. This power in making new hybrids leads to create new strains unperidictable and maybe more aggressive (Brasier et al. 2004; Solla et al. 2005). It is necessary to note, that the differentiation of the new hybrids is not easy based only on morphological characters. Therefore, more molecular research is needed for identification of the subspecies and maybe new hybrids of this species.

REFERENCES

Barnett H, Hunter B. 1998. Illustrated genera of imperfect. 4th ed. APS Press, St. Paul.

Brasier CM, Buck K, Paoletti L, Crawford L, Kirk SA. 2004. Molecular analysis of evolutionary changes in populations of *Ophiostoma novo-ulmi*. Investigación Agraria Sistemasy Recursos Forestales 13: 93-103.

Brasier CM, Kirk SA. 2000. Survival of clones of NAN *Ophiostoma novo-ulmi* around its probable center of appearance in North America. Mycol Res 104: 1322-1332.

Brasier CM, Kirk SA. 2001. Designation of the EAN and NAN races of *Ophiostoma novo-ulmi* as subspecies. Mycol Res 105: 547-554.

Brasier CM. 1991. *Ophiostoma novo-ulmi* sp. nov., causative agent of current Dutch elm disease pandemics. Mycopathol 115: 151-161.

Brasier CM. 1996. Low genetic diversity of the *Ophiostoma novo-ulmi* population in North America. Mycol Res 88: 951-964.

Cannon PF, Kirk PM. 2007. Fungal Families of the World. CABI North American Office. 249-251.

Chen HY, Huang CG. 1999. Ulmaceace In: Flora Republicae Popularis Sinicae. Volume 22. Science Pres, Beijing, China. 328-386.

D'Arcy CJ. 2000. Dutch elm disease. The plant health instructor.

De Hoog GS. 1974. The genera *Blastobotrys, Sporthrix, Calcarisporium* and *Calcarisporiella* gen. nov. Stud Mycol 7: 1-84.

Dunn CP. 2000. The Elms: Breeding, Conservation, and Disease Management. Kluwer Academic Publishers, Norwell, MA.

Eriksson D, Baral H, Currah R, Hansen K, Kurtzman C, Rambold G, Laessoe T. 2003. Outline of Ascomycota-2003. Myconet 9:1403-1418.

Hoegger PJ, Binz T, Heiniger U, 1996. Detection of genetic variation between *Ophiostoma ulmi* and the NAN and EAN races of *O. novo-ulmi* in Switzerland using RAPD markers. Eur For Pathol 26: 57-68.

Hunt J. 1965. Taxonomy of genus *Ceratocystis*. Lloydia, 19:1-58.

Jacobi WR, Koski RD, Harrington TC, Witcosky JJ. 2007. Association of *Ophiostoma novo-ulmi* with *Scolytus schevyrewi* (Scolytidae) in Colorado. Plant Dis 91:245-247.

Jin XL, Zhang RQ, Zhang DL, He P, Cao, FX. 2009. In Vitro plant regeneration of *Zelkova carpinifolia*, an endangered woody species in China, from leaf explants. J Hort Sci Biotech 84 (4): 415-420.

Masuya H, Brasier C, Ichihara Y, Kubono T, Kanzaki N. 2009. The genera *Blastobotrys, Sporthrix, Calcarisporium* and *Calcarisporiella* gen. nov. Stud Mycol 7. New Dis Rep 20: 6.

Newbanks D, Bosch A, Zimmermann MH. 1983. Evidence for xylem dysfunction to Dutch elm disease. Neth J Pl Pathol 76: 196-204.

Paoletti M, Buck KW, Brasier CM. 2006. Selective acquisition of novel mating type and vegetative incompatibility genes via interspecies gene transfer in the globally invading eukaryote *Ophiostoma novo-ulmi*. Mol Ecol 15:249-262.

Parker KG, Readio PA, Tayler LJ, Collins DL. 1941. Transmission of the Dutch elm disease pathogen by *Scolytus multistriatus* and the development of infection. Phytopathol 31:657-663.

Pinon J, Lohou C, Cadic A. 1999. Hybrid Elms (*Ulmus* spp.): Adaptability in Paris and behaviour towards Dutch elm disease (*Ophiostoma novo-ulmi*). Acta Hort 496: 107-114.

Rahnama K. 2004. Dutch elm disease, survival of elm (*Ulmus*) and *Zelkova* species by integrated pest management and the conservation of forest genetic resources. Univ. British Colombia, Forest Sciences, Vancouver, Canada.

Sinclair WA, Campana RJ. 1978. Dutch elm disease : perspectives after 60 years. Cornell University Agricultural Experiment Station, Ithaca, NY.

Solla A, Dacasa MC, Nasmith C, Hubbes M, Gil L. 2008. Analysis of Spanish populations of *Ophiostoma ulmi* and *O. novo-ulmi* using phenotypic characteristics and RAPD markers. Plant Pathol 57: 33-44.

Solla A, Nasmith C, Dacasa MC, Fuentes-Utrilla P, Hubbes M, Gil L. 2005. First report of *Ophiostoma novo-ulmi* ssp. *novo-ulmi* on elms in the Iberian Peninsula. New Disease Reports 12, 34.

Stipes RJ, Campana RJ. 1981. Compendium of Elm Disease. American Phytopathological Society, St. Paul, MN.

Van Alfan N, Mac Hardy W. 1978. Symptoms and host-pathogen interaction. In: Sinclair WA, Compana RJ (eds) Dutch elm disease: Perspectives after 60 years. Cornell University Agricultural Experiment Station, Ithaca, NY.

Webber JF, Gibbs JN. 1989. Insect dissemination of fungal plant pathogens of trees. In: Wilding N, Collins NM, Hammond PM, Webber JF (eds). Insect-Fungus Interactions. Academic Press, London.

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Structure and spatial pattern of land uses patches in the Zagros Mountains region in the west of Iran

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ABSTRACT

Karami A, Sefidi K, Feghhi J. 2014. Structure and spatial pattern of land uses patches in the Zagros Mountains region in the west of Iran. Biodiversitas 15: 53-59. Landscape ecology as a new interdisciplinary science, concepts, theories and methods provides for evaluation and management of land. Quantification of landscape patterns has key role in the interpretation and modeling of spatial and chronically variation of land uses. This study carried out in the Zagros vegetative region in the west of Iran to quantify structure and spatial pattern of land uses and forest fragmentation in the Zagros Mountains region. The mosaic analysis method was used for quantifying landscape metrics. Totally 2783 land use patches were recorded in the study area. The most of the patches were agricultural area and the lowest number of patches recorded for rivers. Diversity indices analysis showed agricultural land use has highest diversity in comparing with other land uses. Rangeland use has distributed in the central region of the study area. Despite the high density agriculture and rangeland a lot of potentials there are two conversions this land as a sustainable ecosystem (forests, agriculture integrated, and rangelands), that can be by applying as an appropriate method in management and control policies and converting artificial land uses to the natural or semi natural land uses according to the advantages of such land uses in view of sustainability. We conclude that fragmentation of natural land uses such forest and rangelands should be reducing and maintain large patches of natural vegetation to sustainable land management in this region.

Key words: Metrics, FRAGSTATS, Iran, land use, landscape ecology

INTRODUCTION

Human development since its presence on this planet was life on natural resources, and intervention in natural ecosystems and the domestication of plants and animals on the planet. Human economical activities are mainly in landscape scale, so the landscape is appropriate spatial scales for the study of environmental change is a result of human activities. Eventually all human activities lead to land use location and structure changes, so landscapes provide a reflection of past human land use and as alive and dynamic framework for sustainable land use are imposed (Xiao and Zhong 1998). There are many similarities between the structure of landscape, land use structure, function of landscape, land use changes and changes in landscape, but the primary goal of ecological studies in all the land is landscape (Naveh and Liberman 1984). Development landscape ecology provides a suitable theoretical basis to study land use changes. When the connection between landscape ecology and sustainable development has been created, principles ecological landscape as the main concepts related to sustainable land use is proposed. Obviously, in areas where land management (land use) with the potential ecological imbalance, must provide reasonable and practical solutions to resolve this inconsistency, and the severity of the imbalance is greater, in terms of management reform, has high priority. The first step in planning is knowledge. Knowing the current situation, awareness of process and forecasting the future is base of planning in the landscape management. To determine the status of land management and land use in different areas and compare them together, to set redundancy between optimal and the current situation, can move towards sustainable development and appropriate land. Landscape ecology is strongly associated with land use, particularly which this relationship of aspects the spatial patterns as is made of land use planning and management it the foundation (Wu 2000). According to the landscape ecology principles analysis of spatial and structural characteristics of land use patches has key role in the interpretation and modeling of spatial and chronically variation of land uses (Wegener 1994; Herzog and Lausch 2001). Besides studying the structure according to principles of ecology, quantitative metrics of landscape appropriate suitable tools for quantifying the spatial characteristics of the components of the landscape. Concepts of landscape ecology can be expanded in planning for land use management in order to reduce the negative effects of human manipulations in land using (Lausch and Herzog 2002).

As mentioned, landscapes are strongly changing. In monitoring the areas and landscape changes in the position and applications of various lands should be considered. This information can be very useful for users, designers

and managers in land use managing (Zhang and Ni 2001). Landscapes metrics can consider as algorithms for quantifying the spatial characteristics of patches, classes or landscape whole patches metrics, Metrics with the ecological principles of landscape and interpret it are as the best way to compare the situation of landscape in different lands. These metrics also can be considered as comparative tools to analysis different landscape scenarios or obtain knowledge about landscape land situation changes over time. Meanwhile, such metrics can be used for the design and find an accurate relationship between the structure and function in landscapes (Botequilha-Leitão et al. 2006). According to the given concepts, in this paper has tried to work on landscape ecology, In order to quantify and interpret the location and structure for sustainable land and reduce them to be considered unstable, until damage and easy loss (fragmentation) of these complex patterns to be normal.

The most regions of Iran because of the ecological richness and genetic resources have high ecological value, but in Zagros region because of the of high biodiversity, genetic conditions, cultural, and social climate of the region and particularly on the specific structure of tribal life, traditional economy based on agriculture and animal husbandry and as a result dependence of livelihoods on natural resources management, planning for sustainable and appropriate utilization of these resources are necessary. Therefore it was necessary for greater recognition and status for different regions, the research done in this area.

Thus, the goal of this research was to analysis the position of different land use from each other and try to find how located them in the context of Landscape. Quantify the structure and characteristics of ecosystem as an ecological analysis and understanding the different ecosystems function(among different land use) are basis for comparison how effects of human and environmental changes in overtime on land use(Bell 1999).Also in this research composition and spatial distribution of structural elements in the landscape had studied, that their main role is in improvement ecological functions of the study area, and what corrective actions can cause improvements in ecological structure and in result processes associated with them will be discussed. In other word the main goal of this research we are interested to quantify the information on fragmentation of natural land uses in the Zagrous Mountains region in the west of Iran. The specific objectives were calculating spatial pattern of land use patches including: number of patches (NP), land area fraction by patches (PLAND), patch density (PD) and Shannon's diversity index (SHDI) in class and landscape levels

MATERIALS AND METHODS

Study area

This study was conducted in the Zagros Mountains region in the west of Iran. Kurdistan province is located in the northern Zagros Mountains in the west of Iran (latitude range in: 34◦-, 44◦ 36, 30 N; longitude range: 31◦-45◦, 48, 16 E). Territory of Zagros Mountains region is now one of the oldest sources of biodiversity and the one of the first settlement place of the Iranian people (Razmara 2005). According to meteorological statistics, Zagros Mountains region has a semi-humid climate with very cold winters and the Alpine and average annual rainfall is 512mm, that volume equivalent to14 billion cubic meters annually it is estimated (Anon. 2000). Based on vegetation maps produced about 60% the total area of the Zagros Mountains region have is vegetation cover forest and pasture. In this province due to geographical environment diversity, and uneven condition of weather conditions, land use different types can be observed, but land use with cover forest and pasture associated with species of *Quercus persica*, *Quercus libani*, *Quercus infectoria*, *Crataegus aronia*, *Pistacia mutica*, *Amygdalus communis*, *Cotoneaster* spp. and also grass species such *Salvia eremophila*, *Ferula ovina*, *Achillea wilhelmsii*, *Vicia sativa* and etc. with the highest level and use the region and the species that of plant specific species are considered to these areas (Marvie-Mohadjer 2005). The region soil of type soil rocks with a schist bed rock of type brown calcareous and in the mountains and edges are Rendzine. Agriculture land use focuses more on the west the province (Figure 1). In the last decades construction and developing of new land uses by human in towns and villages across the province led to the have been a creation specific type of land use called the forestry-agriculture-livestock, that need to multipurpose managing lands in "*agroforestry*" systems also use more participate of local people in this area (Shamekhi 2007).

Procedures

This research had carried out in three scales including patches, classes (zones) and Landscape (McGarigal and Marks 1994). The bases of our study were support and maintain more valuable patches and increase convergence of sustainable patches.

In this study we used maps of land use created by the Iran Organization of Forests, Range and Watershed Management (IOFPWM) were prepared using the accurate geostatistics for the total Iran in 2010, It should be mentioned that this map is based on purposes the researcher reclassified and six categories including: the forest defined as land with tree crown cover or equivalent crown canopy level of more than 5 percent and area of more than 0.5 ha, pastures including rangelands and pastures, agricultural lands, no coverage and bare land (e.g. Arid and salty soil land), residential areas and Rivers (e.g. Rivers and canebrake).

The approach used in this research was based on landscape ecology, in this approach, the relationship between structure and function of process-scale approach is landscape had considered (Botequilha and Ahren 2002). Using this approach and its method and techniques, are known as series disruption of ecosystems related to each other, one effective method is considered for ecological analyzing the area (Ingegnoli 2002). Afterward spatial structure and analysis of different metrics of patches was quantified using FRAGSTATS 3.3software (McGarigal and Marks 1994). FRAGSTATS is a Spatial Pattern Analysis Program and complete set of landscape metrics.

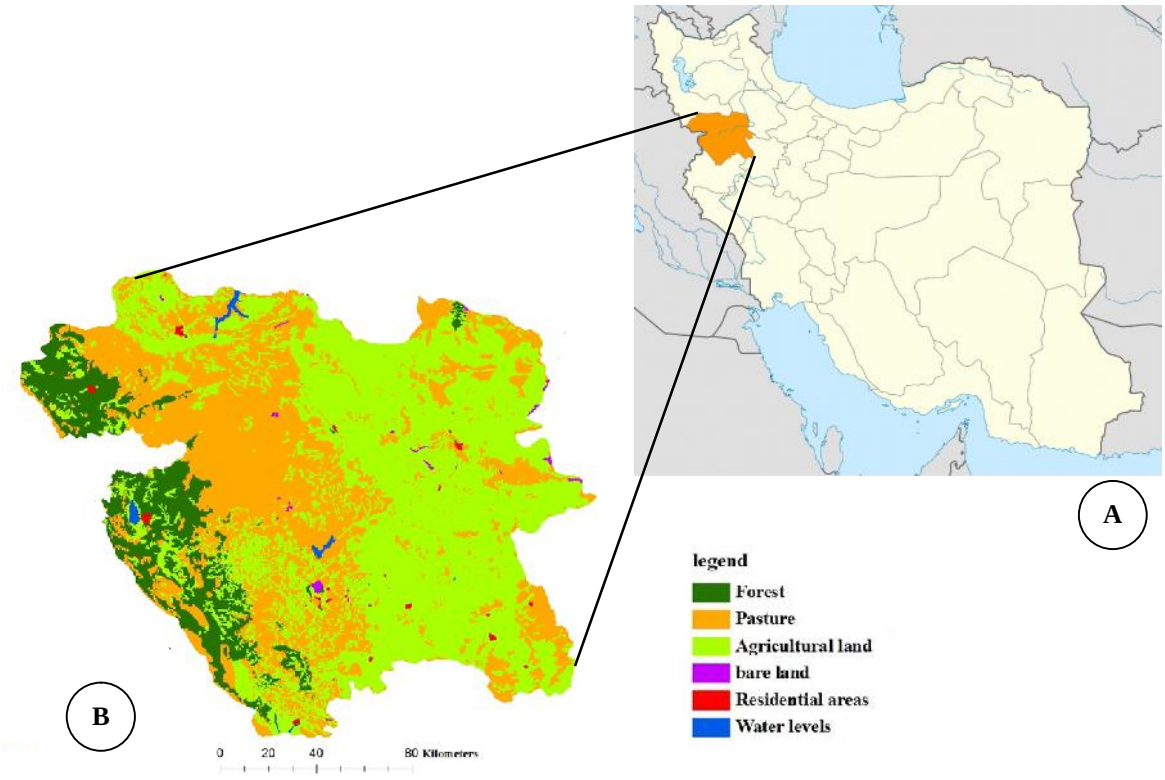

Figure 1A. Location of the study area in the west of Iran. B. Map of land use Kurdistan province (Iran Organization of Forests, Pastures and Watershed Management, 2010 and reclassified by Karami (2011).

This program does not create restrictions on the scale and is suitable software for spatial patterns and various metric landscape patches analyzing that make up the territory in a heterogeneous environment and is suitable in different conditions. The FRAGSTATS ARC software is used to demonstrate the linkage of the U.S. Forest Service's FRAGSTATS program to the Arc Info GIS (ESRI 1992) which is updated version of the USDA Forest Service - General Technical Report PNW-GTR-351. In this research metrics have been calculated according to the purposes in meter or hectare. For each input to FRAGSTATS software, 3 outputs file is created. The file named Patch, Class and the Land as a text file and all files are visible. These tools to analyze spatial patterns, especially in modeling habitat; wildlife protection and forest management are applied. Ability to describe a quality of landscape, a prerequisite is for studying the function and change the landscape, and different metric to achieve this goal; the ecology has been extracted from landscape, for example the application model provided by a Foreman landscape focuses on four models for the sustainable planning (McGarigal and Mark 1995) including (i) Maintain large patches of natural vegetation, (ii) maintenance of wide river corridors, (iii) maintains the continuity of key species among large patches and (iv) maintaining the heterogeneous parts of natural human development in the region. In this study before to data entering operation in FRAGSTATS software, we needed to prepare the data in the IDRISI software, because of raster format of data on Zagros Mountains land use maps. In relation to some of the landscape metrics that were used in this research, we had defined metrics as shown in Table 1. Some metrics are the standard metrics of FRAGSTATS but some of them such as standard deviation of neighbor distance used in analysis fragmentation of land use patches.

Data analysis

We analyzed data in two different levels: (i) metrics analysis in class level to calculate land use Changes in similar land use patches and (ii) metrics analysis at the landscape level to calculate land use total patches in the entire study area.

Class analysis

At this level there are 6 classes included Forest, Rangelands, Agricultural area, bare land, Residential area and Rivers which metrics were calculated for each class. The metrics used in this level included: The mean shape index (MSI), number of patches in class level (NP) which used to calculate the number of patches in each class. Largest patch indexes (LPI), largest patches in each class were calculated. Patch density (PD), Density of patches per class per unit area was calculated. Edge density (ED) and Total edge (TE).

Also the length strips around each land use and complexity of it calculated. Class area (CA), the area covered by each class had calculated. Characteristic of the Euclidean distance between patches include (ENN_MN,

ENN_AM, ENN_MD, ENN_RA, ENN_SD and ENN_CV). Metric related Statistics including mean, median, range, standard deviation and coefficient of variation had calculated between patches. We should be mentioned McGarigal et al. (1994) note that the value of the Fractal dimension as computed in FRAGSTATS is dependent upon the patch size and the units used (Rogers 1993).

Landscape analysis

Metrics analysis at landscape level was done with calculating metrics of total land use patches. For analysis Metric of at the landscape level, in addition, using metrics that mentioned in class level for all patches; Simpson and Shannon diversity index (SHDI, SIDI, MSIDI, SHEI, SIEI and MSIEI)of the metrics were calculated in order to diversity and uniformity analysis of land uses types. The Shannon index of diversity (SHDI, see Shannon and Weaver 1949) is the most widely used index for diversity evaluation. This index, ranging in theory from 0 to infinity, estimates the average uncertainty in predicting which land cover type a randomly selected sub-unit of the landscape will belong to. Also widely used, the Simpson index (SIDI, see Simpson 1949), Producing values from 0 to 1, Simpson's index defines the probability that two equalized subs-units of the landscape, selected at random, belong to different cover types.

Both these indices of diversity combine evaluations of richness and evenness. The landscape metrics are shown in Table 1.

Table 1. Description of metrics used in landscape and class level analysis.

CharacterFormulaandabbreviations	Description	Unit	Range ofchanges
Landscape and class level analysis			
$NP = n$	Number of patches	-	NP>0
$PLAND = P_i = \frac{\sum_{j=1}^{a} a_{ij}}{A}(100)$	Area fraction with patches	%	0<PLAND<100
$PD = \frac{n_i}{A}(10000)(100)$	Number of patches per 100 ha	#	PD>0
$ED = \frac{\sum_{k=1}^{m} e_{ik}}{A}(10000)$	Edge density, wherei is the land use classes andk is for edge length	Meter per hectare	ED>0
Landscape level analysis			
$SHDI = -\sum_{i=1}^{m} (P_i \ln P_i)$	Shannon's diversity index	-	SHDI≥1
$SIDI = 1 - \sum_{i=1}^{S} Pi^2$	Simpson's diversity index	-	0 ≤SIDI≤ 1
$LPI = \frac{\max(a_{ij})}{A}(100)$	Largest patch index	Percentage (%)	0<LPI<100
$LSI = \frac{e_i}{\min e_i}$	Landscape shape index	-	LSI≥1
$MNN = \frac{\sum_{i=1}^{m} h_i}{m}$	Mean nearest-neighbor distance	(mu)	MNN>0
$NNSD = \sqrt{\frac{\sum_{i=1}^{m}(h_i - MNN)^2}{m}}$	Nearest-neighbor standard deviation	(mu)	NNSD>0
$TE = \sum_{K=1}^{m} e_{iK}$	Total edge	(mu)	TE ≥ 0
$SHEI = \frac{-\sum_{i=1}^{m}(P_i \ln P_i)}{\ln m}$	Shannon's evenness index	-	0 ≤ SHEI ≤ 1
$SIEI = \frac{1 - \sum_{i=1}^{m}(p_i^2)}{1 - \left(\frac{1}{m}\right)}$	Simpson's evenness index	-	0 ≤ SIEI ≤ 1
$CA = \sum_{j=1}^{n} a_{ij}\left(\frac{1}{10,000}\right)$	Class area	(ha)	CA > 0

They increase under situations where the number of land cover types (landscape richness) increases, or the equitability of distribution of land amongst the various cover types (landscape evenness) increases, or both (Nagendra 2002).

RESULTS AND DISCUSSION

According to the analysis of land use patches in the Zagros Mountains region (Figure 1B), agricultural patches observed more in the east of Kurdistan province, forest patches in the west and rangelands in the central part as north-south strips are distributed. The map of land use distribution illustrated in Figure 1B, which variety of land uses and patches are detectable.

Metric analysis of class level

Metric analysis of class level with calculating percent of land use metrics, patch density, average of patches size, the largest size of patches, metric of landscape shape and the average landscape patches had done. As shown in Table 2, the density of agriculture patches (PD) in this region is higher than other land uses, and the forest, rangeland users, and the land without cover (bare land) were the next of orders, respectively. According to Table 2, and the number and distribution of patches of urban and residential areas in the landscape level, the close relationship and intimately between nature and humans there are in level and should be considered in planning sustainable land management**.** According to Table 2, the largest land use area and the greatest number of patches, respectively, recorded in agricultural land, Rangelands and forest. Bare lands including no covered area have minimum area and river lands showed lowest number have in this level compared to the other land uses. The number of residential areas patches (urban patches) in this level had shown in Table 2, according to this metric and area of this province, high relation between human community's presence and change in nature cane revealed.

Table 2. Patches structure related metrics in the class level

Land use types (Map unit)	Zagros Mountains region,map 1 : 250,000 scale metrics in the level of class							
	CA (ha)	NP (n)	PD (m)	LPI (%)	ED (m)	TE (m)	LSI	PLAND(%)
Forest	373432.12	223	0.01	6.24	3.96	7309130	14.91	12.68
Pastures	1243724	919	0.034	24.36	10.41	24260814	21.68	41.28
Agricultural land	1268342	1560	0.038	32.26	10.35	31503691	20.44	45.87
Bareland	4789.58	38	0.0003	0.01	0.01	129204.7	1.67	0.01
Residential	6169.49	30	0.0007	0.06	0.04	204448.5	2.05	0.1
Rivers	8382	13	0.0007	0.04	0.04	255599.6	2.28	0.06

Table 3. Mean (± S.E.), weighted mean, Median and Range of Euclidean distance the nearest neighbor metric in class level in the Zagros Mountains region in the west of Iran

Land uses	Mean(km)	Weighted mean (km)	Median	Range
Forest	1.83 ±2.8	0.45	0.50	14.65
Rangelands	0.51 ±0.62	0.12	0.26	3.95
Agricultural area	0.43 ±086	0.10	0.20	7.78
Other land uses[a]	120.49	120.49	120.49	0
Total, allland uses	123.26 ±10.4	121.16		

Note: [a] Other land uses including residential areas, bare lands and rivers.

Table 4. Statistical characteristic of metrics of land uses patches in landscape level in the Zagros Mountains region Map with 1:1000000 scale.

Symbol	FRAGSTATS metrics	FRAGSTATS statistics
TE	Total edge(mu)	63762887.13
PR	Patch Richness (No unit)	6
PRD	Patch Richness Density (Meter In 100hectares)	0.002
RPR	Relative Patch Richness (%)	100
CA	Class area (ha)	2904839
PN	Patch number (No unit)	2783
PD	Patch density (Meter In 100hectares)	0.08
LPI	Largest patch index (%)	32.26
ED	Edge density (Meterper hectare)	13
LSI	Landscape shape index (No unit)	17.38
AREA_MN	Mean patch area (mu)	67.35
AREA_AM	Mean weighted patch area (mu)	50776.53
AREA_MD	Median patch area (mu)	1117.72
AREA_RA	Range in patch area (mu)	92317.42
AREA_SD	Standard deviation in patch area (mu)	7450.16
AREA_CV	Coefficient of variation in patch area (mu)	666.54
ENN_MN	Mean patch distance (mu)	1549.36
ENN_AM	Mean distance -weighted patch (mu)	221.14
ENN_MD	Median patch distance (mu)	249.93
ENN_RA	Range in patch distance (mu)	99913.08
ENN_SD	Standard deviation in patch distance (mu)	8910.04
ENN_CV	Coefficient of variation in patch distance (mu)	575.07

Analysis of the total land area fraction (Table 2, PLAND) and total edge (Table 2, TE) metrics among land uses in the Zagros Mountains region showed that according to the percentage cover metrics, agricultural lands, rangeland and forested area in this region had covered the largest area, respectively.

As we illustrated in Figure 3, statistical characteristics of areas related metric showed the main area of land use patches in agricultural, pasture and forest land uses through the province was higher in comparison with other land uses. The range of mean area variation in rangelands and forest land use patches was more than the mean of other land uses. This fact means the patches of rangelands and forestry had composed from the changing area and human based disturbances and interference in this land use was considerably over the time.

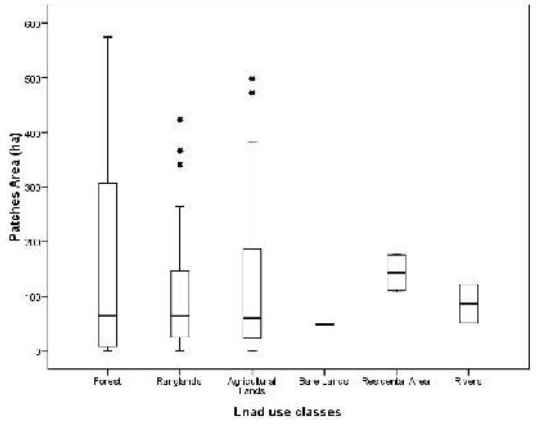

Figure 3. Statisticalcharacteristic of land use area metrics in class levels.

The values of the statistical metric of the Euclidean distance between the patches showed land use of the river, residential areas and rangelands patches had a high value in study area respectively (Table 3). Also given land use patches encompass the greatest value of the mean, weighted mean and the Euclidean median of distance between the patches, respectively. Analysis the statistical characteristics of the standard deviation and coefficient of variation Euclidean distance metrics among the land use patches revealed that the values of these metrics for residential and pasture land uses had the highest value.

Metric analysis at landscape level

In this analysis, the total area of the Zagros Mountains region assessed as an integrated landscape. Table 4 showed the differences in metric values and the spatial distribution of land uses in landscape level (province). Comparable results of land use metrics in landscape level showed the most of the patches were composed of small patches of land use at the provincial level (Table 4).

We had calculated diversity index for land use patches, results showed this value in the province was around one that means a diversity of land use area in this region high is high. Variation in diversity index had shown in Figure 4.

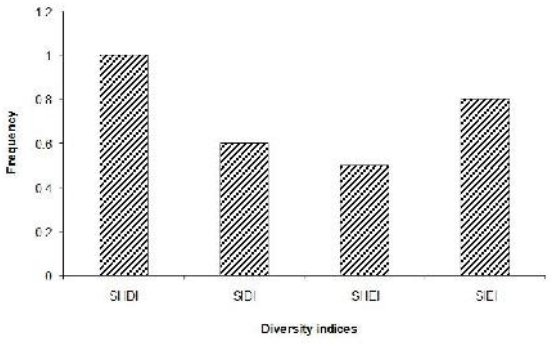

Figure 4. Frequency of diversity indexes among some different land use patches in landscape level.

Discussion

Different factors affect the formation and arrangement of patches in a landscape including: processes of geology, topography, soil, etc. (Natural) and various human interventions (artificial). The quantitative metric can be considered as a suitable tool for identifying and understanding the land use changes As the results showed the concept of using metrics and spatial pattern of land use patches are based on fragmentation are by different land uses which are the most important index to evaluate human based changes and variation in the nature and natural landscapes (Botequilha-Leitão and Ahern 2002).

Different regions of the earth according to the different ecological condition, different climatic and economic-social processes and human activities showed variable land use patterns. Removing the large patches of agricultural area cause to fragmentation and create human made patches that this is an effective phenomenon of the life cycle of the Earth. In this area density of patches and distance between natural patches such as forest revealed human based disturbances caused to change and fragmentation of land uses.

The use of concepts of landscape ecology in the many scopes and issues such as design of landscape, environmental impact assessment, ecosystem management, rural development is applicable. Landscape concepts and metrics in the land use planning for describing and explaining the communication-pattern model process is required (Foresmanet al. 1997; Gulinket al. 2001). For example, Landscape concepts and metrics can be used for the design appropriate different land uses.

As the results revealed the density of agricultural land use patches was greater than other land uses in this region. However the density of forest land is lower than other land uses in at the provincial level, the reason is that the natural forests just cover western parts of the province as well rangelands distributed more on north-south strip in the central parts of the provinces. According to the composition and structure of metrics, it can be concluded that from the western region of provinces to east natural land use patches is going to reduce and artificial land uses are going to increase. In landscape level, the ecological processes and human activities have an important role in the formation spatial pattern of the landscape, so that can be expressed that the spatial patterns, caused by ecological processes, and in other hand ecological processes, can reflect changes in landscape. Function of landscapes is highly affected by with the landscape structure Therefore formation of land uses is strongly related to the structure and function of the landscape (Zhang et al. 2008).

Accordingly, and considering to this fact that in this province of west to east precipitation decrease and physiographical properties is better and in instead residential areas, good soil, etc. That makes situation suitable for human communities' establishment and farming. This issue very well shows the effects of ecological processes and in following those human based factors on construction of the structure and composition of landscapes. Number of patches metric analysis revealed the vulnerability of each ecosystem in this region (the natural,

semi-natural and artificial land uses) can be classified, so that an increasing number of land use patches caused to increase the vulnerability of land use patches, and conversely whatever those numbers of patches are low, threshold of land uses vulnerability is high. According to this fact and the results of this study the agricultural and rangeland uses are more exposed to the vulnerability in comparing to the other natural land uses. As well by using total edge metric and shape complexity of each land uses level of each land uses exposure with surrounding land uses can be calculated, therefore whatever value of this metric is more, land uses the desired (especially about the natural and sustainable land uses) are more vulnerable to changes, according to this analysis, agriculture and pasture land uses are susceptible to the vulnerability and are more sensitive ecosystems, and should be manage these areas more cautious in future planning. As mentioned, patchy structure is composed from many small patches and fragmentation has been extraordinary. In this research to discover the distribution and spatial distribution of land use patches Simpson and Shannon diversity index as metrics were used, if the amount of this metric is more than 1, univalve distribution and if equal is of a random, and if is less than the form of a have uniform distribution, as are observed, this amounts to Zagros Mountains region is calculated nearly 1 and equal to 1, thus can be expression land users the distribution of patches in the Zagros Mountains region is greater random and uniform.

Results showed that this region occupied by heterogeneity mosaics of land uses patches including, patches of natural, semi natural and human made land uses. Natural patches are including rivers, bare land, forest and rangeland. Patches of semi-natural area including agricultural land and human made land uses the patches such as residential area. Range of patch area changes in agriculture, pasture and forest land uses in landscape level is high and distribution of this patch in the provinces is regional.

In the Zagros Mountains region, despite a high density of agricultural and rangeland uses (semi-the natural and the natural patches) have a high potentials to convert this land uses into sustainable ecosystems (forest and integrated agriculture), that needed to suitable administrative procedures and policy control.

CONCLUSION

Landscape metrics can be useful in the management of natural resources and land uses sustainable. But while these metrics are used for future planning as the decision support system, should be intensified and a batch that the each metric that belongs to be determined. One of the advantages of assessment patches using the landscape metric is awareness from extent of intensity of landscape in the shortest possible time using the digital data. On the other hand, in this method for the destruction of determine hierarchy between work units, the minimum expertise is applicable, that the by using results obtained from the hierarchy of destruction between work units can be managed land uses according to the nature and environmental condition, so we suggest in planning land use in this area we need to assess this area according to the metrics.

REFERENCES

Anon. 2000. Weather report from Kurdistan. Jamab Consultant Engineers Company, Page165.

Bell S .1999. Landscape: pattern, perception and process. E and F SPON, London.

Botequilha-Leitao A, Jozeph M, Ahern J. 2006. Measuring landscapes: A planner's handbook. Island Press, Washington, D.C.

Botequilha-Leitão A, Ahern J. 2002. Applying landscape ecological concepts and metrics in sustainable landscape planning. Landsc Urban Plan 59 (2): 65-93.

Esri A. 1992. Understanding GIS: the ArcInfo method. Environmental Systems Research Institute, Redlands, CA.

Foresman TW, Pikkett STA, Zipperer W C. 1997. Methods for spatial and temporal land use and land cover assessment for urban ecosystems and application in the greater Baltimore-Chesapeake region. Urban Ecosyst 1 (4): 201-216.

Gulink H, Mugica M, De Lucio J V, Atauri J A. 2001. A framework for comparative landscape analysis and evaluation based on land cover data with an application in the Madrid region (Spain). Landsc Urban Plan 55(4): 257-270.

Herzog F, Lausch A. 2001. Supplementing land-use statistics with landscape metrics: Some methodological consideration. Environ Monitor Assess 72 (1): 37-50.

Ingegnoli V. 2002.Landscape Ecology: A widening foundation. Springer, New York.

Lausch A, Herzog F. 2002. Applicability of landscape metrics for the monitoring of landscape change: issues of scale, resolution and interpretability. Ecol Indicat 2 (1-2): 3-15.

Marvie-Mohadjer MR. 2005.silviculture and forest tending. University of Tehran press, Tehran.

McGarigal K, Marks BJ. 1994. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure, version 2. Forest Science Department. Oregon States University. Corvallis, OR.

McGarigal KB, Marks BJ.1995. Fragstats: Spatial pattern analysis program for quantifying landscape structure. Reference manual. Forest Science Department. Oregon State University. Corvallis, OR.

Nagendra H. 2002.Opposite trends in response for the Shannon and Simpson indices of landscape diversity. Appl Geogr 22: 175-186.

Naveh Z, Liberman A. 1984. Landscape ecology: theory and application. Springer, New York.

Razmara H A. 2005. Culture and Geography of Iran. Tehran Geographic Circle of Army Staff 5: 13-133.

Rogers CA. 1993. Describing landscapes: Indices of structure. [M.Sc. Thesis], Simon Fraser University, Burnaby, British Columbia.

Shamekhi T. 2007. Agroforestrys. Tehran University press, Karaj, Iran. [Persian].

Shannon CH, Weaver W. 1949. The mathematical theory of communication. University of Illinois Press, Illinois.

Wegener M .1994. Operational urban models: State of the art. J Amer Plan Assoc 60 (1): 17-29.

Wu J. 2000. Landscape ecology: Pattern, process, scale and grade. Higher Education Press, Beijing.

Xiao DN, Zhong LS. 1998. Ecological principles of landscape classification and assessment. Chinese J Appl Ecol 9: 217-231 [Chinese].

Zhang HY, Ni JR. 2001. Discussion on the space methods of the city space ecology adjusts and control. City Plan Rev 25 (7): 15-18.

Zhang Q, Ban Y, Liu J, Shu Q, Hu Y. 2008. Analysis of landscape dynamics in shanghais using landscape metrics: Effects of spatial resolutions. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVII. Part B6b, Beijing, 2008.

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Reaction and fractal description of soil bio-indicator to human disturbance in lowland forests of Iran

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ABSTRACT

Mollaei-Darabi S, Kooch Y, Hosseini SM. 2014. Reaction and fractal description of soil bio-indicator to human disturbance in lowland forests of Iran. Biodiversitas 15: 60-66. Earthworms are expected to be good bio-indicators for forest site quality. The deforestation of land into another function could changes the soil features that could effect on earthworm population. This study was conducted to understand the changes of soil functions, resulting from exploitive management using some soil features and their fractal dimensions. Two sites were selected, consisting of an undisturbed forest site (FS) and a completely deforested site (DS) in lowland part of Khanikan forests located in Mazandaran province, north of Iran. Within each site 50 soil samples were obtained from 0-30cm depth along two sampling lines with 250 meter length for each. Deforestation brought a lower soil quality in the sites under the study. Decreasing silt, clay, moisture, pH, carbon to nitrogen ratio, available Ca, earthworm density and biomass, increasing bulk density and sand were few outcomes of the deforestation. Except for clay, the deforestation affect on fractal dimension of soil features. The fractal dimension of bulk density, silt, moisture, pH, earthworm density and biomass were decreased imposed by deforestation. Our results suggest that deforestation should be regarded as an effective factor on variability of soil features that are tied to forest ecology. This is significant for evaluating forest management policies and practices with respect to effects on soil and also for the use of soils as indicators, especially earthworms as bio-indicator, of forest ecosystems.

Key words: Earthworm, deforestation, fractal dimension, soil feauture, top soil

INTRODUCTION

Earthworms are arguably the most important components of the soil biota in formation and maintenance of soil structure and fertility. Earthworms, although not numerically dominant but their large size makes them one of the major contributors to invertebrate biomass in soils (Kooch et al. 2013a). Their activities are important for maintaining soil fertility in a variety of ways in forests, grasslands and agro ecosystems (Palm et al. 2013). Earthworms are also expected to be good bio-indicators for forest site quality (Rahmani 2000). Earthworm's populations are as indicator that is representative of destruction in exploited regions and nature return indicator in reclamation projects (Kooch et al. 2013a). Earthworms are subject to physical, chemical and biological changes in soil, so they have a major role in soil structure and performance, transfer minerals to different horizons and also organics to lower horizons of soil (Rahmani 2000; Palm et al. 2013). Creation of holes in path of earthworms increases water penetration and soil aeration. It has been shown that 60% of earthworm's paths at soil depth of 15 cm and 18% of earthworm's paths at soil depth of 80 cm have been covered by tree roots (Palm et al. 2013). The earthworms cause remarkable increase in soil microorganisms and have an important effect on soil invertebrate's diversity and feed cycle (Groffman et al. 2004).

The year 2011 was 'The International Year of Forests'. This designation has generated momentum bringing greater attention to the forests worldwide. Forests cover almost a third of the earth's land surface providing many environmental benefits including a major role in the hydrologic cycle, soil conservation, prevention of climate change and preservation of biodiversity. Forest resources can provide long-term national economic benefits. For example, at least 145 countries of the world are currently involved in wood production (Chakravarty et al. 2012). Sufficient evidence is available that the whole world is facing an environmental crisis on account of heavy deforestation. For years remorseless destruction of forests has been going on and we have not been able to comprehend the dimension until recently. Nobody knows exactly how much of the world forests have already been destroyed and continue to be razed each year. Data is often imprecise and subject to differing interpretations. However, it is obvious that the area of forests is diminishing and the rate of temperate forest destruction is escalating worldwide, despite increased environmental activism and awareness (Chakravarty et al. 2012). Deforestation is the conversion of forest to an alternative permanent non-forested land use such as agriculture, grazing or urban development (Van Kooten and Bulte 2000). Deforestation is primarily a concern for the developing countries (Myers 1994).

Hyrcanian forest ecosystem is considered to be one of the last remnants of natural deciduous forests in the world.

In comparison to European broad-leaved forests, the Hyrcanian forests seem to have remained from the Tertiary and to be relict ecosystem. In Iran, Hyrcanian (Caspian) forests are located at green strip extending over the Northern Slops of Alborz range of mountains and Southern coasts of the Caspian Sea. This zone has a total area of 1.84 million ha comprising 15% of the total Iranian forests and 1.1% of the country's area. These forests stretch out from sea level up to an altitude of 2800 m and encompass different forest types (Khosroshahi and Ghavvami 2006). Today, these forests are depleting rapidly due to population growth, and associated socioeconomic problems, industrial development, urbanism, and more recently intensive/ irregular tourism. About 60% of Hyrcanian forests are managed for timber production and the remainders are degraded to different intensities. The existence of various land-uses, and their increasing alteration, mainly by local communities, mismanagement of natural resources over long periods of time, plans for industrial development (e.g., establishment of industrial towns adjacent to the forested areas), public road construction without detailed environmental considerations and shortage of human/ financial resources for sustainable monitoring and management of the forest resources are threatening the existence of the Caspian forests (Poorzady and Bakhtiari 2009).

Deforestation has many significant ecological consequences. The removal of vegetation results in increased erosion of soil sediments, which are many times deposited in water bodies, consequently depositing soil particles and nutrients. A decrease in vegetation also corresponds with a decrease in nutrient uptake in the soil, resulting in an increased rate of nutrient leaching from the soil. The effects of deforestation on soil physical, chemical and biological properties have been studied in both temperate and boreal forests around the world (Caruso 2002; Nkongolo and Plassmeyer 2010). Deforestation is known to cause severe disturbances, including changes in microclimatic conditions and light availability that affect plant growth (Xu et al. 2008). It also causes subtle changes in soil structure and nutrient dynamics that are detectable both immediately and or after several years of deforestation (Malgwi and Abu 2011). Soil fauna, especially earthworms as bio-indicator, are responsible for organic matter decomposition, nutrient cycling and maintenance of soil structure and thus have great role in long-term sustainability of forest ecosystems (Duffkova and Macurova 2011). Despite continued focus on the interaction between deforestation and soil processes, relatively little is known about the relationship between deforestation and soil fauna or whether deforestation changes in soil fauna influence soil ecosystem functioning. While forest degradation is rampant in the lowland forests of the northern Iran, no information exists on the effect of these changes on soil features. Such studies are particularly important in view of the role of soil features in the management and reclamation of deforested areas. The present study evaluates the reaction and fractal description of earthworms to variability of soil physico-chemical features imposed by deforestation in a lowland part of northern Iran.

MATERIALS AND METHODS

Study area

With an area of 2807 ha, the Khanikan forests are located in the lowland and midland of Mazandaran province in north of Iran, between 36° 33́ 15″, 36° 37′ 45″ latitude North, and between 51° 23′ 45″, 51° 27′ 45″ longitude East (Figure 1a). The elevation of the forest area ranges between 50 and 1400 m above sea level (a.s.l.). Minimum temperature in December (7.5°C) and the highest temperature in June (24.6°C) are recorded, respectively. Mean annual precipitation of the study area were from 47.5 mm to 237.6 mm at the Noushahr city metrological station, which is 10Km far from the study area. The climate is temperate moist and the dry months extend from May to September. The soil is forest brown soil showing a texture that ranges between sandy clay loam to clay loam (Kooch et al. 2007). The dominant forest types included Hornbeam (*Carpinus betulus* L.) and Persian ironwood (*Parrotia persica* C.A. Meyer), respectively (Kooch et al. 2007). A lowland part of these forests, almost 7 ha, were destroyed because of extensive exploitation carried out by local residents about 30 years ago (Figure 1a).

Soil sampling and analysis

Two sites (about 300 m apart from each other) were selected, consisting of an undisturbed forest site (FS) and a completely deforested site (DS). Within each site 50 soil samples were obtained from 0-30cm depth along two sampling lines with 250 meter length for each. The interval between samples along lines and also the distance between lines were selected 10 m (Figure 1b). Soils were air-dried and passed through 2-mm sieve (aggregates were broken to pass through a 2 mm sieve). Bulk density was measured by Plaster (1985) method (clod method). Soil texture was determined by the Bouyoucos hydrometer method (Bouyoucos, 1962). Soil moisture was measured by drying soil samples at 105° C for 24 hours. Soil pH was determined using an Orion Ionalyzer Model 901 pH meter in a 1:2.5, soil: water solution. Total carbon was determined using the Walkey-Black technique (Allison, 1975). The nitrogen was measured using a semi Micro-Kjeldhal technique (Bremner and Mulvaney, 1982). Available Ca was determined with an atomic absorption spectrophotometer (Burt 2004). Earthworms were collected simultaneously with the soil sampling by hand sorting. Worms were stored on ice and returned to the laboratory. They were then washed in water, dried for 48 hours at 60°C, and massed (Edwards and Bohlen 1996).

Statistical analysis

Kolomogorov-Smirnov test was used for testing normality and Levene test for data homogeneity testing. Independent sample t-test was used to find differences in soil features between the two sites. Analysis of the whole data set was done in SPSS Ver. 13.5. The software package used for detecting fractal dimension of soil features was GS^+ version 9 (Gamma Design Software, LLC, Plain well, MI).

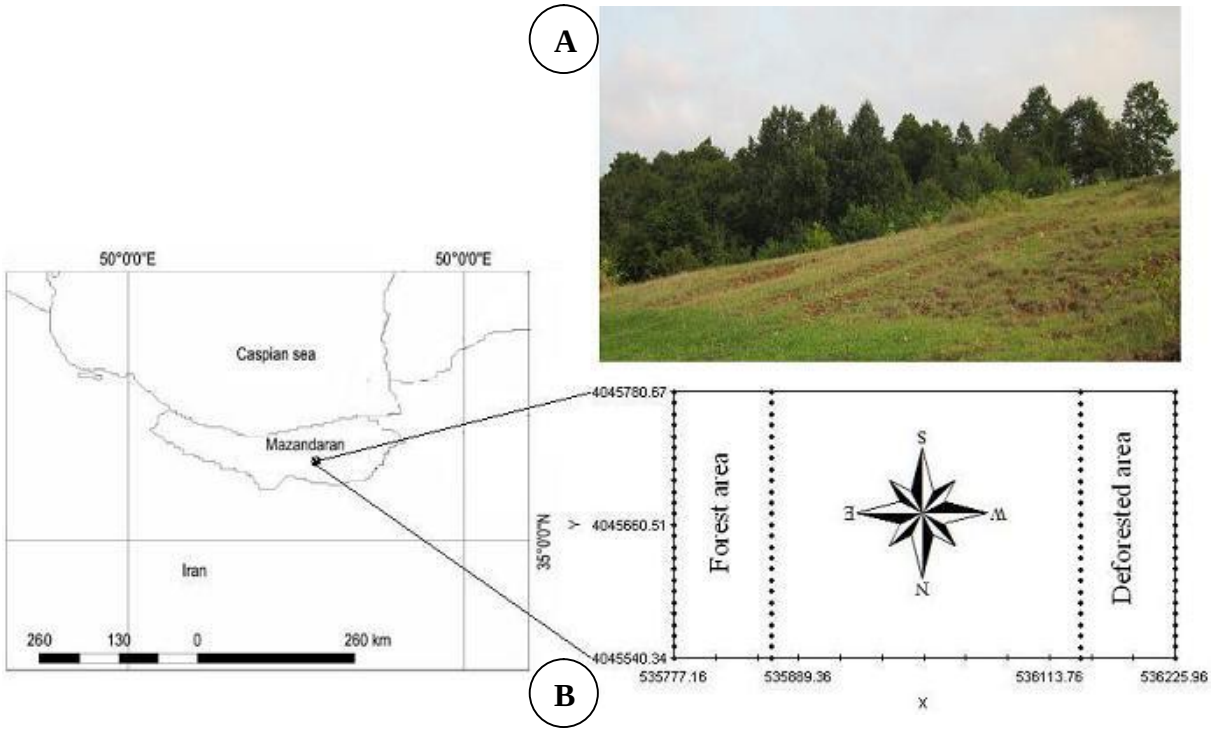

Figure 1. A photo of study area located in Mazandaran province, north of Iran (A). Schematic representation of the experimental design (figure not to scale) adopted for soil sampling pattern in two FS and DS (B).

RESULTS AND DISCUSSION

The changes in soil features and also the fluctuations along sampling lines (fractal dimensions) are presented in Table 1 and Figure 2 respectively. The mean of bulk density was significantly higher at DS (1.01 g cm^{-3}) when compared with FS (0.87 g cm^{-3}) (Table 1). Whereas, fractal dimension of bulk density was more in the FS (1.99) than DS (1.94) (Figure 2). Sand also followed the same trend having significantly higher values at DS (65.10%) than FS (53.24%) (Table 1). A greater amount of fractal dimension was detected in DS (1.95) than FS (1.91) for this character (Figure 2). Mean silt values were significantly higher at the FS (26.43%) than at the DS (22.08%) (Table 1). Higher value of fractal dimension was found at the FS (1.96) than DS (1.93) for silt content (Figure 2). The amounts of clay were significantly higher at the FS (21.27%) than DS (13.13%) (Table 1). The fractal dimension for the clay parameter was same in both of sites (1.97) (Figure 2). Soil moisture observed at the FS (45.89%) greater than at DS (28.72%) (Table 1). FS devoted higher value of fractal dimension (1.97) compared to FS (1.96) for moisture character (Figure 2).

The pH was slightly acidic at both the sites. The mean pH was lower at the DS (5.70) than FS (6.58) (Table 1). Fractal dimensions presented more value for FS (1.99) than DS (1.81) related to soil pH (Figure 2). The mean values of carbon to nitrogen ratio observed at FS (10.17) were significantly higher than the value at the DS (3.25) (Table 1). The fractal dimension of this soil character was detected a little more in DS (1.97) compared with FS (1.96) (Figure 2). Mean available Ca values were significantly higher at the FS (34.23 mg g^{-1}) than at the DS (20.42 mg g^{-1}) (Table 1). Higher value of fractal dimension for available Ca was found at the DS (1.95) than FS (1.93) (Figure 2). Earthworm density and biomass were significantly higher at the FS (0.60 n m^{-2} and 0.26 mg m^{-2}, respectively) than DS (0.30 n m^{-2} and 0.07 mg m^{-2}, respectively) (Table 1). As the same, the fractal dimensions presented more values for earthworm density and biomass in FS (1.96 and 1.98, respectively) than DS (1.95 and 1.94, respectively) (Figure 2).

Table 1. Mean (±standard error of mean) soil features of FS and DS

Soil features	Site condition		Statistical characters	
	FS	DS	T-value	Sig.
Bulk density (g cm^{-3})	0.87±0.01 b	1.01±0.02 a	-4.57	0.00
Sand (%)	53.24±2.17 b	65.10±2.26 a	-3.77	0.00
Silt (%)	26.43±1.53 a	22.08±1.44 b	2.06	0.04
Clay (%)	21.27±1.59 a	13.13±1.30 b	3.95	0.00
Moisture (%)	45.89±1.23 a	28.72±1.04 b	10.61	0.00
pH	6.58±0.05 a	5.70±0.05 b	12.24	0.00
Carbon to nitrogen ratio	10.17±0.04 a	3.25±0.02 b	13.88	0.00
Available Ca (mg g^{-1})	34.23±0.07 a	20.42±0.07 b	12.47	0.00
Earthworm density (n m^{-2})	0.60±0.13 a	0.26±0.07 b	2.18	0.03
Earthworm biomass (mg m^{-2})	0.30±0.07 a	0.07±0.02 b	3.02	0.00

Note: FS = undisturbed forest site; DS = completely deforested site. N = 50 for FS and N = 50 for DS from 0-30 cm soil depth. Within the same raw the means followed by different letters are statistically different ($P \leq 0.05$).

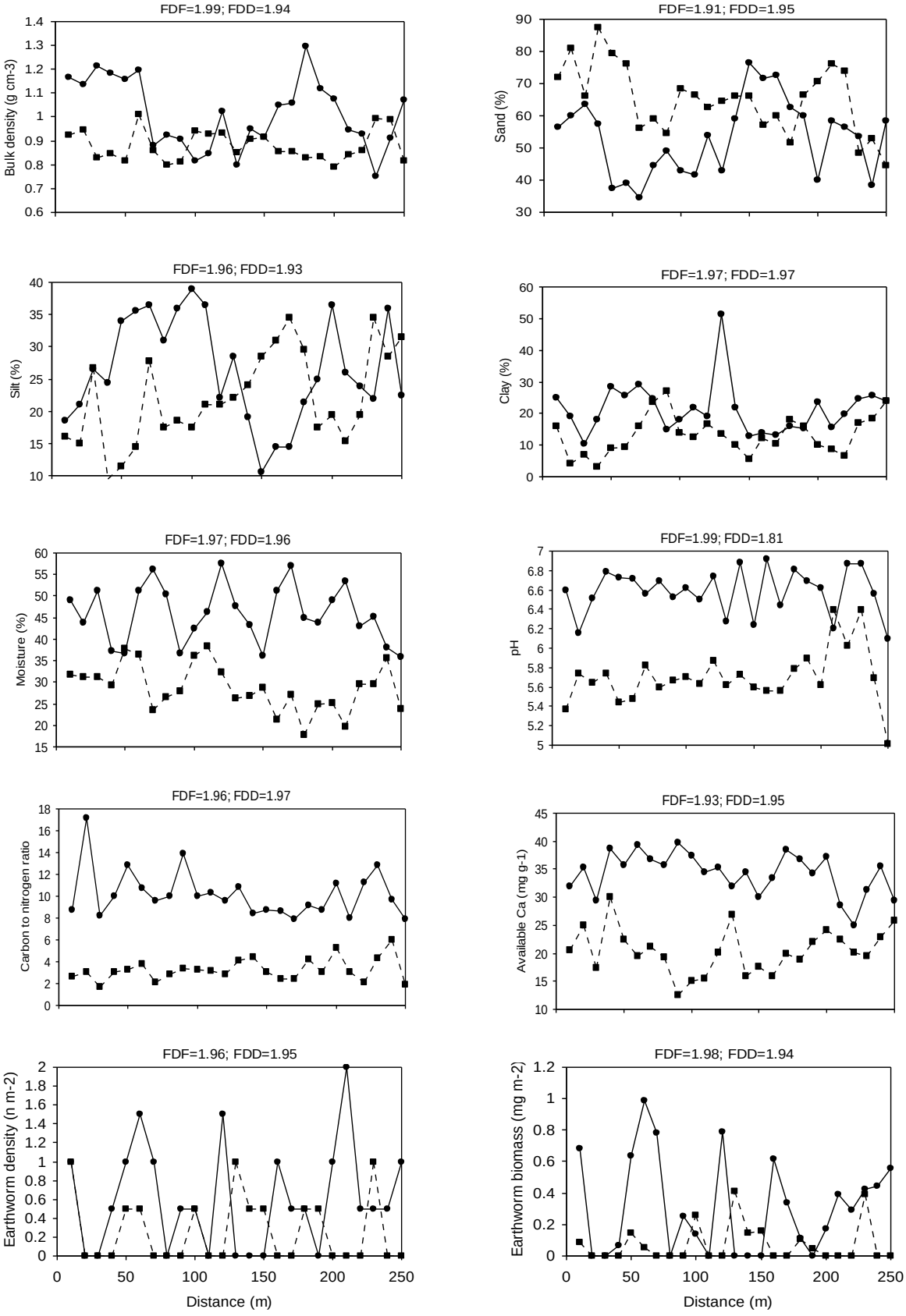

Figure 2. Variability of soil features along the sampling line in study area. Filles circle with continues line represent values on every sampling of FS. Filled square with discrete line represent values on every sampling of DS. FDF means Fractal Dimension of intact Forest. FDD means Fractal Dimension of Deforested area.

Deforestation in the temperate regions has long been considered to lead to the degradation of the soil features related to soil fertility. Earthworm is one of the important organism in the soil that a susceptible to the faint changes of environmental, especially moisture, temperature and the amount of litter supply (Yusnaini et al. 2002). According to researchers findings (e.g., Brady and Weil 2002) erosion rates appear to have increased in DS compared to the FS. The increased erosion then acted as an important driver, which affected other soil features and nutrient levels. Erosion could have increased the bulk density of the DF (Brady and Weil 2002). It is important to note, however, that compaction due to local residents and also livestock in the DS and potentially lower amounts of vegetative residue inputs into the soil leading to lower levels of soil organic matter in DS as compared to the FS could also have contributed in creating the differences in the soils' relative bulk densities (Abassi et al. 2007; Khresat et al. 2008). In agreement with the bulk density levels found in the DS and FS in the current study, many other studies have also found bulk density to be higher in disturbed sites compared to natural forests, especially in highly degraded or overgrazed pasture lands (Abril and Bucher 2001; Celik 2005; Basaran et al. 2008).

In addition, a greater amount of bulk density at the DS can be related to soil texture. Kooch (2007) found that bulk density has a negative correlation with content of clay and positive correlation with sand, thus the bulk density tended to be less in clay soils compared with sandy soils. Lower values of bulk density may be due to presence of high organic matter content at the FS because OM had a significant effect on the bulk density of soils (Handayani et al. 2012). The components of soil texture are influenced by canopy cover in the forest ecosystems (Kooch et al. 2013b). With degradation of forest and opening of canopy cover rainfall will effect on these components as direct. Clays and silts with considering smaller size transferring to beneath layers whereas sands are stable in upper soil. This status can be regarded in this research also. As, greater amounts of sand contents were found at the DS compared to FS. Increase in absorption of solar radiation by mineral soil due to removal of forest cover by deforestation has led to the warming of the soil which in turn caused increased air and soil temperature and following reduce of soil moisture (Hashimoto and Suzuki 2004) in our research. Soil acidification often occurs with NO^{3-} leaching and nitrification (Kooch et al. 2010). We are suspect that the leaching in DS is due to reduction of soil pH values. Further differences in available Ca between two sites could be due to soil pH. As FS had higher pH than DS the availability of base cations like Ca increases with increase in pH (Onweremadu 2007).

Regarding to higher carbon to nitrogen ratio in FS compared DS; the greater amounts of carbon and nitrogen were detected in FS (Unpublished data). Deforestation can impact soils in multiple ways including reducing organic carbon and nitrogen (Pennock and Kessel, 1997). It has also been shown to reduce the cation exchange capacity of the soil and the levels of soil nutrients such as calcium (Eden et al. 1991). Organic carbon and organic matter are added to the soil primarily from decomposing vegetative residues such as leaves, litter, and roots and a decrease in these inputs can lead to a decrease in soil organic carbon and matter (Bernoux et al. 1998). Also, organic matter and organic carbon often accumulate at the top of the soil profile and therefore their abundance in a soil can be reduced by erosion (Abbasi and Rasool 2005; Zheng et al. 2005). The higher levels of organic carbon in the FS compared to the DS could be attributed to these factors. Deforestation and the essential removal of all tree biomass for use as fuel wood removed organic material high in nutrients (Khresat et al. 2008). Therefore, following the cut, the DS soils would have had fewer inputs of vegetative residues than the FS soils.

Higher erosion rates after the removal of the overstory in the forest ecosystems could also be removing decomposable vegetative material as well as the upper levels of soil where organic matter would accumulate. The removal of the overstory vegetation have increased the solar radiation reaching the soil surface and raised daytime temperatures. This would decrease organic matter by increasing organic matter mineralization rates in the soil (Zou et al. 2007). Zheng et al. (2005) found erosion to result in a loss of 69% of organic matter seven years after deforestation. Nitrogen can enter the soil through organic matter, precipitation, and also through biological nitrogen fixation. Nitrogen leaves the soil through leaching, volatilization, and biological uptake (Wachendorf et al. 2008). The higher levels of total nitrogen in the FS compared to the DS can be explained by the higher amounts of organic matter in the forest soils. In addition, removing the overstory in the DS could have caused increased organic matter decomposition and nitrogen transformation rates resulting in more nitrogen being leached out of the soil (Khresat et al. 2008). In another study where erosion was an important driver of site characteristics, Zheng et al. (2005) reported that erosion following deforestation resulted in a 46.7% decrease in total nitrogen.

The accurate information on earthworm ecology and population is very important for maintaining the sustainability of forest productivity. The use of this information can be directed toward maximizing beneficial effects and contributing to richness of the concerned lands. According to our findings in present research, whole of studied soil features were significantly imposed by deforestation. Also, our data showed that FS has more appropriate position for earthworm living. Greater amounts of moisture (Saleh Rastin, 1978; Londo 2001; Nachtergale et al. 2002; Whalen and Costa 2003; Valckx et al. 2009), pH (Neirynck et al. 2000; Deleporte 2001; Decaëns and Rossi 2001; Jiménez et al. 2001; Whalen and Costa 2003) and Ca (Kooch and Jalilvand 2008) in FS creates good conditions for gathering of earthworms. Our results suggest that deforestation should be regarded as an effective factor on variability of soil features that are tied to forest ecology. This is significant for evaluating forest management policies and practices with respect to effects on soil and also for the use of soils as indicators, especially earthworms as bio-indicator, of forest ecosystems.

A fractal dimension is a ratio providing a statistical index of complexity comparing how detail in a pattern (strictly speaking, a fractal pattern) changes with the scale at which it is measured. It has also been characterized as a measure of the space-filling capacity of a pattern that tells how a fractal scales differently than the space it is embedded in; a fractal dimension does not have to be an integer (Kenneth 2003). In the present research the fluctuation and fractal dimension of soil features were studied in FS and DS. The analysis of spatial dependence presented different spatial distribution and spatial dependence for whole of soil features. Bulk density, silt, moisture, pH, earthworm density and biomass presented shorter variability amplitude in FS compared to DS. Whereas sand, carbon to nitrogen ratio and Ca showed shorter variability amplitude in DS. In general, our finding implied that soil features have weak spatial correlation in both of studied sites, especially FS.

CONCLUSION

Lowland forests in the northern Iran have been influenced by humans for centuries, mainly through activities such as timber extraction and grazing. The present structure and composition of these forests are largely a result of these past activities. Deforestation brought a lower soil quality in the sites under the study. Soil quality was examined through determination and comparing of some soil physico-chemical and biological. Decreasing silt, clay, moisture, pH, carbon to nitrogen ratio, available Ca, earthworm density and biomass, increasing bulk density and sand were few outcomes of the deforestation. Except for clay, the deforestation affect on fractal dimension of soil features. The fractal dimension of bulk density, silt, moisture, pH, earthworm density and biomass were decreased imposed by deforestation.

REFERENCES

Abbasi MK, Rasool G. 2005. Effects of different land-use types on soil quality in the hilly area of Rawalakot Azad Jammu and Kashmir. Acta Agriculturae Scandinavica 55: 221-228.

Abbasi MK, Zafar M, Khan SR. 2007. Influence of different land-cover types on the changes of selected soil properties in the mountain region of Rawalakot Azad Jammu and Kashmir. Nutr Cycl Agroecosyst 78: 97-110.

Abril A, Bucher EH. 2001. Overgrazing and soil carbon dynamics in the western Chaco of Argentina. Appl Soil Ecol 16: 243-249.

Allison LE. 1975. Organic carbon In: Black CA (Ed.). Methods of soil analysis. American Society of Agronomy, Part 2, Madison, WI.

Basaran M, Erpul G, Tercan AE, Canga MR. 2008. The effects of land use changes on some soil properties in Indagi Mountain Pass-Cankiri Turkey. Environ Monit Assess 136:101-119.

Bernoux M, Cerri CC, Jener CN, Moraes FL. 1998. The use of stable carbon isotopes for estimating soil organic matter turnover rates. Geoderma 82: 43-58.

Bouyoucos GJ. 1962. Hydrometer method improved for making particle size analysis of soils. Agron J 56: 464-465.

Brady NC, Weil RR. 2002. The Nature and Properties of Soil, 13th ed. Prentice Hall, New Jersey.

Bremner JM, Mulvaney CS. 1982. Nitrogen-total. In: Page A.L, Miller R.H, Keeney RR. (Eds.). Methods of Soil Analysis, Part 2. Second ed. American Society of Agronomy, Madison, WI.

Burt R. 2004. Soil Survey Laboratory Methods Manual. Soil Survey Investigations Report No. 42. Version 4.0. Lincoln, United States Department of Agriculture Natural Resources Conservation Service.

Caruso B. 2002. A survey comparing streams from forested and deforested watersheds to assess impact of land use change on the northeastern shore of Lake Tanganyika. Nyanza 2002 Annual Report.

Celik I. 2005. Land-use effects on organic matter and physical properties of soil in a southern Mediterranean highland of Turkey. Soil Till Res 83: 270-277.

Chakravarty S, Ghosh SK, Suresh CP, Day AN, Sgukla G. 2012. Deforestation: Causes, effects and control strategies, global perspectives on sustainable forest management. Dr. Clement A. Okia (ed.), InTech. http://www.intechopen.com/books/globalperspectives-onsustainable-forest-management/deforestation-causes-effects-and-control-strategies.

Decaëns T, Rossi JP. 2001. Spatio-temporal structure of earthworm community and soil heterogeneity in a tropical pasture. Ecography 24: 671-682.

Deleporte S. 2001. Changes in the earthworm community of an acidophilus lowland beech forest during a stand rotation. Soil Biol 37: 1-7.

Duffkova R, Macurova H. 2011. Soil biological quantity and quality parameters of grasslands in various landscape zones. Pl Soil Environ 57: 577-582.

Eden MJ, Furley PA, McGregor DFM, Milliken W, Ratter JA. 1991. Effect of forest clearance and burning on soil properties in northern Roraima, Brazil. For Ecol Manag 38: 283-290.

Edwards CA, Bohlen PJ. 1996. Biology and Ecology of Earthworms, 3rd. Chapman and Hall, London.

Groffman MP, Bohlen JP, Fisk CM, Fahey JT. 2004. Exotic earthworm invasion and microbial biomass in temperate forest soils. Ecosystems 7: 45-54.

Handayani IP, Prawito P, Ihsan M. 2012. Soil changes associated with Imperata cylinderica grassland conversion in Indonesia. Interl J Soil Sci 7: 61-70.

Hashimoto S, Suzuki M. 2004. The impact of forest clear-cutting on soil temperature: A comparison between before and after cutting and between clear-cut and control sites. J For Res 9: 2407-2415.

Jiménez JJ, Rossi JP, Lavelle P. 2001. Spatial distribution of earthworms in acid soil savannas of the eastern plains of Colombia. Appl Soil Ecol 17: 267-278.

Kenneth F. 2003. Fractal Geometry. Wiley, New York.

Khosroshahi M, Ghavvami S. 2006. Warning, the conservation of nature, Poone Publishing, Tehran.

Khresat S, Al-Bakri J, Al-Tahhan R. 2008. Impacts of land use/cover change on soil properties in the Mediterranean region of northwestern Jordan. Land Degrad Dev 19: 397-407.

Kooch Y. 2007. Determination and differentiation of ecosystem units in relation to soil properties in Khanilan forests. [M.Sc. Thesis], Mazandaran University, Iran.

Kooch Y, Jalilvand H. 2008. Earthworms as ecosystem engineers and the most important detritivors in forest soils (Review). Pakistan J Biol Sci 11: 819-825.

Kooch Y, Hosseini SM, Mohammadi J, Hojjati SM. 2010. The effects of gap disturbance on soil chemical and biochemical properties in a mixed beech-hornbeam forest of Iran. Ecologia Balkanica 2: 39-56.

Kooch Y, Hosseini SM, Mohammadi J, Hojjati SM. 2013a. Effects of pit and mound landscape on soil ecosystem engineers at local scales-a case Study in Hyrcanian forest. Mol Soil Biol 4: 7-15.

Kooch Y, Hosseini SM, Mohammadi J, Hojjati SM. 2013b. Variability of light and soil physics indicators following gap formation in the Caspian forest, Iran. Environ Sci: An Indian J 8: 244-251.

Kooch Y, Jalilvand H, Bahmanyar MA, Pormajidian MR. 2007. Ecological distribution of indicator species and effective edaphical factor on the northern Iran lowland forests. J Appl Sci 7: 1475-1483.

Londo AJ. 2001. Bucket mounding as a mechanical site preparation technique in wetlands. NIAF 18: 7-13.

Malgwi WB, Abu ST. 2011. Variation in some physical properties of soils formed on a hilly terrain under different land use types in Nigerian Savanna. Intl J Soil Sci 6: 150-163.

Myers N. 1994. Tropical deforestation: rates and patterns. In: Brown K, Pearce D (eds). The causes of tropical of tropical deforestation. The economic and statistical analysis of factors giving rise to the loss of the tropical forest. UCL Press, NY.

Nachtergale L, Ghekiere K, Schrijver AD, Muys B, Lussaert S, Lust N. 2002. Earthworm biomass and species diversity in windthrow sites of a temperate lowland forest. Pedobiologia 46: 440-451.

Neirynck J, Mirtcheva S, Sioen G, Lust N. 2000. Impact of *Tilia platyphyllos* Scop. *Fraxinus exceslsior* L, *Acer pseudoplatanus* L, *Quercus robur* L, and *Fagus sylvatica* L. on earthworm biomass and physico-chemical properties of loamy topsoil. For Ecol Manag 133: 275-286.

Nkongolo NV, Plassmeyer CJ. 2010. Effect of vegetation type on soil physical properties at Lincoln university living laboratory. Research J Forestry 4: 1-13.

Onweremadu EU. 2007. Availability of selected soil nutrients in relation to land use and landscape position. Intl J Soil Sci 2: 128-134.

Palm J, Van Schaik NL, Schorder B. 2013. Modeling distribution patterns of anecic, epigeic and endogeic earthworms at catchment-scale in agro-ecosystems. Pedobiologia 56: 23-31.

Pennock DJ, Kessel C. 1997. Clear-cut forest harvest impacts on soil quality indicators in the mixed wood forest of Saskatchewan, Canada. Geoderma 75:13-32.

Plaster EJ. 1985. Soil science and management. Delmar Publishers Inc, Albany, NY.

Poorzady M, Bakhtiari F. 2009. Spatial and temporal changes of Hyrcanian forest in Iran. For Biogeosci For 2: 198-206.

Rahmani R. 2000. Investigation of population and biodiversity of invertebrates in forest types of Neka. [Ph.D. Dissertation]. Tarbiat Modarres University, Iran.

Saleh Rastin N, 1978. Soil biology, Publishing of Tehran University, Iran.

Valckx J, Cockx L, Wauters J, Van Meirvenne M, Govers G, Hermy M, Muys B. 2009. Within-field spatial distribution of earthworm populations related to species interactions and soil apparent electrical conductivity. Appl Soil Ecol 41: 315-322.

Van Kooten GC, Bulte EH. 2000. The economics of nature: managing biological assets. Blackwells, NY.

Wachendorf C, Lampe C, Taube F, Dittert K. 2008. Nitrous oxide emissions and dynamics of soil nitrogen under 15N-labled cow urine and dung patches on a sandy grassland soil. J Pl Nutr Soil Sci 171:171-180.

Whalen JK, Costa C. 2003. Linking spatio-temporal dynamics of earthworm populations to nutrient cycling in temperate agricultural and forest ecosystems. Pedobiologia 47: 801-806.

Xu Q, Jiang P, Xu Z. 2008. Soil microbial functional diversity under intensively managed bamboo plantations in Southern China. J Soils Sed 8: 177-183.

Yusnaini S, Niswati A, Arif MAS, Matsumoto M, Nonaka M. 2002. Earthworm population in deforested lands in hilly area of Sumberjaya West Lampung. J Tanah Trop 14: 141-146.

Zheng F, He X, Gao X, Zhang C, Tang K. 2005. Effects of erosion patterns on nutrient loss following deforestation on the Loess Plateau of China. Agric Ecosyst Environ 108: 85-97.

Zou C, Wang K, Wang T, Xu W. 2007. Overgrazing and soil dynamics in eastern Inner Mongolia of China. Ecol Res 22: 135-142.

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The threates on the biodiversity of Bisotun Wildlife Refuge and Bisotun Protected Area (BPA & BWR) in the west region of Iran

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ABSTRACT

Reyahi-Khoram M, Rizvandy M, Reyahi-Khoram R. 2014. The threates on the biodiversity of Bisotun Wildlife Refuge and Bisotun Protected Area (BPA & BWR) in the west region of Iran. Biodiversitas 15: 67-74. Nature is necessary for the preservation of species and biodiversity richness; as a result, it has been protected for thousands of years. Bisotun Protected Area and Bisotun Wildlife Refuge (BPA & BWR) with about 95000 hectares is located in Kermanshah province in the west of Iran. The object of this study is to determine the physical properties and analyze the constraints that threaten the BPA & BWR. This research was conducted during the period from May, 2011 to November, 2012 in BPA & BWR. In this research, various animal and plant species were recognized through documentary analysis and also directs field observations. The obtained result indicates that major threates have occurred in biodiversity and ecosystem of BPA & BWR during 1980-2010. During these years, the study area has completely failed and lost some of its biological diversity. Limiting factors that affect wildlife population growth including destruction and conversion of habitats, unauthorized hunting and high frequency presence of animal and human, have influenced the restoration potential of wildlife, the habitats and other conservation areas.

Key words: Biodiversity, Bisotun, environment, habitat, wildlife

INTRODUCTION

Preserving large predators is important but challenging because these species are typically wide-ranging, select multiple habitats at different scales and often present spatial or habitat separation between the breeder and floater sectors of a population (Tanferna et al. 2013). Protection of biodiversity and genetic Diversity could reliably support the goals of development. Today's, the process of destruction of habitats has outrivaled restoration and reconstruction. Extinction of species in all growth ecosystems has had a soaring increase and once the scientists do not investigate and solve this crisis, within a short time it would threaten the life of many plant and animal species (Reyahi-Khoram and Norisharikabad 2010). A protected area can be defined as “geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values”. It has become a universally adopted way of conserving biodiversity for a wide range of human values (Ahmad et al. 2012). Wildlife refuge means Areas covering typical wildlife habitats selected with the purpose of preserving the population of animal species and improving their level of quality. The minimum area of a wildlife refuge must suffice to fulfill the animal species needs as well as the integrity and interactions among its units. These areas are appropriate places for educational and research activities especially those pertaining to wildlife. Compatible utilizations and controlled tourism are allowed in refuges (Darvishsefat et al. 2008).

The climatic diversity of Iran has resulted in the growth of 7576 plant species, the occurrence of 517 bird species, 208 reptile species, 170 fish species, 164 mammal species and 22 amphibians (Reyahi-Khoram and Norisharikabad 2010). The legislation of the Protection Bill and the establishment of the Iranian Center for Hunting in 1956 are considered as the first documented actions taken toward protecting the Iranian wildlife population and diversity. This led to the formation of a new governmental organization in 1967 entitled the Hunting and Fishing Organization. Therefore, the year 1967 marked the pioneer attempts for the foundation of the Iranian protected areas, 95 years after the establishment of the first national park in the world (Yellowstone National Park in the USA) and 19 years after the foundation of the World Conservation Union (IUCN). In this year, the proposal for the foundation of three national parks and 15 protected areas was approved by the Supreme Council of Hunting and Fishing as the first series of protected areas in Iran. (Darvishsefat et al. 2008).

Kermanshah province is in the western of Iran, covers an area of 24,434.25 sq km which is approximately 1.5 percent of Iran's total land area. Kermanshah has a moderate mountainous climate and has been the home of man since the Paleolithic and Neolithic age. The economic livelihood of the population is dependent on agriculture,

tourism and manufacturing (Mohammadi and Khalifah 2010). Kermanshah province has one wildlife refuge (Bisotun Wildlife Refuge) and four protected areas: Bisotun, Bozin Merkhil, Badroparishan and Galajee covering an area of 166,000 hectares which is nearly 6.8% of the total area of the province.

The aim of this research is to evaluate the physical properties and analyze the constraints that threaten the Bisotun Protected Area and Bisotun Wildlife Refuge (BPA & BWR) in the province. Other objectives of the research include defining the ways to improve the plans for biodiversity conservation and protection.

MATERIALS AND METHODS

This research was conducted during the period from May, 2011 to November, 2012 in BPA & BWR to identify various plant and animal species through documentary analysis and also direct field observations. Means, the physical properties and condition of BPA & BWR were studied based on careful field observation and document research during the study period. Accredited scientific references were used to identify dominant plant and animal species (Ziaie, 1996; Lotfi 2000; Mansoori 2001; Mozaffarian 2006; Reyahi Khoram et al. 2013). Therefore, various animal and plant species were recognized during the mentioned period. Applied results presented in this study are based on the valid audit reports from experts and forest rangers in various times and locations in the studied area.

To determine the ecological resources of the area, digital maps were used and on this basis the topology situations as well as ground cover of studied area have been accomplished. In addition, Geographic Information System (GIS) and other technology such as remote sensing were used in this study (Demers 2009). The software used was Arc View (version 3.2a) with the Universal Transverse Mercator (UTM) projection and scale was 1/50,000.

RESULTS AND DISCUSSION

General status of the region

BPA & BWR are two of the areas in the country where the richness of biodiversity has been preserved by Department of Environment (DoE) of Iran. These areas are in critical danger of expansion of human population centers, unsustainable industrial and agricultural activities and other human impacts.

Bisotun Protected Area (BPA) with 40,000 hectares surface area is situated between 34º,22',00" and 34º,37',30" northern latitudes and between 47º,09',00" and 47º,26',30" eastern longitudes, on Northern East of Kermanshah Township, Iran. Slightly behind the mentioned area, is Bisotun Wildlife Refuge (BWR) with 55,000 hectares surface area that is situated between 34º, 27', 30" and 34º, 44', 00" Northern East latitudes and between 46º, 54', 00" and 47º, 11', 00" eastern longitudes (Figure 1). However, regions are located in west of Iran. In 1975, BPA and BWR were officially declared as protected area and Wildlife Refuge respectively.

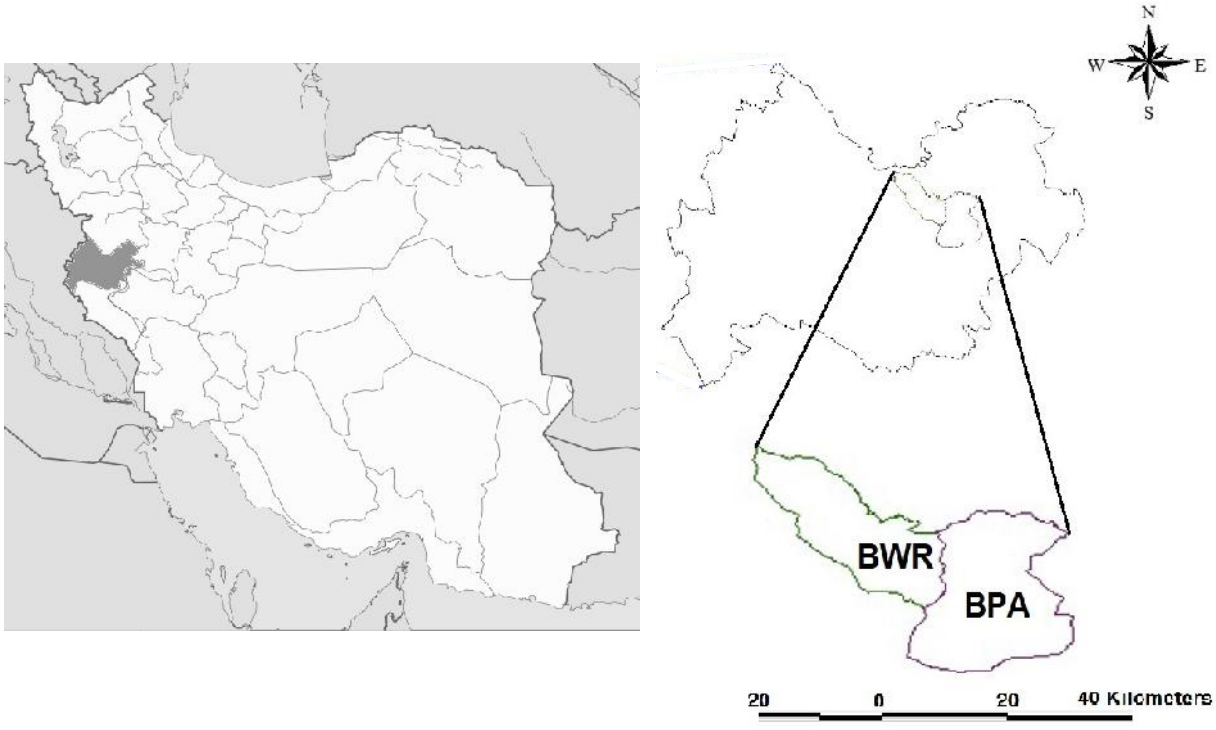

Figure 1. General status of BPA & BWR in Kermanshah Province, Iran.

In 2009, Poraw Cave at BPA was announced as national natural monuments by DoE. This cave is located in the Poraw Mountain (Zagros Mountain Range) and the cave opening is a small hole. It is to be noted, that Poraw Cave has unique characteristics that distinguish it from similar caves. Means it is a vertical cave with a height of 3000 meters from sea level located in a Karst formation. The cave measures approximately1454 meters in length and 751 meters in depth and inside the cave there are 26 wells in depths ranging between 5 to 42 m. Caving is extremely difficult because the cave body is rocky and porous. It should be noted that Poraw Cave is also important from tourism point of view.

Therefore, BPA & BWR with about 95000 hectares is located in a mountain area characterized by vast open plains which are surrounded by cities. In the other hands, the cities of Kermanshah, Harsin, Kangavar, Songhor and Kamyaran are located around the said regions.

Razavar River on the north of the region, Dinvar River on the east, the flat plains surrounding the river, as well as communication roads have led to formation of various types of habitats and concentration of economic activities around the region. In general, the studied region is effective under arid to semi-arid climate condition with cool to hot summers and cold winters.

Wildlife of the region

The studied region has a variety of animal species including Mammals, Birds, Reptiles, and Fishes. In the following, the characteristics of each are explained.

Mammals

Because the region is mountainous and has been preserved by DoE, most wild animal species can be observed in these areas. Totally 22 mammal species belong to 12 family were recorded throughout the study area (Table 1). Here, some important and typical species in the study area are described in the following section.

Wild goat. This species is one of the largest herbivore of the study area. At present time, its population has extremely diminished because of the limiting factors. The sharp decrease in the number of wild goat in the studied area could be attributed to lack of suitable habitat due to human interference, especially over-grazing impact, expansion of human habitats, development of industrial and service activities, lack of control and management as well as irregular, unlimited and unauthorized hunting by clan hunters, nomads, farmers and other native people and also, severe drought in recent years. Field studies showed that although the condition for successful migration of this species between Varmanjeh wildlife refuge and BPA & BWR is available, wild goat cannot easily pass between the two regions. The species pass only through limited and impassable cliff valleys. Field studies based on observations and interviewing the local people and forest rangers showed that wild goats in these habitats are mainly young while the old animals are very rarely seen. They can be observed only occasionally on the heights of complete rocky structure. In general, the status of populations of this species has declined within the last two decades due to habitat destruction for agricultural uses, urban and industrial developments and over hunting; so that only small herds of about 2 to 3 animals could be seen. The remaining population is mainly young which are commonly seen in rocky and inaccessible heights. The existing population is very vigilant and unquiet which reacts upon events in its surroundings.

Wild sheep. This species is the giant herbivore of the studied area. Their habitat with a less steep slope is located in the lower portion of Wild goat habitat. This species' population has decreased because of human impact, which includes agriculture and industrial development. Means, decrease in Wild goat population is similar to the causes that have been described previously for Wild Goat.

Table 1 . List of mammal species in BPA & BWR

Scientific name	Family
Canis aureus (Golden jackel)	Canidae
Canis lupus (Wolf)	Canidae
Capra aegagrus (Wild goat)	Bovidae
Felis silvestris	Felidae
Gerbillus nanus	Muridae
Hemiechinus auritus	Erinaceidae
Hyaena hyaena (Striped hyaena)	Hyaenidae
Hystrix indica	Hystricidae
Lepus europaeus (European hare)	Leporidae
Meriones persicus	Muridae
Miniopterus schreibersii	Vespertilionidae
Mus musculus	Muridae
Ochotona Rufescens	Ochotonidae
Ovis orientalis (wild sheep)	Bovidae
Panthera pardus saxicolir (North persian leopard)	Felidae
Paraechinus hypomelas	Erinaceidae
Pipistrellus kuhlii	Vespertilionidae
Rhinolophus euryale	Rhionolophidae
Sciurus anomalus	Sciuridae
Sus scrofa (Wild boar)	Suidae
Ursus arctos (Brown bear)	Ursidae
Vulpes vulpes (Common fox)	Canidae

The habitat of this species is more accessible. The presence of domesticated animal in the habitat of wild sheep is easier than the presence of domesticated animal in the mountainous rocky areas and Wild goat habitat. On this basis, its population is more susceptible than Wild goat population. The recorded observations in the studied region showed that the species population was mostly unquiet and highly vigilant. They respond very quickly to the events such as sound and smell. The observations of this species were possible through long distance. These behaviors proved that wild sheep population in the studied region was extremely influenced by stressful environmental conditions. Although this population is relatively young, its growth and survival rate is slow due to the prevailing environmental conditions such that birth rate of the species does not make up for the animal death due from natural and unnatural causes. Therefore wild goat population has had a descending trend during the past years.

North persian leopard. This species is at the top of food pyramid and is very sensitive to stressful environmental conditions. This species are present in mountainous areas where they find a good prey such as wild goat, wild sheep or wild boar. The appropriate habitat for this animal is mountainous rocky areas. All of these conditions were available in the studied area. Means, wild goat, wild sheep or wild boar are the main native prey species of this region. When the population of these species is stable, north persian leopard species is stable too.

It is impossible to record the real number of north persian leopard species population because of the undercover nature of their life, being nocturnal, having fair habitat conditions, and the calm behavior and habits of animal. This species is only found by chance at a moment and quite accidentally. For this reason, it is not possible to determine the exact numbers available in the study area. The only figures representing the north persian leopard species are related to BPA. The figures represent one north persian leopard species in 1987, one in 1991, and five in 1994. Still there is controversy around five because it is practically out of question to see five north persian leopard species at a time. Even if such figure was correct, the information and reports presented later raised controversy on the presence of the species in the study area.

Questioning the natives that are residing in the area revealed that not even one north persian leopard species was observed during the past five years. Based on the opinions of locals, an overwhelming number of this species lived in BPA & BWR during the 1970s and 80s; but there are no reliable statistics on the real number of north persian leopard species in the studied area. Observations by native people conform to the norm of survival of wild goat and wild sheep during the 1970s and 80s. Means, in the last time, the balance of predator and prey was dominant in the studied area. As prey species have decreased in BPA & BWR, so have the number of north persian leopard. Although there is limited information on the presence of north persian leopard in this area, but no organization or individual has announced its extinction in BPA & BWR.

Brown bear. This species is the only species of the family Ursidae which lives in the study area. The species' population has been reduced by human influences in this area and is observed only by chance and very rarely. Past and current studies show that brown bear population was not widespread and extensive during 1980s but more frequent than today. It seems that habitat destruction and over exploitation by grazing are the most likely factors contributing to these changes.

Moreover, the extension of human habitat into the forests and cutting of shrubs and trees including chestnut and wild pear for various purposes, notably for fuel wood and charcoal, play a significant role in reduction of bears. These factors were exacerbated by drought and other events in the last decade and have made harmful impacts in reduction of bears in the study area. Available information shows that the species were seen in low numbers during the last 2 decades. In the other words, all extant brown bears species of the region are prone to extinction.

Wolf. This species is the largest of the Canidae or dog tribe and is one of the most widespread carnivores in the region. Wolves are capable of traveling long distances in pursuit of prey and persisting in the environment. It survives not merely on big and small animals, but also on domestic animals that play a major role to the persistence of wolves in the study area. The species uses BPA & BWR and Varmanjeh wildlife refuge as a den or a safe place. Wolves are settling more permanently in BPA & BWR because it is more mountainous and thus more impassable than Varmanjeh wildlife refuge. Other reasons for presence of more wolves in BPA & BWR are extensive grazing of domestic animals, rock dens (caves), and a number of mountain refuges. This species has no destructive impact on the population of big herbivores but have a role in improving local ecosystems and natural habitats.

Common fox. The fox is an omnivore and most active at night with a relatively small home range. This species movement to the higher areas in summer seasons although is also commonly seen in rural areas during cold seasons. Based on the observations made in the area, the presence of the species has been confirmed in the surrounding areas particularly in residential areas where they find food. Like other carnivores, the fox population had been large fluctuations during the past two decades and these fluctuations are a downward trend. The decrease in the fox population is partly due to limited food availability, unauthorized hunting and competing with other carnivores.

Golden jackel. The range of this species in BPA & BWR overlaps with that of fox. But the number of fox population species is greater than that of the Golden Jackel. The habits and behavior of golden jackel are a little different from fox. Based on the results and observation, this species is more adapted to the current conditions of the studied region and take greater advantage of all available food sources. In other words, golden jackel successfully competes with foxes, although the feeding regimen has been the same. Based on the experimental observation, the golden jackel population has an ascending trend during the past years. This is in contrast to other species of the study area, which had a descending trend during this period. This increase is the result of lack of rival carnivores in the region, having a wide range of food, adoptability, lack of its natural predators and lack of interest and attention of humans for its prey.

Wild boar. This species lives in many parts of Iran such as the areas close to the rivers or springs. It can live in BPA & BWR and adapts itself to different conditions. Permanent fresh water springs and rivers such as the two rivers flowing in the region (Dinvar and Razavar), grass lands and oak forests have created ideal conditions for this species in the region. Although it is a carnivore, it eats lots of fruits, seeds, berries and vegetables because it is easy to get and available in abundance. Wild boar is abundant in prairie and forest, but is only found in plain areas. The species can be observed occasionally in the groups of 3 to 5 animals regarding the present condition of the region.

Although wild boar has a valuable ecological role in the balance of nature, it is not in a good condition because it can cause considerable damage to agricultural crops. Also, wild boar can be dangerous to people and are known to

cause injuries in rural areas of BPA & BWR. These research and observation indicate that, this species is limited by food shortages in the region. Feces samples analysis of the species showed abundant amounts of rat remains, the persian jird (*Meriones persicus*) and other mammals and small birds.

European hare. This mammal is uniformly distributed across the entire the study area with the exception of rocky and mountain areas. The abundance and distribution of this species in farming lands is higher than the regions with natural features. The high consumption of this species by the carnivores from one side, and its hunting by human predators on the other side, has caused declines in this species in BPA & BWR. As a consequence of these two events, this species lacks extensive distribution despite high production of its members. In general, it moves slowly and remains at home range most of the time. Also, it's offspring inside the home range.

Striped hyena. This animal is an active mammal with an extensive home range. Striped hyena is a skillful hunter, but mostly acts as a scavenger. Thus, its home range depends on the home range of other predators. In BPA & BWR, the hyena population has decreased from several years ago and it is seen more rarely. This situation is coherent with reduction of other species of wildlife in the region as a result of unnatural factors and drought.

Birds

Birds are usually seen in the study area and their frequency is correlated with the relevance of biological-quality factors. The four essential elements of the birds' biological needs, water, food, security and shelter have attracted almost 14% of the bird species in Iran to the study area. Among these factors, the role of security is more important than other factors.

Totally 60 bird species belong to 21 family were recorded within the study area (Table 2). 52% of the birds of BPA & BWR are native while others are migratory. Means, the birds of BPA & BWR are divided into two main groups, based on the time of their presence in the region; native birds and migratory birds.

Native birds of BPA & BWR appear in the region in all of seasons, where they reproduce and do not leave the region. The typical species of native birds includes common raven (*Corvus corax*), little owl (*Athene noctua*), rock dove (*Columba livia*), rook *(Corvus frugilegus),* see-see partridge *(Ammoperdix* griseogularis), common magpie (*Pica pica*), red-billed chough (*Pyrrhocorax pyrrhocorax*) and chukar partridge *(Alectoris chukar*). Some of these species have economic values. The Passeridae family species have adapted to live in human communities and they are distributed around the villages and human communities of the study area.

Migratory birds are part of the biological diversity of BPA & BWR. Some of migratory birds come to the region in spring and reproduce and then leave the region. The typical of this group is black-headed bunting *(Emberiza melanocephala*). Also, some of migratory birds pass through the region during spring and fall time. They are seen in the region for a few days.

Table 2 . List of bird species in BPA & BWR, northern Iran

Family	**Scientific name**
Accipitridae	*Accipiter gentilis*
Accipitridae	*Accipiter nisus*
Alaudidae	*Alauda arvensis*
Phasianidae	*Alectoris chukar*
Phasianidae	*Ammoperdix griseogularis*
Anatidae	*Anas crecca*
Anatidae	*Anas platyrhynchos*
Anatidae	*Anser anser*
Apodidae	*Apus apus*
Accipitridae	*Aquila chrysaetos*
Accipitridae	*Aquila heliaca*
Accipitridae	*Aquila pomarina*
Accipitridae	*Aquila rapax*
Ardeidae	*Ardea cinerea*
Ardeidae	*Ardera purpurea*
Strigidae	*Athene noctua*
Strigidae	*Bubo bubo*
Accipitridae	*Buteo buteo*
Sylviidae	*Cettia cetti*
Columbidae	*Columba livia*
Columbidae	*Columba oenas*
Columbidae	*Columba palumbus*
Coraciidae	*Coracias garrulus*
Corvidae	*Corvus corax*
Corvidae	*Corvus corone*
Corvidae	*Corvus frugilegus*
Corvidae	*Pica pica*
Corvidae	*Pyrrhocorax pyrrhocorax*
Ardeidae	*Casmerodius albus*
Phasianidae	*Coturnix coturnix*
Cuculidae	*Cuculus Canorus*
Ardeidae	*Egretta garzetta*
Emberizidae	*Emberiza melanocephala*
Falconidae	*Falco cherrug*
Falconidae	*Falco peregrinus*
Falconidae	*Falco subbuteo*
Falconidae	*Falco tinnunculus*
Alaudidae	*Galerida cristata*
Corvidae	*Garrulus glandarius*
Accipitridae	*Gypaetus barbatus*
Accipitridae	*Gyps fulvus*
Accipitridae	*Hieraeetus fasciatus*
Sylviidae	*Hippolais pallida*
Sylviidae	*Locustella luscinioides*
Sylviidae	*Locustella naevia*
Alaudidae	*Melanocorypha calandra*
Meropidae	*Meriops apiaster*
Passeridae	*Montfringilla nivalis*
Accipitridae	*Mulvus migrans*
Accipitridae	*Neophron percnopterus*
Passeridae	*Passer domesticus*
Passeridae	*Passer hispaniolensis*
Passeridae	*Petronia brachydactyla*
Sylviidae	*Phylloscopus trochilus*
Picidae	*Picoides major*
Picidae	*Picoides medius*
Picidae	*Picoides minor*
Picidae	*Picoides syriacus*
Pteroclidae	*Pterocles coronatus*
Pteroclidae	*Pterocles orientalis*

The typical migratory species recorded in documents and observations include mallard ducks (*Anas platyrhynchos*), common teal (*Anas crecca*), greylag goose, (*Anser anser*), grey heron (*Ardea cinerea*), purple heron (*Ardea purpurea*), great egret (*Casmerodius albus*), little egret (*Egretta garzetta*), eurasian hobby (*Falco subbuteo*), peregrine falcon (*Falco peregrinus*), saker falcon (*Falco*

cherrug), common kestrel (*Falco tinnunculus*), griffon vulture (*Gyps fulvus*), tawny eagle (*Aquila rapax*) and common buzzard (*Buteo buteo*).

Also, the availability of various types of food in the region attracts birds of different food regimens. From the point of view of food regimen, the birds of BPA & BWR are divided into three main groups: (i) Carnivorous: these birds eat rodents, mice or other small mammals. Carnivorous birds such as falcons, eagles and hawks, which are abundant in the study area. (ii) Herbivorous: these are species of birds which depend on plants for their nutrition. Among the birds which feed on plants the Columbidae family are indigenous or native to the study area and the most important member of this family is *Columba livia*. (iii) Omnivorous: the species of Corvidae family such as *Pica pica* and *Corvus corne* are the most abundant omnivorous species of the region.group of birds can eat everything is easy to access.

Documentary information and field observations prove that some of the typical species of the region have more attention in recent years. Here, some important species in the study area are presented in this section.

Chukar partridge. Chukar partridge is native to the region. It lives in mountainous areas and also observed in plains and farms during cold season. The observations indicate the overall reduction in the number of this species in the region. The number of chukar partridges observed in the BPA & BWR exceeds the chukar partridges in Varmanjeh wildlife refuge. Because BPA & BWR is more mountainous and has high rocky regions with a local habitat to the Chukar Partridge. The reasons of decrease in number of chukar partridges in recent years are difficult to identify. Potential local factors include extensive presence of cattle and sheep dog in the region which has influenced the reproduction, unauthorized hunting, collecting eggs and chicks of chukar partridge by native people and also natural elements such as cold temperatures and heavy snowfall states are often observed there.

See-see partridge. This bird is a native, mountainous species with economic value. Its preferred habitats are the Mounds of the region. The usual number of individuals observed of this species in BPA & BWR is much lower than the number of partridge in the region. The present trend indicates an extreme decrease during recent years. The reduction in the population could be attributed to excessive hunting of the birds and collecting of their eggs, destruction and occupation of preferred habitats and the drought during recent years which may have led to the decline in reproduction and population.

Red-billed chough. Review of literature and field studies indicated the extensive presence of this bird in rocky heights. It has been found that its presence in BPA & BWR is more widespread than Varmanjeh wildlife refuge. It should be noted that the report indicates a decrease in the number of species recorded during recent years. Based on the inspections the downward trend of this species is due to reduction of food and hard climatic conditions particularly during periods of extensive drought. This species is an active bird and can fly beyond the BPA & BWR. But it performs its activities such as reproduction and most of biological activities inside the region and in mountainous areas.

Golden eagle. This species is one of the largest hunting birds of the study area. The preferred habitat of golden eagle is in the middle-high elevation areas of the Rocky Mountains. It nests on the precipices of the rocks and uses it for many years. This species is frequently observed in mountainous areas due to its size and magnificence. For this reason, reviewing the information offered in daily reports book of environmental guard stations in BPA & BWR shows that it has been present in the area from many years ago but its population has been monotonically decreasing with time and interconnectivity.

Reptiles

The reptiles found in BPA & BWR include snakes, turtles and lizards. Reptiles are cold blooded animals and so far about 26 reptile species have been identified in the region. Thirteen species of snakes have been identified in the region; three of these are poisonous, 4 species are semi-poisonous and other is non-poisonous. Since some reptiles are poisonous and they cannot adapt to human life, less research was down about them compared to other animals. Although Reptiles are scattered throughout BPA & BWR and Varmanjeh wildlife refuge, but lizards are observed in plains areas and Snakes are seen in rocky regions and turtles are generally found in riparian areas or flood plains particularly around Dinvar and Razavar rivers.

Amphibians

Three amphibian families have been found in BPA & BWR. Frogs are the most common amphibians in the study area. Also, Ranidae family is the most prominent frog family in the region. The amphibians are carnivorous and can eat fish, small reptiles, worms and insects. Also, are creatures that are consumed by a wide range of predators such as many mammals and birds. Amphibians are distributed in the areas around rivers and water reservoirs. Means, frogs habitats are generally near a water body and are often used as resting sites for many fish eating birds. Other amphibians in the region include green toad (*Bufo virdis*), tree frog (*Hyla savignyi*)) and common toad (*Bufo bufo*). All amphibians have the greatest potential to impact ecological values in the region.

Fish

The Dinvar and Razavar rivers would have provided suitable habitat for the reproduction and survival of a large number of fish species. 13 species of fish have been identified in these two rivers (Table 3). The fishes that are present in these waters are warm water fishes and there is no cold water fish in the said rivers. Every species has ecological value; but only a few have economic value in the fisheries. For this reason, fishing by local people is not considered in the study area. These fishes are restricted only to Teleostei group and mostly belong to Cyprinidae family. Based on the results of observations, most of the fish were carnivorous while a few of them are completely herbivorous and their natural habitat is clear freshwater rivers where they were born and spawn eggs.

Table 3 . List of Fish species in BPA & BWR

Family	Scientific name
Cyprinidae	*Barbus esocinus*
Cyprinidae	*Barbus grypus*
Cyprinidae	*Barbus lacerta*
Cyprinidae	*Capoeta damascina*
Cyprinidae	*Capoeta trutta*
Cyprinidae	*Carassius auratus*
Cyprinidae	*Chalcalburnus chalcoides*
Cyprinidae	*Garra rufa*
Cyprinidae	*Leuciscus cephalus*
Cyprinidae	*Luciobarbus capito*
Mastacembelidae	*Mastacembelus mastacembelus*
Balitoridae	*Nemacheilus frenatus*
Balitoridae	*Nemacheilus kermanshahensis*

Plant coverage of the region

Since economic condition of the native people in rural areas is related to farming, gardening and animal husbandry, BPA & BWR suffer from animal grazing or human activity. About 387 plant species have been identified in the region of which 42 species are endemic of Iran and should be managed as a genetic reserve (Darvishsefat 2006). The important plant species of BPA & BWR are presented in table 4. It is clear that plant cover in the study area is an important factor in water distribution within a watershed. Therefore, grazing management should be designed to prevent or reduce potential adverse effects to the environment. Otherwise, it would cause acute damage to the environment and economic loss for the future.

Table 4. List of important plant species in BPA & BWR

Family	Scientific name
Caryophyllaceae	*Acanthophyllum* sp.
Rosaceae	*Amygdalus scoparia*
Boraginaceae	*Anchusa* sp.
Asteraceae	*Anthemis* sp
Papilionaceae	*Astragalus* sp.
Campanulaceae	*Campanula* sp.
Ulmaceae	*Celtis australis*
Rosaceae	*Cerasus* sp
Asteraceae	*Cirsium* sp.
Rosaceae	*Cotoneaster* sp.
Rosaceae	*Crataegus* sp.
Asteraceae	*Echinops* sp.
Euphorbiaceae	*Euphorbia* sp.
Moraceae	*Ficus johannis boiss*
Lilliaceae	*Fritillaria imperialis*
Fabaceae	*Glycyrrhiza glabra*
Anacardiaceae	*Pistacia atlantica*
Fagaceae	*Quercus brantii*
Ranunculaceae	*Ranunculus* sp.
Rosaceae	*Rosa canina*
Asteraceae	*Senecio* sp.
Poaceae	*Taeniatherum crinitum*

Discussion

As a result, the remaining small population of wildlife consists of young animals. It seems that the newborn population can not compensate for the natural death rate, because of factors such as long-term drought, unauthorized hunting and habitat loss. Therefore the growth rate of existing populations is low and makes no significant contribution to the increase in the number of population. Review of the boundaries of the study area showed that BPA & BWR and Varmanjeh wildlife refuge are surrounded by asphalt roads, agricultural farms and fruit gardens. There is no suitable habitat around the study area. Hence the studied region is separated as an island from other habitats.

The conservation of biodiversity is recognized as a key ecosystem service (Faith and Walker 2002). A few management studies that have been carried out have focused on the improvement of management and environmental education activities in protected areas (Brandon et al. 2005; Xu J. et al. 2006; Geneletti and Iris 2008; Reyahi-Khoram 2010; Andrade and Rhodes 2012). The results of this study may be compared with another study conducted in Kenya reported that Natural forests and mountainous protected areas are critical for ecological services; but are now increasingly becoming endangered ecosystems. Further, they are getting degraded through a variety of land uses such as livestock grazing, deforestation and charcoal burning. The net result has been serious threat to biodiversity and wildlife habitats, ecosystem degradation and loss of ecological services (such as water availability). Conservation authorities and the government have a responsibility to conserve and protect the country's ecosystems and associated biodiversity as both a national service and contribution to global biodiversity conservation (Kiringe and Okello 2007)

Recommendation

In order to follow up the policies and approved programs of DoE related to habitat conservation and wildlife management, it is recommended to protect the BPA & BWR from wildlife hunters and livestock grazing. There are many indigenous people living throughout the world. According to the necessity and needs of the indigenous people and their problematic condition, it is recommended to utilize both indigenous knowledge and scientific knowledge to provide learning/ education for mentioned people around the study area concerned about environmental conservation and sustainability. Since carrying capacity of an ecological system is directly affected by the development, it is recommended that the carrying capacity of the BPA & BWR should be determined before converting it to agricultural development or industrial development projects.

Now a day, ecotourism is one of the most rapidly growing and involves many sectors of the economy and increase the income of local people, improve their quality of life and protect the environments in which they live and on which they depend. Regarding the ecotourism concept and the necessity and importance of their economic functions, it is suggested that the local people's community should become better informed of their surrounding natural environment, recognition of ecotourism's social and economic importance and the role that it plays.

CONCLUSION

The obtained result indicates that the major threats have occurred in BPA & BWR during 1980-2010. During these years, the study area has completely failed and lost some of its biological diversity. Limiting factors that affect wildlife population growth including: destruction and conversion of habitats, unauthorized hunting and high frequency presence of animal and human that have influenced on potential development and restoration of BPA & BWR. The effects of these negative events and weakness in control could decrease wildlife security and increase habitat fragmentation.

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REFERENCES

Ahmad CB, Abdullah J, Jaafar J. 2012. Community activities around protected areas and the impacts on the environment at krau wildlife reserve, Malaysia. Proceeding of ASIA Pacific International Conference on Environment-Behaviour Studies in Cairo, Egypt, 31 October-2 November 2012.

Andrade GSM, Rhodes JR. 2012. Protected areas and local communities: an Inevitable partnership toward successful conservation strategies. Ecol Soc 17 (4): 14.

Brandon K, Gorenflo L.J., Rodrigues A.S.L. and Waller RW. 2005. Reconciling biodiversity conservation, people, protected areas, and agricultural suitability in Mexico. World Dev 33 (9):1403-1418.

Darvishsefat A. 2006. Atlas of protected areas of Iran, Islamic Republic of Iran, Department of the Environment, Tehran.

Darvishsefat AA, Khosravi A, Borzuii A. 2008. Concept of the national atlas of protected areas of Iran and its realization. Proceeding Conference of TS 8H-GIS in Environmental Management, Integrating Generations in Stockholm. FIG Working Week 20081(4-19 June 2008). [Sweden]

Demers M. 2009. Fundamental of Geographic Information System. John Wiley & Sons, New York.

Faith DP, Walker PA. 2002. The role of trade-offs in biodiversity conservation planning: linking local management, regional planning and global conservation efforts. J Biosci 27 (4): 393-407.

Geneletti D, Iris VD. 2008. Protected area zoning for conservation and use: A combination of spatial multi criteria and multi objective evaluation. Landscape Urban Plan 85 (2): 97-110.

Jafari SM, Akhani H. 2008. Plants of Jahan nama Protected Area, Golestan Province, N. Iran. Pak J Bot 40 (4): 1533-1554.

Kiringe JW, Okello MM. 2007. threats and their relative severity to wildlife protected areas of Kenya, Appl Ecol Env Res 5 (2): 49-62.

Lotfi M. 2000. Snakes of Iran, Department of the Environment, Tehran.

Mansoori J. 2001. Field guide to the birds of Iran. Nashre Zehn Aviz, Tehran.

Mohammadi M, Khalifah Z. 2010. Local people perceptions toward social, economic and environmental impacts of tourism in Kermanshah (Iran). Asian Soc Sci 6 (11): 220-225.

Mozaffarian VA. 2006. A dictionary of Iran plant names. Farhang Moaser Publisher, Tehran.

Reyahi-Khoram M, Karami-Nour M. 2010. A case study on environmental evaluation and planning for range and forest management by means of Geographic Information System (GIS). J Agric Sci Technol 4 (6): 57-62.

Reyahi-Khoram M, Norisharikabad V. 2010. Biodiversities and limiting factors of Lashgardar Protected Area (LPA) Hamadan province, Iran. Biodiversitas 11 (4): 216-221.

Reyahi-Khoram M, Norisharikabad V, Safikhani M. 2013. Land dedication for ecodynamic design and ecological conservation, a case study, Int J Des Nat Ecodyn 8 (1): 88-102.

Tanferna A , López-Jiménez L , Blas J, Hiraldo F, Sergio F. 2013. Habitat selection by black kite breeders and floaters: Implications for conservation management of raptor floaters, Biol Conserv 160: 1-9.

Xu J, Chen L, Lu Y, Fu B. 2006. Local people's perceptions as decision support for protected area management in Wolong Biosphere Reserve, China. J Environ Manag 78 (4): 362-372.

Ziaie H. 1996. A filed guide to the mammals of Iran, Department of the Environment, Tehran.

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Conservation status and distribution pattern of the Indus River Dolphin in River Beas, India

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ABSTRACT

Khan MS, Pant A. 2014. Conservation status and distribution pattern of the Indus River Dolphin in River Beas, India. Biodiversitas 15: 75-79. Decline in the populations of Indus River Dolphins *Platanista gangetica minor* throughout its range of distribution and a perception that it is a 'keystone species' for riverine ecosystem stirred the idea of proposed study. Deficiency of baseline data on its distribution and ecology is a major constraint that this (only known sub-population in India) species' conservation is facing in the country. Thus to ascertain its conservation status and distribution pattern, the study was conducted between December 2010 to June 2012. During the study, three schools of dolphins have been identified, one each along Beas bridge-Gagdewal; Baguwal-Dhunda and Karmowala-Harike that comprised of adult, sub-adult and calves. The occurrence dolphins was found attributed to preferred habitat features such as deep pools, slow water current, abundant prey base and low disturbance.

Key words: Conservation, distribution, dolphin, River Beas

INTRODUCTION

The world's freshwaters are among the most bio-diversified ecosystems, inhabited by almost 6% of described species yet covering only 0.8% of the earth's surface. However, they are also hotspots of endangerment and are experiencing declines in biodiversity far greater than those in other ecosystems (Dudgeon et al. 2006; Strayer and Dudgeon 2010). Similar to their habitat, fresh-water dolphins and porpoises are also among the world's most threatened mammals. Freshwater cetacean are distributed among nine river systems or brackish lagoons in Asia, and most of them are listed on the IUCN Red List as Endangered or Critically Endangered (IUCN 2010). After decades of concern about its status, the baiji *Lipotes vexillifer*, is believed to be functionally extinct (Turvey et al. 2007). Its extinction clearly demonstrates the paucity of appropriate approach for cetacean conservation and also questioned the future viability of remaining freshwater cetaceans.

The South Asian river dolphin *Platanista gangetica* occurs in a monotypic genus that includes the Indus River Dolphin *Platanista gangetica minor*, resident in the Indus River system in Pakistan and India, and the Ganges River Dolphin *Platanista gangetica gangetica* found in the Ganges-Brahmaputra and Karnaphuli-Sangu river systems in India, Bangladesh, and Nepal. Both subspecies are listed as Endangered in the IUCN Red List (Braulik 2004; Smith et al. 2004).

River dolphins occupy the top position in riverine ecosystem and hence act as the fulcrum for keeping the balance of its ecosystem. But being found in the world's most densely populated human environments, river dolphins are among the world's most threatened mammalians further their ecological requirements link them to food and water security issues in South Asia (Reeves et al. 2000; Khan 2013). Asian river dolphins have disappeared from much of the historic ranges and are believed to be declining rapidly in many areas where they still occur (Reeves et al. 2000). One such species is Indus River Dolphin locally called as *Bhulan* which is endemic to Indus river system and considered as second most threatened river dolphin after Baiji (Reeves, et al. 2000; Khan 2013). Once the Indus River Dolphin was found in approximately 3400 Km of Indus river and its tributaries from the foothills of Himalayas to the limits of tidal zone in Pakistan (Anderson 1879 and Braulik 2006).

The continuum of its distribution wrecked into small fragmented sub populations, one such population is reported from Punjab (India) in 2007 between Beas city (N 31°30'30.5" E 75°18'2.5") to Harike Barrage (N 31°9'6.8" E 75°57.8'6.5") and is believed to be the only surviving population of Indus River Dolphin in India (Behera et al. 2008; Khan 2013). According to an estimate the Indus River Dolphin now occupies only one fifth of its former range (Reeves et al. 1991). The species is facing a daunting array of challenges for its survival due to pollution, across river constructions (e.g. dams and barrages), water abstraction, destructive methods fishing and incidental caught into the gillnets of fishermen (Braulik 2006). Use of its meat as food is also reported from Sindh Pakistan, hence classified as endangered in IUCN (Braulik 2004).

Historically river dolphins were found in the wide range of freshwater riverine habitat, their upstream distribution

was constrained by rocky and shallower river habitat while in the downstream they were found till the estuarine zone where the salinity forms a boundary (Reeves et al. 2000). Populations of river dolphins have declined dramatically in past two decades and the trend is still continue, much of their distribution range has already been lost (Reeves et al. 2000; Mohan 1989; Reeves et al. 1993 and Smith 1996). The dwindling status of Indus River Dolphins population indicates the ever degrading riverine habitat. Indus river and its tributaries runs through the semi arid and irrigated agriculture landscape, practices like water diversion in canals for irrigation, riverbed extraction further added the stress on riverine ecosystem. Riverine corridors, throughout the range of distribution of Indus River Dolphins, need some sort of protection and the direct dependency of locals on water must be reduced or diverted (Khan 2013).

MATERIALS AND METHODS

Study area

Punjab instead of having semi arid bio-geographical condition supports an impressive range of natural endowments in terms of agro-ecology. The state of Punjab is a drainage basin of Indus river system derives its name *Punj + Aab* (which means the land of five rivers) from five major tributaries of Indus river (i.e. Sutlej, Beas, Ravi, Jhelum and Chenab). However, after the state's partition in 1947, only Sutlej and Beas flow through it, while Ravi touches it at its north border. Total freshwater ecosystem contributes only 1.71 percent area of the state which includes rivers, lakes, ponds, water logged, and reservoirs etc. Among these, rivers is the most common type of freshwater ecosystem, sharing 69.38 percent of total freshwater area while man-made reservoirs is the second major type of freshwater ecosystem, accounting 13.74 percent of total freshwater area of state.

The *Beas River* originates in the Rohtang pass of the Himalayas in the central Himachal Pradesh in India at an altitude of 3977.64 m and flows for the length of 470 km before uniting with the Sutlej river at Harike Pattan south of Amritsar in Punjab. The surveyed stretch falls in three districts of Punjab namely Amritsar, Tarntaran and Kapurthala between 31°30’ and 75°18’ N Latitude and 31°10’ and 74°58’ E Longitude . The altitude of the area ranges between 217 m and 195 m above sea level (Figure 1). All through its course, a strip of shallow alluvial soil fringes its banks which are subject to inundation during the rainy season. The main channel of the river is broad, dotted with islands and wide pools. The depth of water varies from about 1.5 m during the dry seasons to about 4.5 m during the rainy seasons.

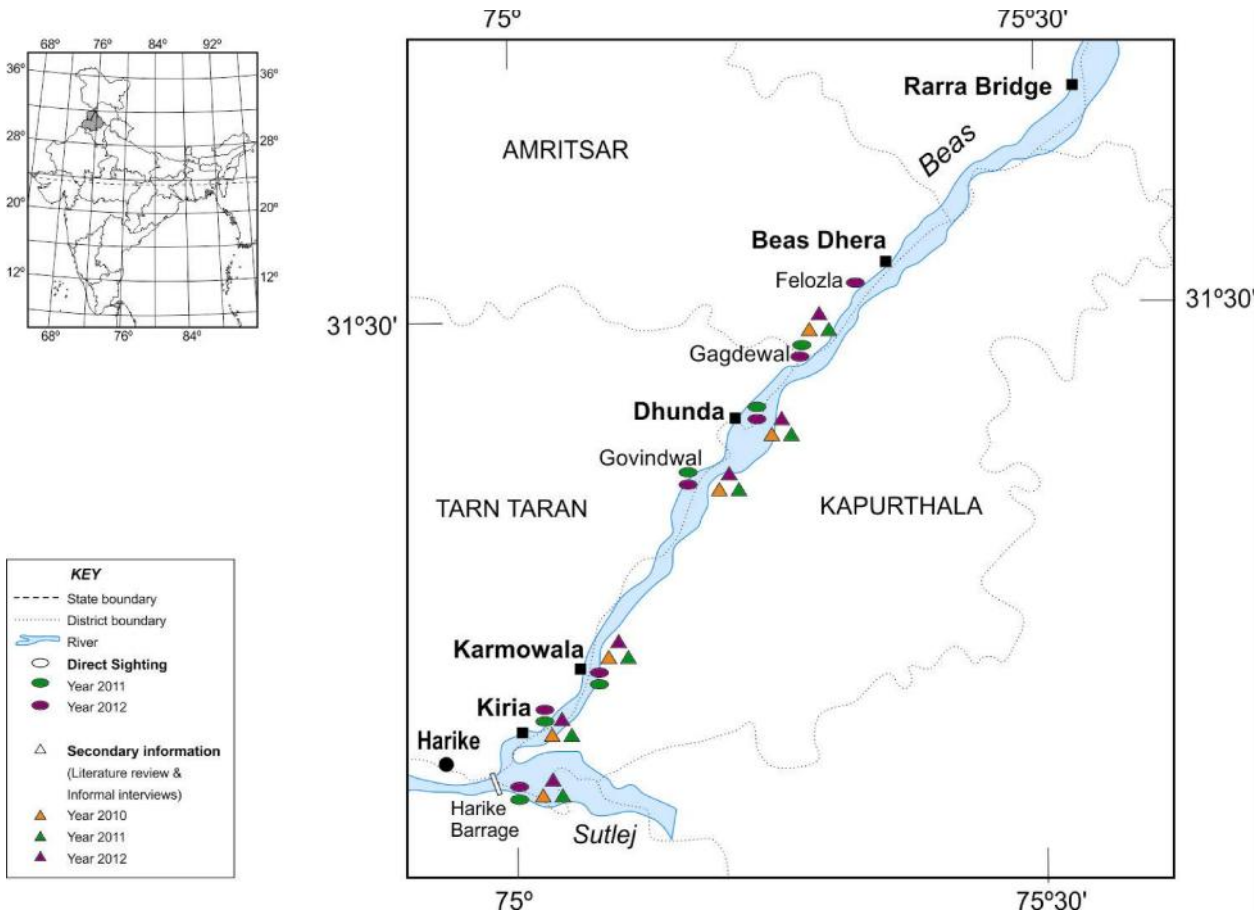

Figure 1. Sighting records of Indus River Dolphin in River Beas and Harike wetland, Punjab.

Figure 2. The habitat of Indus River Dolphin

As the river flows downwards the sandiness of the substrate gets reduced. The linear riparian habitats of the river stretch comprise of flowing water, islands and banks, hold a good variety of fauna. Large congregation of birds can be seen during winters. Among the mammalian community the area is known to support small populations of Bluebull *Boselaphus tragocamelus*, Wild Boar *Sus scrofa* and Golden Jackal *Canis aureus*. Reptilians like Indian Star Tortoise *Geochelone elegans* and Monitor Lizard *Calotes benghalensis* and several poisonous and non-poisonous species of snakes are also reported to occur in the drier parts such as grasslands and the agricultural fields adjoining the river stretch (Figure 2).

Primary data collection

The monthly intensive surveys for Indus River Dolphin population count were conduct since December 2010. River stretch was divided into 5km sampling segments. At each segment presence/absence of Indus River Dolphin was recorded, habitat parameters were quantified and disturbance was assessed. The field team consisted of three observer (including one researcher and two field assistants) and a boatman. Smith and Reeves (2000) survey methods for wide channel were followed. Boat speed was maintained at 8-10 km in a downstream direction following the deepest channel with a zigzag pattern from bank to bank. Although 3 observers were used at a time, 2 searched 90° off the right and left beam of the vessel and 1 rear observer, searching 180° behind the survey vessel. Positions of observers were rotated every 30 minutes to avoid fatigue. Vessel speed was reduced in preferred dolphin microhabitats, viz, confluences, meanderings, downstream of mid-channel islands and where there is large aggregation of fishermen or water birds (Wakid and Braulik 2009).

A dolphin group was defined if dolphins were not no more than 1000 m apart, A 20 minute stoppage was made in areas of high dolphin abundance to make a more accurate group size estimate. All sightings were confirmed by a second observer.

Secondary data collection

As a part of the survey, informal interviews were conducted at every encounter with locals to seek information on dolphin occurrence in the stretch. Questionnaire was oral, informal and cantered on coloured plates of authentic field guides on Indian mammals. The questionnaire survey included following procedures: (i) Having people identify local aquatic mammals from pictures. (ii) Asking for physical description of Dolphins. (iii) If the respondents were found to be positive they were investigated further for supplementary.

RESULTS AND DISCUSSION

Field assessments examined the possible existence and conservation viability of the only reported breeding population of the Endangered Indus River Dolphin. Observations showed that dolphins occur in River Beas and the Harike wetland (Figure 1). A total of 16 sighting frequencies were possible during the study period. These sightings were largely concentrated in zones Karmowala-Harike [f = 5]; Baguwal-Dhunda [f = 5]; Gagdewal-Baguwal [f = 3] and Beas bridge-Gagdewal [f = 3] (Figure 1). 3 groups were identified, one each along Beas bridge-Gagdewal; Baguwal-Dhunda and Karmowala-Harike that comprised of adult, sub-adult and calves (Figure 1). On 6 occasions adult Dolphins were recorded solitary. During the course of the study opportunistic sightings of adult

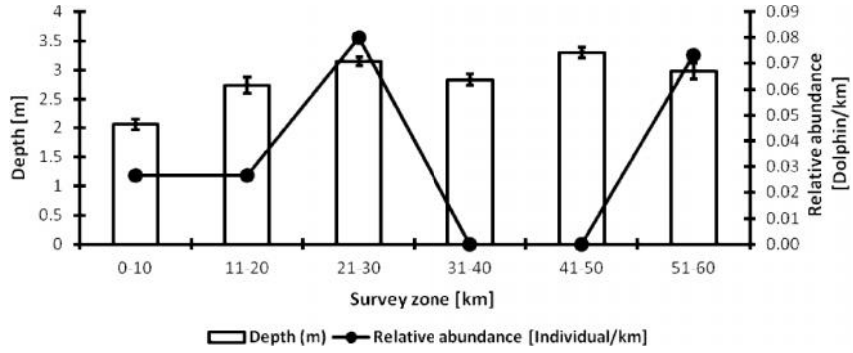

Figure 3.A. Dolphin occurrence was found strongly associated with deep pools

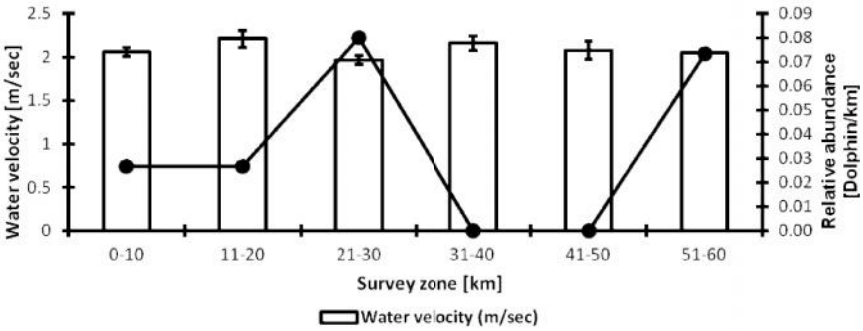

Figure 3.B. Dolphin occurrence was found strongly associated with slow water current

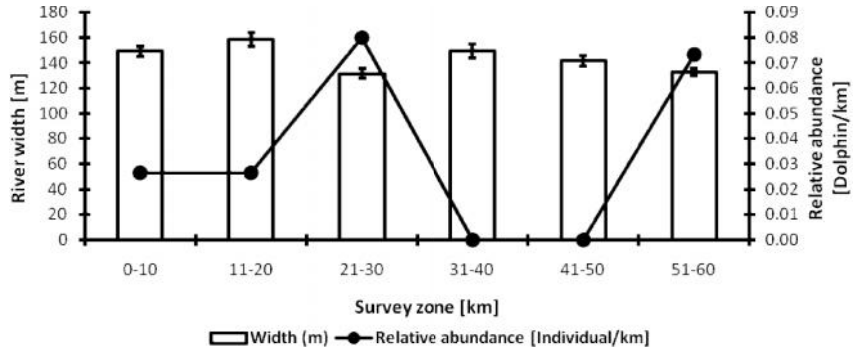

Figure 3.C. Dolphin occurrence was found strongly associated with moderate to wide river width

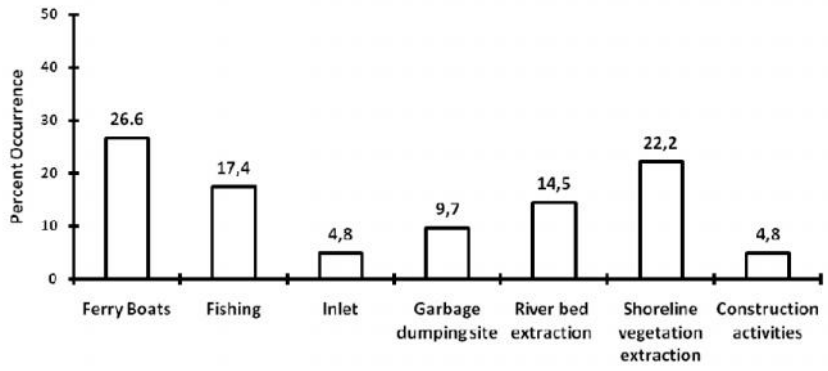

Figure 4. Percent occurrence of recorded disturbances

Dolphins were also recorded, 4 at Harike Wildlife Sanctuary while 2 at Karmowala. These opportunistic sighting records have been excluded from the analyses.

Unlike many marine dolphins, Indus River Dolphins do not form easily defined, interactive groups. Instead, they are frequently observed in loose aggregations with little apparent interaction between individuals (Braulik 2006). Their occurrence has been attributed to preferred habitat features such as deep pools, slow water current, abundant prey base and low disturbance. During the study period, dolphins were generally sighted in loose groups of 2-3 individuals at three different sites in river Beas and they preferred habitats with deep pools [$t = -2.82$; $p<0.01$], slow water current [$t = 4.49$; $p<0.001$] and moderate to wide river width [$t = -2.30$; $p<0.01$] (Figure 3.A; 3.B, and 3.C). The available habitat recorded suitable for Indus River Dolphin *Platanista gangetica minor* and other associated fauna is limited and disturbed. Peripheral areas of the sanctuary are more vulnerable from disturbances; hence on urgent basis such habitats must be conserved.

Destructive anthropological activities further intensify the pressure on their fragmented small populations. In current scenario river dolphins and their habitat are facing a series of serious problems which need to be estimated and mitigated. The problems includes (i) extensive of fish throughout their range of distribution which consequently reduces the availability of their prey. (ii) Degradation of their habitat through increased sedimentation, which is usually caused due to the deforestation of river basin. (iii) Industrial and human waste. (iv) Agricultural runoff with high concentration of chemical fertilizers and poisonous pesticides. (v) Accidental entanglement in fishing nets causes the death of dolphins. (vi) Construction of large, cross river water development structures, for example dams and barrages causes the isolation of small fragmented sub-populations and perhaps, is the

most deadly threat to river dolphins (Khan 2013; Reeves et al. 2000).

Data were collected on 7 variables perceived as disturbance toward the existing population of Dolphins in the study area. Disturbance factors like Ferry boats (26.6%), shoreline vegetation extraction (22.2%), commercial fishing (17.4%) and riverbed substrate extraction (14.5%) were founded extensively during the field visits while garbage dumping sites (9.7), inlets (4.8%) and backsides construction (4.8%) were recorded in small magnitudes (Figure 4).

Water systems particularly rivers are witnessing the landslide changes in the land use and land cover of their basins. Urbanization, industrialization, modern agricultural practices, hydro developmental projects and other developmental activities ensures the better human access to water but unfortunately, it often accompanied by impairment to ecosystem and its biodiversity with potentially serious cost which are usually unquantifiable (Abell et al. 2008). Proposing interventions to halt this degradation to the rivers includes scientific assessment of their biodiversity, strict implementation of conservation laws of the land together with ensuring the sustainable to fulfil the needs of the society (Vorosmarty et al. 2010).

CONCLUSION

The finding of this study emphasizes on the relationship of riparian communities and natural resources and indicates activities which detrimentally affect the habitat and should be discouraged. The detailed approach adopted in the present work is clearly necessary to begin to understand the precise relationships between species distribution, ecology and habitat attributes-information that is essential for conservation measures and the implementation of management practices. Riparian communities with a stake in the long term future of the freshwater species and habitats across the region must be fully engaged in the development and conservation planning processes in order to assure the future sustainability of associated livelihoods and the ecosystem services provided by fully functioning freshwater ecosystems.

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REFERENCES

Abell R, Thieme ML, Revenga C, Bryer M, Kottelat M, Bogutskaya N, Coad B, Mandrak N, Balderas SC, Bussing W, Stiassny MLJ, Skelton P, Allen GR, Unmack P, Naseka A, Rebecca N, Sindorf N, Robertson J, Armijo E, Higgins JV, Heibel TJ, Wikramanayake E, Olson D, López HL, Reis RE, Lundberg JG, Pérez MHS, Petry P. 2008. Freshwater ecoregions of the world: a new map of biogeographic units for freshwater biodiversity conservation. Bioscience 58: 403-414.

Anderson J. 1879. Anatomical and Zoological Researches: Comprising an Account of the Zoological Results of the Two Expeditions to Western Yunnan in 1868 and 1875; and a Monograph of the Two Cetacean Genera *Platanista* and *Orcella* (sic). Quaritch, London.

Behera SK, Nawab A, Rajkumar B. 2008. Preliminary investigations confirming the occurrence of Indus River Dolphin *Platanista gangetica minor* in River Beas, Punjab, India. J Bombay Nat His Soc 105 (1): 90-91.

Braulik GT. 2004. Conservation and status of the Indus River dolphin, *Platanista gangetica minor*, in 2001. [Direct inquiries to: GillBraulik@downstream.vg]

Braulik GT. 2006. Status assessment of the Indus River Dolphin *Platanista gangetica minor*, March- April 2001. Biol Conserv 129: 579-590.

Dudgeon D, Arthington AH, Gessner MO, Kawabata Z-I, Knowler DJ, Leveque C, Naiman RJ, Prieur-Richard AH, Soto D, Stiassny MLJ, Sullivan CA. 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. Biol Rev 81: 163-182

IUCN. 2010. IUCN Red List of Threatened Species, ver. 2010.2. www.iucnredlist.org [accessed 01 March 2014]

Khan MS. 2013. Indus River Dolphin: The survivor of river Beas, Punjab, India. Curr Sci 104 (11): 1464-1465.

Mohan RSL. 1989. Conservation and management of the Ganges river dolphin, *Platanista gangetica*, in India. In: Perrin WF, Brownell, Jr. RL, Zhou K, Liu J (eds.), Biology and conservation of the river dolphins. IUCN Species Survival Commission Occasional Paper No. 3. IUCN, Gland, Switzerland.

Reeves RR, Chaudhary AA, Khalid U. 1991. Competing for water on the Indus plain: is there a future for Pakistan's river dolphins? Environ Conserv 18: 341-349.

Reeves RR, Leatherwood S, Mohan RSL. 1993. A future for Asian river dolphins: Report from a seminar on the conservation of river dolphins of the Indian Subcontinent, New Delhi, India. Whale and Dolphin Conservation Society, Bath, England, 18-19 August 1992.

Reeves RR, Smith BD, Kasuya T. 2000. Biology and Conservation of Freshwater Cetaceans in Asia. (eds.) IUCN, Gland, Switzerland and Cambridge, UK.

Smith A. 1996. The river dolphins: the road to extinction. In: Simmonds MP, Hutchinson JD (eds.). The conservation of whales and dolphins. John Wiley and Sons Ltd., New York.

Smith BD, Braulik G, Sinha RK. 2004. *Platanista gangetica* ssp. *gangetica* IUCN 2010 IUCN Red List of Threatened Species, ver. 20102 www.iucnredlist.org/apps/redlist/ details/41756/0. [accessed 15 August 2013].

Smith BD, Reeves RR. 2000. Survey methods for population assessment of Asian river dolphins. In: Reeves RR, Smith BD, Kasuya T (eds) Biology and Conservation of Freshwater Cetaceans in Asia, Occasional Papers of the IUCN Species Survival Commission, No. 23: 97-115.

Strayer DL, Dudgeon D. 2010. Freshwater biodiversity conservation: recent progress and future challenges. J North Amer Benthol Soc 29: 344-358.

Turvey ST, Pitman RL, Taylor BL, Barlow J, Akamatsu T, Barrett LA, Zhao X, Reeves RR, Stewart BS, Wang K, Wei Z, Zhang X, Pusser LT, Richlen M, Brandon JR, Wang D. 2007. First human-caused extinction of a cetacean species? Biol Lett 3: 537-540.

Vorosmarty CJ, McIntyre PB, Gessner MO, Dudgeon D, Prusevich A, Green P, Glidden S, Bunn SE, Sullivan CA, Reidy Liermann C, Davies P M. 2010. Global threats to human water security and river biodiversity. Nature 467: 555-561.

Wakid A, Braulik G. 2009. Protection of endangered Gangetic dolphin in Brahmaputra River, Assam, India. Final report to IUCN-Sir Peter Scott Fund.

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Birds of Lansdowne forest division and adjacent suburban landscapes, Garhwal Himalayas, Uttarakhand, India: Community structure and seasonal distribution

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ABSTRACT

Kukreti M, Bhatt D. 2014. Birds of Lansdowne forest division and adjacent suburban landscapes, Garhwal Himalayas, Uttarakhand, India: Community structure and seasonal distribution. Biodiversitas 15: 80-88. This study of bird species diversity aims at understanding the distribution patterns and structures of avifauna of the two forest ranges and adjoining suburban areas of the Lansdowne forest division, Uttarakhand, India. Data on the abundance and richness were collected by standardized Verner's line transect method for two years (January 2011 to December 2012). A total of 216 species were recorded from the study area. Family Muscicapidae with 30 species was found to be dominant in the forest habitats, while family Corvidae with 10 species was found to be dominant in the suburban areas. Results indicate that the forests had more complex bird community structure in terms of higher species richness (8.95 vs 8.59), higher species diversity (Shannon's index 3.86 vs 3.74), higher evenness (0.085 vs 0.080) and more rare species (74 vs 15) as compared to urban habitats. Bird species richness (BSR) and bird species diversity (BSD) fluctuated across seasons but not across habitat types. In order to sustain avian diversity, it is recommended that anthropogenic disturbance should be reduced and traditional agroforestry should be developed in the study area.

Key words: Avian diversity, Garhwal Himalayas, Lansdowne forest, species richness, suburban

INTRODUCTION

Biodiversity is a contraction of 'biological diversity'. It has been defined by many scientists, governmental and non governmental organizations usually as species richness, which is distributed unequally around the earth (Mittermeier et al. 1998; Myers et al. 2000; Barthlott and Winger 2001). According to the Millennium Ecosystem Assessment report (2005), the current extinction rates for mammals, birds and amphibians is up to one thousand times higher than the one witnessed in the fossil records. Hence, there is a need for long term documentation of diversity in natural environment. In the Indian subcontinent, approximately 1300 avian species are found which constitute about 13% of the world bird assembly (Grimmett et al. 1998). In the Western Himalayas, one of the Endemic Bird Areas (EBAs) (Birdlife International 2012), some recent studies focus on avian diversity and describes the extensive biodiversity assessments (Singh 2000; Chettri et al. 2001; Laiolo 2002; Price et al. 2003; Sultana et al. 2007; Acharya et al. 2011). At this point of time there are some published research works in the Pauri Garhwal district on avian community ecology with special reference to diversity, abundance, distribution and other ecological gradients (Naithani and Bhatt 2010, 2012). However, there is hardly any report from the study area comparing the forest avian biodiversity with the suburban/rural landscapes. In the present study, an attempt is being made to find out the patterns and distributions of the bird communities in different forest sites and adjoining suburban areas of the Kotdwar and Laldhang forest ranges of the Lansdowne forest division (Pauri Garhwal, Uttarakhand, Western Himalaya).

MATERIALS AND METHODS

Study area

Lansdowne forest division is located on 29°37' to 30°2' North latitude and 78°19'13'' to 78°43'0'' East longitudinally in the south west portion of district Pauri Garhwal. The forest division is located on Rajaji National Park towards its western side and Corbett Tiger Reserve towards its east (Figure 1). In the north eastern part of Lansdowne range, Chir (*Pinus roxburghii*) and Banj (*Quercus leucotrichophora*) forests can be found. The remaining parts are occupied by Sal (*Shorea robusta*) and associated species: *Acacia catechu, Dalbergia sissoo, Cassia fistula, Holoptelea integrifolia, Syzygium cumini, Mallotus philippensis, Aegle marmelos, Ziziphus mauritiana, Ougeinia oojeinensis, Bombax ceiba, Albizia odoratissima, Anogeissus latifolia, Holarrhena pubescens, Ficus benghalensis and Adina cordifolia.* Major Shrubs of the sites studied are *Lantana camara, Murraya koenigii, Parthenium hysterophorus, Ardisia solanacea, Desmodium triflorum* and *Asparagus*

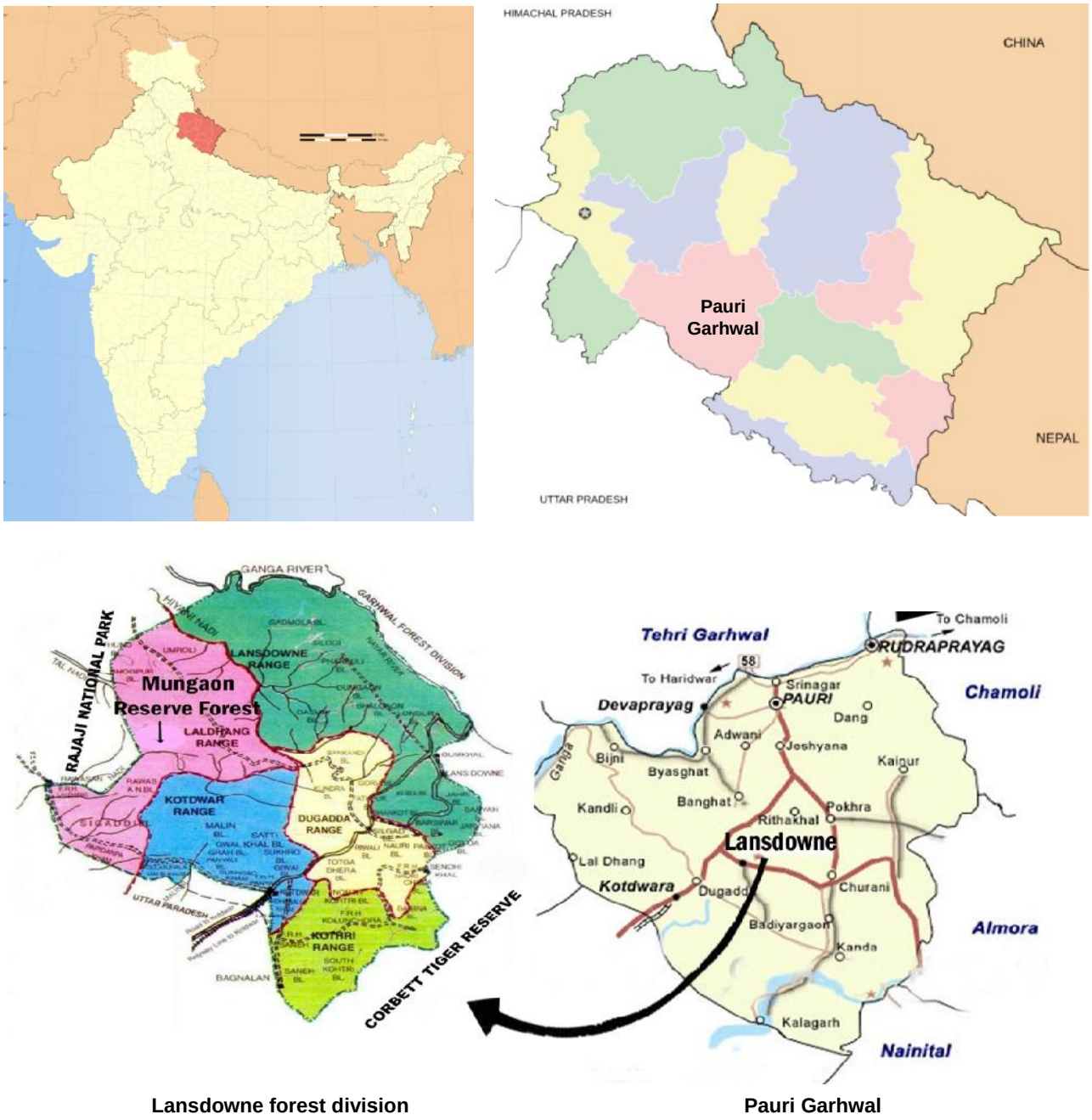

Figure 1. Showing location of Lansdowne forest division, Pauri Garhwal district in Uttarakhand, India.

adscendens. Climatically the area can be divided into three distinct seasons viz., rainy season (July to October), winter (November to February), summer (March to June).

Field procedure

The biodiversity assessment was carried out in the three forest and adjacent suburban habitat types (Table 1) using Verner's (1985) variable line transect method. Altogether 288 visits (24 months × 6 transects × 2 habitats) were made in total of 24 transects for consecutive two years i.e. January 2011 to December 2012, covering all the seasons. All transects within forest and suburban habitats were of equal length (1Km. each). Observation of birds in each predefined transects/routes was made by walking once a month. In summer, bird counts were undertaken between 05:00 AM and 08:00 AM and 04:00 PM to 06:00 PM, while in winters, predefined transects were covered from 06:30 AM to 09:30 AM and 03:00 PM to 06:00 PM on fine days. Birds were not surveyed in extreme weather, like when wind or rain interfered with the audibility of bird calls, when fog or rain impaired visibility, partly cloudy sky or when cold weather limited bird activity. We maintained the same survey protocol in subsequent years. Bird field guide by Grimmett et al. (2001) and Ali (2002) were used for identification of birds. For nomenclature, we followed Inskipp et al. (1996). We used the Gaston (1994)

Table 1. Showing geographical information of study sites.

Sites	Geographical position		Elevation
Forest	N	E	
Site A (Kanvashram)	29° 47' 49. 98''	78° 27' 39.09''	200-600 m
Site B (Nadikatal)	29° 54' 40.38"	78° 26' 13.96"	600-900 m
Site C (Mungaon)	29° 54' 25.43''	78° 25' 49.70''	900-1200 m
Suburban			
Site A (Bhimsinghpur)	29° 47' 14.26"	78° 27' 01"	200-600 m
Site B (Nisni)	29° 54' 55.01"	78° 26' 21.42"	600-900 m
Site C (Mungaon)	29° 54' 18.58''	78° 26' 00.67''	900-1200 m

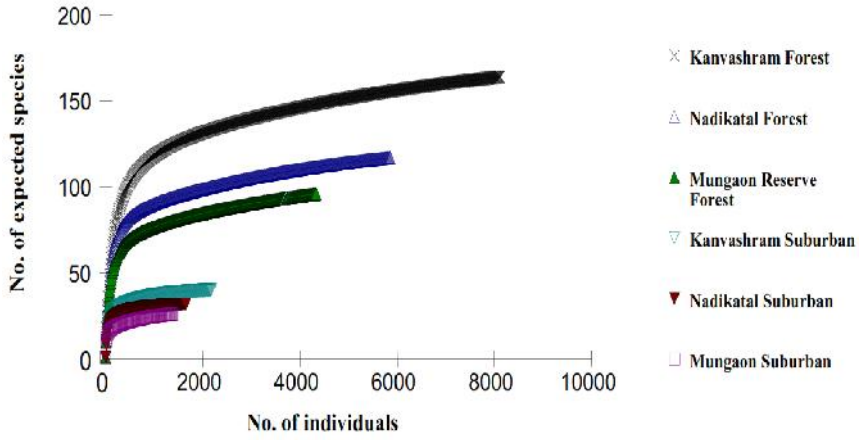

Figure 2. Rarefaction curves for bird species richness estimated from forest and suburban habitats in the study area.

criteria to define the rarity, below 10 individuals observed per sighting was categorized as rare species of the study area. We also categorized each species as common (c), fairly common (f), uncommon (u) and rare (r) based on our sighting records.

Bird species diversity (BSD) and bird species richness (BSR) were measured using Shannon's index (*H'*) and Margalef's index (*R*), respectively (MacArthur and MacArthur 1961, Magurran, 2004).To estimate evenness, we used evenness index (*E*) (Magurran 2004) between forest and suburban habitats. BioDiversity Pro software (McAleece et al. 1997) was to generate rarefaction curve in order to determine whether sampling efforts was adequate. The data was obtained as mean of transects at each site for each month and pooled for two consecutive years at each zone. Two way-ANOVA was also used to test for inter-seasonal differences in BSR, BSD values across study areas. To quantify the similarity among species composition at different sites, Sorensen's index (Magurran 2004) was used. Beta diversity ($\beta = S/\acute{\alpha}$) where S is the total number of species recorded and $\acute{\alpha}$ is the average sample diversity; scale 0 (minimum β diversity) to 1 (maximum β diversity) (Whittaker 1960) value was obtained between habitats of each study area to know extent of variation between habitat types.

RESULTS AND DISCUSSION

Avian community structure

A total of 216 bird species belonging to 43 families were observed in suburban and forest habitats. 124 species (57%) were found exclusively in forest, 15 species (6%) were restricted to suburban habitat and 80 species (37%) were common to both habitat types. The details of abundance, resident status and threatened category according to International Union for the Conservation of Nature (IUCN) have been given in Table 2. Three threatened species (IUCN 2012) having poor abundance such as River Lapwing {*Vanellus duvaucelii* (Near Threatened; 11 individual) found in study site A, Kanvashram forest near Malini river; Figure 1.A.}, White Rumped Vulture {*Gyps bengalensis* (Critically Endangered; 8 individuals)}, Egyptian Vulture {(*Neophron percnopterus* (Endangered; 5 individual)} were found in the study area.

The analysis of Variance (ANOVA-Two way) revealed that forest bird community was found more diverse than adjoining suburbs in terms of BSD (3.86 vs 3.74; F = 1.895, df = 11, $P< 0.05$) and BSR (8.95 vs 8.59; F = 1.479, df = 11, $P<$ 0.05) and more rare species (74 vs 15). Species rarefaction curves (Figure 2) from different habitats also showed that forest habitats had a higher number of avian species than suburban habitats. In both the habitats, the BSD, BSR and BSE were maximum during summer (April to May) and minimum in late winter (December to January) seasons {(Forest: BSR range from 8.50±0.10 to 9.60±0.17; BSD: 3.75±0.14 to 4.02±0.26 and BSE: 0.080±0.13 to 0.094±0.01); for suburbanized areas: BSR ranges from 8.32±0.61 to 9.12±0.52; BSD:3.12±0.10 to 3.89±0.92; BSE: 0.080± 0.25 to 0.094±0.20)}.

The similarity index showed greater overlap/similarity (65.50%) between bird communities for forest and suburban at site B (Nadikatal, Nisni) and site A (Kanvashram, Bhimsinghpur) than between site C {Mungaon (village and forest)} and site A (31%) or between site C and site B (35%). A comparison of bird communities between forest and suburban habitats revealed low values of beta diversity in each study area (site C: 0.33, site B and site A: 0.70) indicating lesser similarity in species composition between habitat types. However, when bird communities were compared among study areas, a relatively high beta diversity values (0.76 for suburban and 0.70 for forest) were observed between site C and site A (showing greater species variation between these two study

Table 2. Checklist of the birds observed in Lansdowne forest division (Kotdwar and Laldhang range) and adjacent suburban/rural areas with their status, abundance and habitat.

Family/Scientific name	Common name	Status	Abundance	Habitat
PHASIANIDAE				
Pavo cristatus	Indian Peafowl	R	c	Common
Gallus gallus	Red Junglefowl	R	f	Forest
Lophura leucomelanos	Kalij Pheasant	R	f	Forest
Francolinus francolinus	Black Francolin	R	r	Forest
Francolinus pondicerianus	Grey Francolin	R	u	Forest
Perdicula asiatica	Jungle Bush Quail	R	u	Forest
PICIDAE				
Celeus brachyurus	Rufous Woodpecker	R	r	Forest
Dendrocopos macei	Fulvous-breasted Woodpecker	R	f	Forest
Dendrocopos canicapillus	Grey-capped Pygmy Woodpecker	R	c	Forest
Dendrocopos hyperythrus	Rufous-bellied Woodpecker	R	f	Forest
Picus chlorolophus	Lesser Yellownape	R	r	Forest
Picus canus	Grey-headed Woodpecker	R	f	Forest
Picus flavinucha	Greater Yellownape	R	r	Forest
Picus xanthopygaeus	Streak-throated Woodpecker	R	r	Common
Dinopium benghalense	Black-rumped Flameback	R	c	Common
Dinopium shorii	Himalayan Flameback	R	r	Forest
Chrysocolaptes lucidus	Greater Flameback	R	u	Forest
MEGALAIMIDAE				
Megalaima zeylanica	Brown-headed Barbet	R	c	Common
Megalaima virens	Great Barbet	R	r	Forest
Megalaima asiatica	Blue-throated Barbet	R	f	Common
Megalaima haemacephala	Coppersmith Barbet	R	r	Forest
Megalaima lineata	Lineated Barbet	R	r	Forest
BUCEROTIDAE				
Ocyceros birostris	Indian Grey Hornbill	R	c	Common
UPUPIDAE				
Upupa epops	Common Hoopoe	R	c	Common
CORACIIDAE				
Coracias benghalensis	Indian Roller	R	f	Forest
Eurystomus orientalis	Dollarbird	R	r	Forest
ALCEDINIDAE				
Alcedo atthis	Common Kingfisher	R	f	Forest
HALCYONIDAE				
Halcyon capensis	Stork-billed Kingfisher	R	r	Forest
Halcyon smyrnensis	White-throated Kingfisher	R	c	Common
CERYLIDAE				
Ceryle rudis	Pied Kingfisher	R	f	Forest
Megaceryle lugubris	Crested Kingfisher	WM	r	Forest
MEROPIDAE				
Merops orientalis	Green Bee-Eater	R	c	Common
Nyctyornis athertoni	Blue-bearded Bee-Eater	R	r	Forest
Merops leschenaulti	Chestnut-headed Bee-Eater	R	f	Common
CUCULIDAE				
Hierococcyx varius	Common Hawk Cuckoo	R, AM	f	Forest
Clamator jacobinus	Pied Cuckoo	SM	u	Rural
Phaenicophaeus leschenaultii	Sirkeer Malkoha	SM	r	Forest
Eudynamys scolopacea	Asian Koel	R	c	Common
CENTROPODIDAE				
Centropus sinensis	Greater Coucal	R	u	Forest
PSITTACIDAE				
Psittacula eupatria	Alexandrine Parakeet	R	f	Common
Psittacula krameri	Rose-ringed Parakeet	R	c	Common
Psittacula himalayana	Slaty-headed Parakeet	R, AM	u	Common
Psittacula cyanocephala	Plum-headed Parakeet	R	c	Common
APODIDAE				
Apus affinis	House Swift	R	f	Rural
STRIGIDAE				

Glaucidium cuculoides	Asian Barred Owlet	R	r	Common
Glaucidium radiatum	Jungle Owlet	R	u	Forest
Otus sunia	Oriental Scops Owl	R	r	Forest
CAPRIMULGIDAE				
Caprimulgus macrurus	Large-tailed Nightjar	R	r	Forest
COLUMBIDAE				
Columba livia	Rock Pigeon	R	c	Rural
Streptopelia chinensis	Spotted Dove	R	c	Rural
Streptopelia orientalis	Oriental Turtle Dove	R, AM	f	Forest
Streptopelia decaocto	Eurasian Collared Dove	R	u	Rural
Streptopelia tranquebarica	Red Collared Dove	SM	r	Forest
Chalcophaps indica	Emerald Dove	R	r	Forest
Treron sphenura	Wedge-tailed Green Pigeon	R, AM	r	Common
Treron phoenicoptera	Yellow-footed Green Pigeon	R, AM	r	Forest
Treron apicauda	Pin-tailed Green Pigeon	R	u	Forest
RALLIDAE				
Amaurornis phoenicurus	White-breasted Waterhen	R	r	Forest
SCOLOPACIDAE				
Actitis hypoleucos	Common Sandpiper	WM	r	Forest
Tringa ochropus	Green Sandpiper	WM	r	Forest
CHARADRIDAE				
Vanellus duvaucelii	River Lapwing	R	f	Forest
Vanellus indicus	Red-wattled Lapwing	R	c	Common
ACCIPITRIDAE				
Pernis ptilorhyncus	Oriental Honey-buzzard	R	u	Forest
Elanus caeruleus	Black-shouldered Kite	R	f	Common
Milvus migrans	Black Kite	R, AM	c	Common
Neophron percnopterus	Egyptian Vulture	R	u	Common
Gyps bengalensis	White-rumped Vulture	R	r	Forest
Gyps himalayensis	Himalayan Griffon	WM	r	Forest
Spilornis cheela	Crested Serpent Eagle	WM	u	Forest
Accipiter badius	Shikra	R	f	Common
Accipiter nisus	Eurasian Sparrowhawk	WM	u	Forest
Accipiter gentilis	Northern Goshawk	WM	r	Common
Butastur teesa	White-eyed Buzzard	R	u	Forest
Spizaetus cirrhatus	Changeable Hawk Eagle	SM	u	Forest
FALCONIDAE				
Falco tinnunculus	Common Kestrel	WM	r	Common
PHALACROCORACIDAE				
Phalacrocorax niger	Little Cormorant	UC	r	Forest
ARDEIDAE				
Egretta garzetta	Little Egret	WM	f	Forest
Mesophoyx intermedia	Intermediate Egret	WM	r	Forest
Bubulcus ibis	Cattle Egret	R	c	Rural
Ardeola grayii	Indian Pond Heron	R	r	Forest
PITTIDAE				
Pitta brachyura	Indian Pitta	SM	r	Forest
EURYLAIMIDAE				
Psarisomus dalhousiae	Long-tailed Broadbill	SM	r	Forest
IRENIDAE				
Chloropsis hardwickii	Orange-bellied Leafbird	WM	r	Common
Chloropsis aurifrons	Golden-fronted Leafbird	R	u	Forest
LANIDAE				
Lanius cristatus	Brown Shrike	WM	u	Forest
Lanius schach	Long-tailed Shrike	R	c	Common
Lanius tephronotus	Grey-backed Shrike	WM	r	Forest
CORVIDAE				
Urocissa erythrorhyncha	Red-billed Blue Magpie	R, AM	u	Common
Cissa chinensis	Common Green Magpie	R	r	Forest
Dendrocitta vagabunda	Rufous Treepie	R	c	Common
Dendrocitta formosae	Grey Treepie	R, AM	f	Forest
Corvus splendens	House Crow	R	c	Rural
Corvus macrorhynchos	Large-billed Crow	R	c	Common
Oriolus oriolus	Eurasian Golden Oriole	SM	r	Common
Oriolus xanthornus	Black-hooded Oriole	R	f	Forest
Oriolus traillii	Maroon Oriole	R, AM	r	Forest

Coracina macei	Large Cuckooshrike	R	u	Forest
Coracina melaschistos	Black-winged Cuckooshrike	R, AM	r	Forest
Coracina melanoptera	Black-headed Cuckooshrike	R	f	Forest
Pericrocotus roseus	Rosy Minivet	SM	r	Common
Pericrocotus cinnamomeus	Small Minivet	R	f	Forest
Pericrocotus ethologus	Long-tailed Minivet	R, AM	f	Common
Pericrocotus flammeus	Scarlet Minivet	R, AM	r	Common
Hemipus picatus	Bar-winged Flycatcher-shrike	R	f	Forest
Rhipidura hypoxantha	Yellow-bellied Fantail	R, AM	f	Forest
Rhipidura albicollis	White-throated Fantail	R	c	Common
Dicrurus macrocercus	Black Drongo	R	c	Common
Dicrurus leucophaeus	Ashy Drongo	WM	r	Forest
Dicrurus caerulescens	White-bellied Drongo	R	r	Forest
Dicrurus aeneus	Bronzed Drongo	R, AM	r	Forest
Dicrurus hottentottus	Spangled Drongo	R, AM	f	Forest
Hypothymis azurea	Black-naped Monarch	R	r	Forest
Terpsiphone paradisi	Asian Paradise-flycatcher	R, AM	f	Common
Aegithina tiphia	Common Iora	R	r	Forest
Tephrodornis pondicerianus	Common Woodshrike	R	f	Forest
CINCLIDAE				
Cinclus pallasii	Brown Dipper	R	r	Forest
MUSCICAPIDAE				
Monticola cinclorhynchus	Blue-capped Rock Thrush	SM	r	Common
Monticola solitarius	Blue Rock Thrush	WM	r	Common
Myophonus caeruleus	Blue Whistling Thrush	R, AM	c	Forest
Zoothera citrina	Orange-headed Thrush	SM	r	Forest
Turdus boulboul	Grey-winged Blackbird	R, AM	u	Common
Muscicapa sibirica	Dark-sided Flycatcher	WM	f	Forest
Muscicapa dauurica	Asian Brown Flycatcher	SM	r	Forest
Ficedula strophiata	Rufous-gorgeted Flycatcher	WM	r	Forest
Ficedula parva	Red-throated Flycatcher	WM	r	Forest
Ficedula westermanni	Little Pied Flycatcher	R	f	Forest
Ficedula tricolor	Slaty-blue Flycatcher	WM	r	Forest
Eumyias thalassina	Verditer Flycatcher	R, AM	f	Common
Niltava sundara	Rufous-bellied Niltava	R, AM	u	Forest
Cyornis unicolor	Pale Blue Flycatcher	WM	r	Forest
Cyornis rubeculoides	Blue-throated Flycatcher	SM	f	Forest
Culicicapa ceylonensis	Grey-headed Canary-Flycatcher	R, AM	c	Forest
Luscinia pectoralis	White-tailed Rubythroat	WM	r	Forest
Luscinia svecica	Bluethroat	WM	f	Forest
Copsychus saularis	Oriental Magpie Robin	R	c	Common
Copsychus malabaricus	White-rumped Shama	R	r	Forest
Saxicoloides fulicata	Indian Robin	R	c	Common
Phoenicurus caeruleocephalus	Blue-capped Redstart	WM	r	Forest
Phoenicurus ochruros	Black Redstart	WM	f	Forest
Chaimarrornis leucocephalus	White-capped Water Redstart	WM	f	Forest
Rhyacornis fuliginosus	Plumbeous Water Redstart	WM	f	Forest
Enicurus maculatus	Spotted Forktail	R	r	Forest
Saxicola torquata	Common Stonechat	WM	f	Forest
Saxicola caprata	Pied Bushchat	R	f	Common
Saxicola ferrea	Grey Bushchat	R, AM	u	Common
Cercomela fusca	Brown Rock Chat	R	c	Common
STURNIDAE				
Sturnus malabaricus	Chestnut-tailed Starling	R, AM	f	Common
Sturnus pagodarum	Brahminy Starling	R	c	Rural
Sturnus contra	Asian Pied Starling	R	c	Rural
Acridotheres tristis	Common Myna	R	c	Rural
Acridotheres fuscus	Jungle Myna	R	c	Common
SITTIDAE				
Sitta castanea	Chestnut-bellied Nuthatch	R	u	Common
Sitta frontalis	Velvet-fronted Nuthatch	R	u	Common
Tichodroma muraria	Wallcreeper	WM	u	Common
CERTHIIDAE				
Certhia himalayana	Bar-tailed Treecreeper	WM	r	Common
PARIDAE				
Parus major	Great Tit	R	c	Common
Parus monticolus	Green-backed Tit	R, AM	u	Forest
Parus xanthogenys	Black-lored Tit	R	r	Common
AEGITHALIDAE				
Aegithalos concinnus	Black-throated Tit	R	r	Forest

HIRUNDINIDAE				
Riparia paludicola	Plain Martin	R	u	Forest
Hirundo concolor	Dusky Crag Martin	R	f	Rural
Hirundo daurica	Red-rumped Swallow	R	f	Rural
PYCNONOTIDAE				
Pycnonotus melanicterus	Black-crested Bulbul	R, AM	r	Forest
Pycnonotus jocosus	Red-whiskered Bulbul	R	u	Common
Pycnonotus leucogenys	Himalayan Bulbul	R	c	Common
Pycnonotus cafer	Red-vented Bulbul	R	c	Common
Hypsipetes leucocephalus	Black Bulbul	R, AM	f	Common
CISTICOLIDAE				
Prinia criniger	Striated Prinia	WM	u	Forest
Prinia flaviventris	Yellow-bellied Prinia	WM	r	Forest
Prinia hodgsonii	Grey-breasted Prinia	R	c	Common
Prinia socialis	Ashy Prinia	R	f	Common
Prinia inornata	Plain Prinia	R	f	Forest
ZOSTEROPIDAE				
Zosterops palpebrosus	Oriental White-eye	R	c	Common
SYLVIIDAE				
Cettia pallidipes	Pale-footed Bush Warbler	WM	u	Common
Orthotomus sutorius	Common Tailorbird	R	c	Common
Phylloscopus collybita	Common Chiffchaff	WM	f	Common
Phylloscopus inornatus	Yellow-browed Warbler	WM	r	Common
Phylloscopus humei	Hume's Warbler	WM	u	Forest
Phylloscopus trochiloides	Greenish Warbler	R, AM	u	Common
Phylloscopus reguloides	Blyth's Leaf Warbler	WM	r	Forest
Seicercus burkii	Golden-spectacled Warbler	WM	u	Forest
Seicercus xanthoschistos	Grey-hooded Warbler	R, AM	f	Common
Garrulax albogularis	White-throated Laughingthrush	R	u	Forest
Garrulax leucolophus	White-crested Laughingthrush	R, AM	u	Common
Garrulax lineatus	Streaked Laughingthrush	R	u	Common
Pellorneum ruficeps	Puff-throated Babbler	R, AM	u	Forest
Pomatorhinus erythrogenys	Rusty-cheeked Scimittar Babbler	R, AM	u	Forest
Pomatorhinus schisticeps	White-browed Scimitar Babbler	R, AM	u	Forest
Stachyris pyrrhops	Black-chinned Babbler	R	f	Forest
Turdoides striatus	Jungle Babbler	R	c	Common
Macronous gularis	Striped Tit-Babbler	SM	u	Forest
Leiothrix lutea	Red-billed Leiothrix	R, AM	f	Common
Minla cyanouroptera	Blue-winged Minla	R	r	Forest
Sylvia curruca	Lesser Whitethroat	WM	u	Forest
ALAUDIDAE				
Alauda gulgula	Oriental Skylark	WM	r	Forest
NECTARINIIDAE				
Dicaeum erythrorhynchos	Pale-billed Flowerpecker	R	f	Forest
Dicaeum ignipectus	Fire-breasted Flowerpecker	WM	r	Common
Nectarinia asiatica	Purple Sunbird	R	c	Common
Aethopyga siparaja	Crimson Sunbird	R	f	Common
Aethopyga ignicauda	Fire-tailed Sunbird	WM	u	Forest
PASSERIDAE				
Passer domesticus	House Sparrow	R	c	Rural
Passer rutilans	Russet Sparrow	R	r	Forest
Petronia xanthocollis	Chestnut-shouldered Petronia	R	f	Common
Motacilla alba	White Wagtail	WM	f	Forest
Motacilla maderaspatensis	White-browed Wagtail	R	f	Common
Motacilla citreola	Citrine Wagtail	WM	r	Forest
Motacilla flava	Yellow Wagtail	WM	u	Forest
Motacilla cinerea	Grey Wagtail	R, AM	u	Common
Anthus rufulus	Paddyfield Pipit	SM	r	Rural
Anthus hodgsoni	Olive-backed Pipit	WM	f	Common
Prunella strophiata	Rufous-breasted Accentor	WM	f	Rural
Lonchura striata acuticauda	White-rumped Munia	WM	r	Forest
Lonchura punctulata	Scaly-breasted Munia	R	f	Common
Ploceus philippinus	Baya Weaver	R	f	Common
Serinus pusillus	Fire-fronted Serin	WM	r	Forest
FRINGILLIDAE				
Carpodacus erythrinus	Common Rosefinch	WM	f	Forest

Note: R: Resident, WM: Winter Migratory, SM: Summer Migratory, RAM: Resident Altitudinal Migrant, UC: Uncertain, c: Common, f: Fairly Common, u: Uncommon, r: Rare.

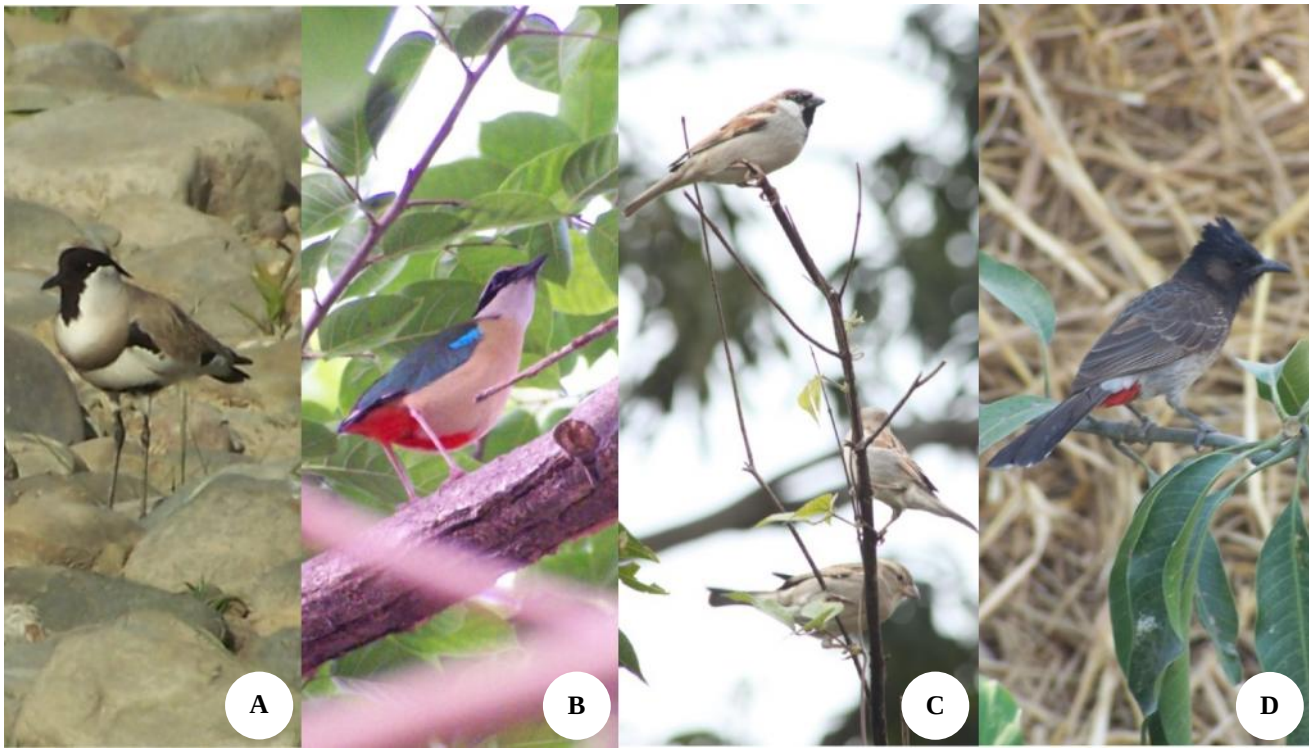

Figure 3. Some birds of Lansdowne forest division and adjacent suburban landscapes, Garhwal Himalayas, Uttarakhand, India. A. River Lapwing (near threatened avian species), B. Indian Pitta (forest bird), C. House Sparrow (suburban bird), D. Red-vented Bulbul (common to suburban and forest habitats)

areas) than between site B and site A (0.63 for suburban and 0.41 for forest) or between site C and site B (0.57 for suburban and 0.41 for forest). Photographs of a near threatened and three selected exemplary bird species representing forest area, suburban habitat and common habitat have been appended as Figures 3.A to 3.D.

Discussion

This study noticeably suggests that bird species richness was significantly higher in natural than suburban habitat which is understandable because vegetation provides food as well as shelter to the birds (Palomino and Carrascal 2006). Other workers also found higher species richness, diversity and dominance in the forest habitat as compared to urbanized habitat (Beissinger and Osborne 1982; Catterall et al. 2010, Shochat et al. 2010). However, in the present study, species richness and diversity slightly differed in the forest and suburban landscapes, perhaps because of the presence of traditional agroforestry systems in the area. The result was in congruence to Scherr and McNeely (2008) who indicated that these agroforests supports good numbers of wild plants and animal species as in natural forests. Lawler (2001) reported that these traditional agro-ecosystems contribute to sustain the regional biodiversity of many invertebrate and vertebrate species. Similarly, Loss et al. (2009) concluded that the mere presence of small patches of landscapes in urban landscapes can increase the species richness in urban ecosystems. Presence of good numbers of the birds common in forest and suburban habitats suggest that many species that occur in the rural habitat can persist only in the nearby presence of the native forest. Similar observations have been made by earlier workers (Perfecto and Vandermeer 2002; Sekercioglu et al. 2007).

Results also indicated that the species diversity and richness were found to be high in summer (April to May) to late monsoon (August to September). This fluctuation in the species diversity may be due to the summer migratory birds and more visibility of birds due to breeding season. According to Hurlbert and Haskell (2003), the increase in diversity or abundance may also be due to high resource supply (Connell and Orias 1964; Wright 1983; Currie 1991) or increased temperature which may reduce thermoregulatory loads and allow organisms to allocate more energy to growth and reproduction (Turner et al. 1988; Lennon et al. 2000) and leads to higher equilibrium in avian community. However, in this study, there was no significant difference in BSR and BSD values between habitat types.

The family Accipitridae with two threatened species needs high conservation priorities in the study area. Animal carcasses which usually available near suburbs as food should be collected and tested for the presence of diclofenac drug which may be used for treatment of livestock on regular basis to provide safe zones for feeding and breeding. According to Thiollay (1994) raptors which are important as bioindicator of habitat quality and pollution, are also crucial for maintaining the dynamics and

diversity of ecosystems by lowering numbers of dominant prey species, thereby allowing less common prey species to survive. The poor presence of River Lapwing (Near Threatened) may be due to high anthropogenic disturbance in and around rivers and small streams, through activities like mining of river beds for boulders and sand because of high demand for construction works like houses, industrial areas, dams etc. The over river bed mining/quarrying sometimes damage the river bank due to access ramps to river bed, causing eyesore, damage to the vegetation, soil erosion, and micro disturbance to ground water. Noise and vibrations because of the moving trucks and tractor trolleys, loading and unloading from collection areas creates disturbances that affects the normal migratory routes of birds or may even cause them to stay in human habitats, thus causing increase in human-wildlife conflicts.

CONCLUSION AND RECOMMENDATIONS

This report indicates the current status of avian community composition (abundance, richness and diversity) in the study area. The biodiversity assessment of the area will help wildlife managers and other stakeholders to tailor conservation policies in the area as there is great threat to avian biodiversity of these lower Shivalik foothills, which are more prone to anthropogenic disturbances. The traditional agroforestry practices in Garhwal hills should be encouraged, as diversification in plant species contributes to species richness and sustains the regional biodiversity of avian and other species.

REFERENCES

Acharya BK, Sanders NJ, Vijayan L, Chettri B. 2011. Elevational Gradients in bird diversity in the Eastern Himalaya: An evaluation of distribution patterns and their underlying mechanisms. PLoS ONE 6: e29097.

Ali S. 2002. The book of Indian birds. 13th revised edition. Bombay Natural History Society, Mumbai.

Barthlott W, Winger M. 2001. Biodiversity: a challenge for development and policy. Springer, Berlin.

Beissinger SR, Osborne DR. 1982. Effects of urbanization on avian community organization. Condor 84: 75-83.

Birdlife Inrenational. 2012. Data Zone. < www.birdlife.org>. Accessed on 14 June 2012.

Catterall CP, Cousin JA, Piper S. Johnson G. 2010. Long-term dynamics of bird diversity in forest and suburb: decay, turnover or homogenization? Divers Distrib 16: 559-570.

Chettri N, Sharma E, Deb DC. 2001. Bird community structure along a trekking corridor of Sikkim Himalaya: a conservation perspective. Biol Conserv 102: 1-16.

Connell JH, Orias E. 1964. The ecological regulation of species diversity. Am Nat 98: 399-414.

Currie DJ. 1991. Energy and large scale patterns of animal and plant species richness. Am Nat 137:27-49.

Gaston KJ. 1994. Rarity, population and community biology. Series 13. Chapman and Hall Ltd., London.

Grimmett R, Inskipp C, Inskipp T. 1998. Birds of the Indian subcontinent. Oxford University Press, New Delhi, India.

Grimmett R, Inskipp C, Inskipp T. 2001. Pocket guide to the birds of Indian Subcontinent. Oxford University Press, New Delhi, India.

Hurlbert AH, Haskell JP. 2003. The effect of energy and seasonality on avian species richness and community composition. Am Nat 161: 83-97.

Inskipp T, Lindsey N, Duckworth W. 1996. An annotated checklist of the birds of the oriental region. Oriental Bird Club, Sandy.

IUCN [International Union for Conservation of Nature]. 2012. IUCN Red List of Threatened Species. Version 2012.1. <www.iucnredlist.org>. Downloaded on 12 July 2012.

Laiolo P. 2002. Effects of habitat structure, floral composition and diversity on a forest bird community in north-western Italy. Folia Zool 51: 121-128.

Lawler SP. 2001. Rice fields as temporary wetlands: A review. Isr J Zool 47: 513-528.

Lennon JJ, Greenwood JJD, Turner JRG. 2000. Bird diversity and environmental gradients in Britain: a test of the species-energy hypothesis. J Anim Ecol 69: 581-598.

Loss SR, Ruiz MO, Brawn JD. 2009. Relationships between avian diversity, neighborhood age, income, and environmental characteristics of an urban landscape. Biol Conserv 142: 2578-2585.

MacArthur RH, MacArthur JW. 1961. On bird species diversity. Ecology 42: 594-598.

Magurran AE. 2004. Measuring Biological Diversity. Blackwell, Oxford.

McAleece N, Gage JDG, Lambshead PJD, Paterson GLJ. 1997. BioDiversity Professional statistics analysis software. <www.sams.ac.uk>.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC.

Mittermeier RA, Myers N, Thompson JB, da Fonseca GAB, Olivieri, S. 1998. Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. Conserv Biol 12: 516-520.

Myers N, Mittermeier RA, Mittermeier CG. da Fonseca GAB, Kent J. 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853-858.

Naithani A, Bhatt D. 2012. Bird community structure in natural and urbanized habitats along an altitudinal gradient in Pauri district (Garhwal Himalaya) of Uttarakhand state, India. Biologia 67: 800-808.

Naithani A, Bhatt D. 2010. A checklist of birds of Pauri district, Uttarakhand, India. Indian BIRDS 6: 153-157.

Palomino D, Carrascal LM. 2006. Urban influence on birds at a regional scale: A case study with the avifauna of northern Madrid province. Landscape Urban Plan 77: 276-290.

Perfecto I, Vandermeer J. 2002. Quality of agroecological matrix in a tropical montane landscape: Ants in coffee plantations in southern Mexico. Conserv Biol 16: 174-182.

Price T, Jennifer Z, Kartika J, Nitin J. 2003. Bird species diversity along Himalaya: a comparison of Himachal Pradesh and Kashmir. J Bombay Nat Hist Soc 100: 394-409.

Singh AP. 2000. Birds of lower Garhwal Himalayas: Dehra Dun valley and neighbouring hills. Forktail 16: 101-123.

Scherr SJ, McNeely JA. 2008. Biodiversity conservation and agricultural sustainability: towards a new paradigm of 'ecoagriculture' landscapes. Philos T Roy Soc B 363: 477-494.

Sekercioglu CH, Loarie SR, Oviedo Brenes F, Ehrlich PR, Daily GC. 2007. Persistence of forest birds in the Costa Rican agricultural countryside. Conserv Biol 21: 482-494.

Shochat E, Lerman SB, Anderies JM, Warren PS, Faeth SH, Nilon CH. 2010. Invasion, competition, and biodiversity loss in urban ecosystems. Bioscience 60: 199-208.

Sultana A, Hussain MS, Khan JA. 2007. Bird communities of the proposed Naina and Pindari Wildlife Sanctuaries in the Kumaon Himalaya, Uttarakhand, India. J Bombay Nat Hist Soc 104: 19-29.

Thiollay JM. 1994. Family Accipitridae (hawks and eagles). In: del Hoyo J, Elliott A and Sargatal J (eds) Handbook of the Birds of the World. Lynx Edicions, Barcelona.

Turner JRG, Lennon JJ, Lawrenson JA. 1988. British bird species distributions and the energy theory. Nature 335: 539-541.

Verner J. 1985. Assessment of counting techniques. Curr Ornithol 2: 247-302.

Wright DH. 1983. Species-energy theory: an extension of species-area theory. Oikos 41: 496-506.

Whittaker RH. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecol Monogr 30: 279-338.

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Diversity and use of ethnomedicinal plants in coastal Karnataka, India

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ABSTRACT

Bhandary MJ, Chandrashekar KR. 2014. Diversity and use of ethnomedicinal plants in coastal Karnataka, India. Biodiversitas 15: 89-93. A study was undertaken in Coastal Karnataka, a culturally and floristically diverse region between the Western Ghats and the Arabian sea in India, to document the diversity and uses of ethnomedicinal plants of the area. This study resulted in the documentation of ethnomedicinal uses of 342 species of plants belonging to 34 families. The dominant families of ethnomedicinal plants were: Fabaceae (38 species), Euphorbiaceae (22 species), Rubiaceae (11 species), Acanthaceae, Asteraceae, Apocynaceae and Rutaceae (10 species each). Among the plants used, 30% are herbs, 27% trees, 25% climbers and 18% shrubs. Majority of the plants are used against several diseases, either alone or in combination with other plants. The most popular medicinal plants, in terms of the number of diseases against which they are used, are *Cyclea peltata*, *Aristolochia indica*, *Cuminum cyminum*, *Curcuma longa*, *Tamarindus indica*, *Asparagus racemosus*, *Ficus racemosa*, *Hemidesmus indicus*, *Ficus religiosa*, *Calotropis gigantea*, *Vitex negundo*, *Aegle marmelos* and *Leucas aspera*. A list of 50 important ethnomedicinal plants of the region which are used in the treatment of 5 or more disorders is provided.

Key words: Coastal Karnataka, ethnobotany, ethnomedicinal plants, traditional medicine

INTRODUCTION

Plants are the important source of medicines both in traditional and modern methods of treatment. About 50,000 of the flowering plants occurring in the world are believed to be having medicinal properties. According to an estimate of the World Health Organisation (WHO), about 80% of the populations in the developing countries still rely on traditional medicine for their primary health care needs.

Knowledge of indigenous cultures about medicinal uses of local plants is an important input for understanding traditional utilization of biological resources, for promoting community healthcare practices and also for developing modern plant-based drugs.. The importance and urgency of scientific documentation of such traditional wisdom on medicinal properties of plants, much of which is restricted to local cultures and transmitted only orally, has been realized by ethnobotanists as it is being irreversibly eroding due to the fast acculturisation of traditional cultures.

India is a rich repository of information on traditional uses of plant resources owing to its rich cultural and floristic diversity. This has been amply proved by the multitude of studies reported on this aspect from the country (Binu et al. 1992, Lalramanghinglova and Jha 1999). The tribal and indigenous communities of India were found to be using more than 10,000 species of wild plants for various purposes which includes about 8,000 species for medicinal uses (Pushpangadan and George 2010). However, the ethnobotanical wealth of some geographical areas of the country, such as the State of Karnataka, is still not fully explored and the studies reported so far pertains only to ethnomedicinal practices specific to some areas, tribal groups and disease categories (Bhandary and Chandrashekar 2001, 2003, 2011; Bhandary et al. 1995, 1996; Harsha et al. 2002, 2003, 2006; Rajkumar and Shivanna, 2010; Shivanna and Rajkumar, 2010; Prakash et al. 2010). In an attempt to fill this lacuna, an extensive study of the plants used in the ethnomedicinal tradition of the coastal areas of Karnataka was undertaken and the findings are reported in this paper.

MATERIALS AND METHODS

Coastal Karnataka, comprising of three revenue districts, namely Dakshina Kannada, Udupi and Uttara Kannada, is a diversified region lying to the western edge of the State of Karnataka in India (Figure 1). Situated between latitudes 12^0.28'-$15^0$31' N and longitudes $74^0$32'-75^0 4' E, it is a narrow belt of land that lies between the Western Ghats and the Arabian Sea having an average width of 50-80 km. and a length of 267 km. The total geographical area is 19,753 sq km. This region receives heavy rainfall, in the range of 2,500-3,000 mm, and it harbors different types of vegetation such as littoral, scrub, moist deciduous and evergreen. The littoral and the scrub forests are found along the coastal belt, the moist deciduous forests mainly in the inland plateaus extending to the foot of the Western Ghats and the evergreen forests localized only in the ghats.

Total population of this area is 46,98,380 with an average density of 300 persons per sq km. According to the

Figure 1. Map of coastal Karnataka showing the study area

Census of India, 2011, Dakshina Kannada has the highest density at 457 persons. Udupi district's density is 304 persons and Uttara Kannada has 140 persons per sq km. The people of the region represent a mixture of rich ethnic and cultural diversity. Besta, Brahmin, Bunt, Devadiga, Gudikar, Idiga, Kumbara and others are the predominant non-tribal indigenous communities while Koraga, Kunbi, Malekudiya, Gowli, Halakki Vokkaliga and Siddi are the important tribal groups inhabiting this region. The area is still predominantly agrarian with about 80 % of the population employed in agriculture and allied activities including growing cash crops of coconut (*Cocos nucifera*), areca nut (*Areca catechu*) and other horticultural products. More than 70 % of cropland is under cereals with paddy (*Oryza sativa*) as the principal crop. Fishing is the other major source of livelihood with about 1,00,000 people directly engaged in this activity. 'Kannada' and 'Tulu' are the major languages while others like 'Marati' and 'Konkani' are also spoken.

Practicing local herbalists or 'nati vaidya's and other knowledgeable elderly people belonging to various non-tribal communities and three of the tribes, namely the Koraga, the Malekudiya and the Halakki vokkaliga form the local guides and source of information for this study, which was the part of a ongoing comprehensive ethnobotanical documentation project started in 1995. During field trips, about 150 herbalists and elders have been repeatedly visited in their own localities, during different seasons. After obtaining their consent, information regarding their knowledge of medicinal plants is recorded with the help of questionnaire-based interviews, open-ended field discussions and also by observation of their actual treatment practices, wherever possible. Simultane-ously, recording of information on various aspects of treatment practices such as diseases treated, method of treatment, vernacular names of plants used, method of herbal collection and medicine preparation, etc., is also collected and recorded. Herbarium materials of the plants were also gathered with the help of the local guides, for authentication of the identity of the plants used. They were identified with the help of local floras (Gamble 1967, Cooke 1967, Saldanha 1984).

RESULTS AND DISCUSSION

Diversity of ethnomedicinal plants

The indigenous communities of the study area were found to be using as many as 342 species of plants in their traditional ethnomedicinal practices. These plants belonged to 34 families. The dominant families of ethnomedicinal plants and number of plants recorded from each family are shown in Figure 2. Fabaceae with 38 species tops this list while Euphorbiaceae with 22 species and Rubiaceae with 11 species occupy the second and third positions. Fabaceae, along with Asteraceae and Lamiaceae, has been emerged as the most species rich medicinal plant family in studies reported from various other areas also (Kakudidi et al. 2000, Kamatenesi-Mugisha et al. 2008).

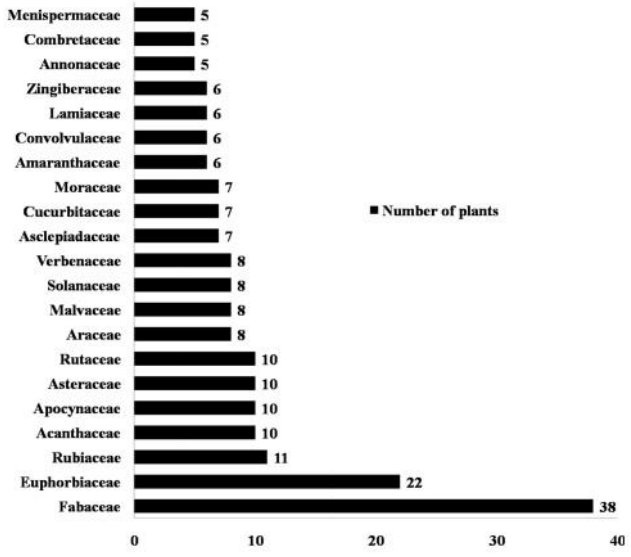

Figure 2. Dominant families of ethnomedicinal plants

Majority of the plants are used against several diseases, either alone or in combination with other plants. 13 species are used in the treatment of 10 or more diseases whereas 72 species are used against 5 or more diseases. The most popular medicinal plants, in terms of the number of diseases against which they are used, are *Cyclea peltata*, *Aristolochia indica* (19 diseases each), *Cuminum cyminum* (17), *Curcuma longa* (13), *Tamarindus indica* (13), *Asparagus racemosus* (12), *Ficus racemosa* (12), *Hemidesmus indicus* (12), *Ficus religiosa* (11), *Calotropis gigantea* (11), *Vitex negundo* (11), *Aegle marmelos* (10) and *Leucas aspera* (10). 50 most important ethnomedicinal plants of Coastal Karnataka with data on their scientific names, family, common names and part/s used are listed in Table 1. Comparison of the medicinal uses recorded in the present study with important works pertaining to Indian traditional and ethnomedicinal plants (Jain 1991; Husain et al. 1992; Warrier et al. 1994-1996; Yoganarasimhan 1996; Kher 2007) indicated that a major proportion of them are hitherto not known and therefore new additions to the Indian ethnomedicinal literature.

Table 1. Important ethnomedicinal plants of Coastal Karnataka

Name of the species	Family	Vernacular names	Parts used
Aristolochia indica L.	Aristolochiaceae	Ishwara beru	Root
Cyclea peltata (Lam.) Hk. F. & Thoms.	Menispermaceae	Hade balli, Padala	Leaf, fruit, root
Cuminum cyminum L.	Apiaceae	Jeerige, Jeerdari	Fruit
Curcuma longa L	Zingiberaceae	Arasina, Manjal	Root
Tamarindus indica L.	Caesalpiniaceae	Hunase, Puli	Stem bark, fruit
Asparagus racemosus Willd.	Liliaceae	Shatavar,	Root tuber
Ficus racemosa L.	Moraceae	Atthi, Arthi	Stem, root, fruit
Hemidesmus indicus (L.) Schult.	Asclepiadaceae	Namada beru, Nannari, ookurma	Root
Ficus religiosa L.	Moraceae	Aswatha, Attosu	Stem bark
Calotropis gigantea (L.) R. Br.	Asclepiadaceae	Akka, Akkamale	Leaf, Latex
Vitex negundo L.	Verbenaceae	Nekki, Lakki	Leaf
Aegle marmelos (L.) Corr.	Rutaceae	Bilva, Bilpatre	Leaf
Leucas aspera (Willd.) Link,	Lamiaceae	Thumbe	Stem, leaf
Barringtonia racemosa (L.) Spreng.	Barringtoniaceae	Samudra pala	Seed
Breynia vitis-idaea (Burm.f.) Fisch.	Euphorbiaceae	Palli thappu	Leaf
Caesalpinia bonduc (L.) Roxb.	Caesalpiniaceae	Gajjuga, Kaat kalenji kayi	Leaf, seed.
Calophyllum inophyllum L.	Clusiaceae	Honne. Ponne kayi	Seed
Caryota urens L.	Arecaceae	Baine, Indu	Root, Stem
Catunaregam spinosa (Thunb.) Tirvengadum	Rubiaceae	Kaare, Kadu kaare	Stem, leaf, fruit
Celastrus paniculatus Willd.	Celastraceae	Gangamma balli	Root
Croton roxbughii Balak.	Euphorbiaceae	Vayu beru, Somar	Stem bark, root
Cucurbita maxima Duch. Ex Lam.	Cucurbitaceae	Sihi kumbala, Kembude	Fruit, root
Elephantopus scaber L.	Asteraceae	Nela mucchir	Whole plant
Ervatamea heyneana (Wall.) Cooke	Apocynaceae	Maddarasa, Kokke kayi	Stem bark
Ficus benghalensis L.	Moraceae	Aalada mara, Golida mara	Stem bark
Hibiscus rosa-sinensis L.	Malvaceae	Dasavala	Leaf
Hybanthus enneaspermus (L.) F. V. Muel.	Violaceae	Purusharatna	Whole plant
Ixora coccinea L.	Rubiaceae	Kiskara, Kepula	Stem, root
Jasminum malabaricum Wt.	Oleaceae	Betta mallige, Adroli	Stem, leaf
Kalanchoe pinnata (Lam.) Pers.	Crassulaceae	Kadu basale	Leaf
Melastoma malabathricum L.	Melastomataceae	Nekkarika, Nekkare	Leaf, root
Memecylon malabaricum (Cl.) Cogn.	Melastomataceae	Ollekodi	Leaf, Tender shoots
Mimusops elengi L.	Sapotaceae	Bakula, Renje	Stem bark
Musa paradisiacal L.	Musaceae	Baale, Baare	Stem
Musa superba Roxb.	Musaceae	Kaadu bale, Kallu bale, Kalbaare	Stem, fruit, seed
Mussaenda belilla Buch.-Ham.	Rubiaceae	Bellate, Bolle tappu	Leaf
Ocimum tenuiflorum L	Lamiaceae	Thulasi	Leaf
Leucas aspera (Willd.) Link,	Lamiaceae	Thumbe	Stem, leaf
Phyllanthus amarus Schum. & Thonn.	Euphorbiaceae	Nela nelli	Whole plant
Phyllanthus emblica L.	Euphorbiaceae	Nelli	Fruit
Pongamia pinnata (L.) Pierre,	Papilionaceae	Honge, Korngu, Karanja	Stem bark, fruit
Rauvolfia serpentina (L.) Benth.	Apocynaceae	Sarpagandha Patalagaruda	Root
Ricinus communis L.	Euphorbiaceae	Haralu, Alambuda	Leaf, fruit
Salacia reticulata Wight,	Hippocrateaceae	Aka nayaka	Stem, root
Syzygium cumini (L.) Skeels,	Myrtaceae	Nerale, Nerolu	Stem bark, seed
Tabarnaemontana divaricata (L.) R. Br.	Apocynaceae	Nandibattalu, Nanjatte	Stem bark
Terminalia arjuna (Roxb. Ex DC.) Wt. & Arn.	Combretaceae	Arjuna, Bili matti, Hole matti	Stem bark
Tinospora sinensis (Lour.) Merr.	Menispermaceae	Amruta balli	Stem bark
Zanthoxylum rhetsa DC.	Rutaceae	Gamate, Jummana kayi, Kavate	Stem bark, fruits
Zingiber officinale Rosc.	Zingiberaceae	Shunti	Root

The analysis of the recorded medicinal plants based on growth habits is shown in Figure 3. The highest proportion is of herbs (30%) while the lowest is of shrubs (18%). Trees make up 27% and 25% plants are climbers. This is similar to the pattern of growth form distribution observed for the ethno-medicinal plants of other regions, such as Kancheepuram district, Tamilnadu (Muthu et al. 2006) and Rewa district of Madhya Pradesh (Shukla et al. 2010). However, the tribals of Pachamalai hills of Tamilnadu use more shrubs (29.5%) than herbs or trees (28. 4% each, Geetharani 2010) whereas trees are the major category of plants in the ethnomedicinal practice of Bomaa community of Ghana (Addo-Fordjour et al. 2008).

Percentage of treatment methods used against each of these main disease categories is shown in Figure 4. The highest number of remedies is documented for skin problems (22%) which are followed by swelling and pain in body parts (20%), and gastro-intestinal and urino-genital problems (15% each). It is important to note that diseases prevailing in modern cultures like cancers, cardio- vascular diseases, hypertension, AIDS, etc., are not found in the list of diseases treated by ethnomedicinal systems of this area. In fact, there are no homologous words for diseases such as cancer, leukemia, hypertension, etc., in the vernacular languages of this region, as generally noted by Balick and Cox (1996) for indigenous medicinal systems of the world, as a whole.

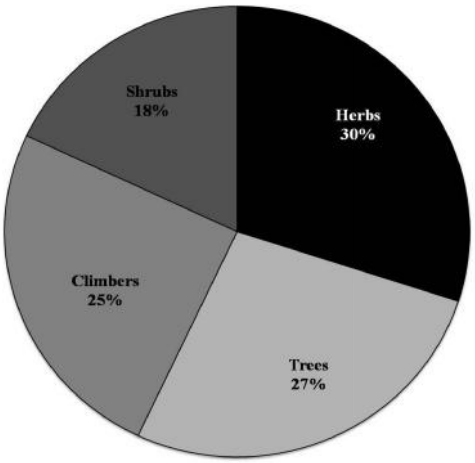

Figure 3. Habit-wise distribution of ethnomedicinal plants

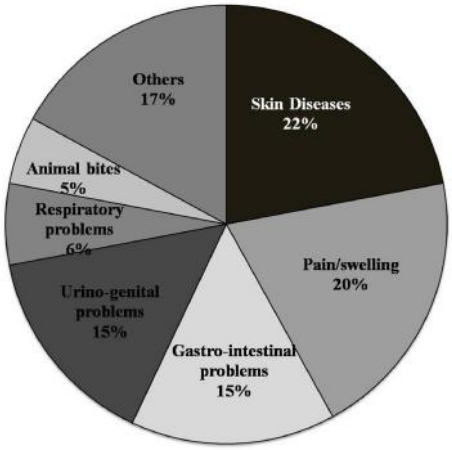

Figure 4. Percentage of ethnomedicinal formulations for various disease categories

Ethnomedicinal use priorities

The 42 various ailments against which ethnomedicinal treatments have been recorded in the study area can be grouped into 7 major categories of symptomatically and organ-system related diseases/problems, such as skin problems, gastro-intestinal disorders, urino-genital disorders, respiratory disorders, body swellings and pain, animal bites and others. The last category includes unrelated problems like fever, jaundice, diabetes, bone fracture, dental problems, eye and ear problems (Table 2). Diagnosis of the diseases by ethnomedicinal practitioners is mainly based on symptoms, information about which is gathered by both visual examination and description provided by the patients.

CONCLUSSION

Indigenous communities of coastal Karnataka possess a rich heritage of ethnomedicinal tradition in which about 342 species of local plants are employed as medicines for treating about 42 different health problems. Much of the ethnomedicinal claims for these plants are hither to not reported and further pharmaco-chemical investigations are essential to confirm these uses.

Table 2. Diseases treated in the ethnomedicine of Coastal Karnataka

Category	Diseases/conditions included
Skin problems	Herpes, scabies, eczema, leucoderma, skin ulcer/wounds, cuts, burns
Body pain/Swellings	Body swelling, rheumatic pain, head ache, stomach ache, body ache, mumps
Urino-genital problems	Leucorrhoea, haemorrhoea, emmenagogue, polyuria, dysuria, urinary stones, fertility problems, anti-abortifacients
Gastro-intestinal problems	Constipation/indigestion, dysentry, diarrhoea, flatulence, intestinal worms, piles
Respiratory problems	Cough, cold, asthma
Animal bites	Snake bite, spider bite, scorpion bite, dog bite
Others	Fever, jaundice, diabetes, bone fracture, ear/eye/dental/hair problems

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REFERENCES

Addo-Fordjour P, Anning AK, Ebenezer Jeremiah Durosimi Belford EJD, Akonnor D. 2008. Diversity and conservation of medicinal plants in the Bomaa community of the Brong Ahafo region, Ghana. J Med Plants Res 2: 226-233

Balick MJ, Cox PA. 1996. Plants, People and Culture-The Science of Ethnobotany. Scientific American Library, New York

Bhandary MJ, Chandrashekar KR. 2001. Treatment for poisonous snake-bites in the ethnomedicine of Coastal Karnataka. J Med Arom Plant Sci 22: 505-510

Bhandary MJ, Chandrashekar KR. 2003. Veterinary herbal medicine of Coastal Karnataka. J Econ Taxon Bot 27: 645-655

Bhandary MJ, Chandrashekar KR. 2011. Herbal therapy for herpes in the ethno-medicine of Coastal Karnataka. Indian J Trad Knowledge 10 (3): 528-532

Bhandary M J, Chandrashekar K R, Kaveriappa KM. 1995. Medical Ethnobotany of the Siddis of Uttara Kannada district, Karnataka. India J Ethnopharmacol 47: 149-156

Bhandary M J, Chandrashekar K R, Kaveriappa KM. 1996. Ethnobotany of the Gowlis of Uttara Kannada, Karnataka. J Econ Taxon Bot 12: 244-249

Binu S, Nayar TS, Pushpangadan P. 1992. An outline of ethnobotanical research in India. J Econ Taxon Bot 10: 405-428

Cooke T. 1967. Flora of Presidency of Bombay, Vol I-III. Botanical Survey of India, Calcutta

Gamble JS. 1967. Flora of Presidency of Madras, Vol I-III. Botanical Survey of India, Calcutta

Geetarani M. 2010. Medicinal plants viz a viz indigenous knowledge among the tribals of Pachamalai Hills. Indian J Trad Knowledge 9: 209-215.

Harsha VH, Hebbar SS, Hegde GR, Shripathi V. 2002. Ethnomedical knowledge of plants used by Kunbi tribe of Karnataka in India. Fitotherapia 73: 281-287

Harsha VH, Hebbar SS, Shripathi V, Hegde GR. 2003. Ethnomedicobotany of Uttara Kannada District in Karnataka, India, Plants in the treatment of skin diseases. J Ethnopharmacol 84: 37-40

Harsha VH, Shripathi V, Hegde GR. 2006. Ethnoveterinary practices in Uttara Kannada District of Karnataka. Indian J Trad Knowledge 4: 253-258

Husain A, Vismani OP, Popli SP, Misra LN, Gupta MN, Srivatsava GN, Abraham S, Singh AK. 1992. Dictionary of Indian medicinal plants. Centre for Indian Medicinal and Aromatic Plants, Lucknow

Jain SK. 1991. Dictionary of Indian Ethnobotany and Folk-medicine. Deep Publishers, New Delhi

Kakudidi EKZ, Bukenya-Ziraba R, Kasenene JM. 2000. The medicinal plants in and around Kibale National Park in Western Uganda. Nor J Bot (Lidia) 5: 109-124

Kamatenesi-Mugisha M, Oryem-Origa H, Odyek O, Makawiti DW. 2008. Medicinal plants used in the treatment of fungal and bacterial infections in and around Queen Elizabeth Biosphere Reserve, western Uganda. Afr J Ecol 46: 90-97

Kher CP. 2007. Indian Medicinal plants-An Illustrated Dictionary. Springler, Berlin

Lalramnghinglova H, Jha LK. 1999. Ethnobotany: A Review. J Econ Taxon Bot 23: 1-27

Muthu C, Ayyanar M, Raja N, Ignacimuthu S. 2006. Medicinal plants used by traditional healers in Kancheepuram District of Tamil Nadu, India. J Ethnobiol Ethnomed 2:43-53

Prakasha HM, Krishnappa M, Krishnamurthy YL, Poornima SV. 2010. Folk medicine of NR Pura taluk in Chikmagalur district of Karnataka. Indian J Trad Knowledge 9: 55-60

Pushpangadan P, George V. 2010. Ethnomedical practices of rural and tribal populations of India with special reference to the mother and child care. Indian J Trad Knowledge 10: 9-17

Rajkumar N, Shivanna MB. 2010. Traditional herbal medical knowledge in Sagar taluk of Shimogga district, Karnataka, India. Indian J Nat Prod Res 1: 102-108

Saldhanha CJ. 1984. Flora of Karnataka, Vol 1. Oxford & IBH Publishers, New Delhi

Shivanna MB, Rajkumar N. 2010. Ethno-medico-botanical knowledge of rural folk in Bhadravathi taluk of Shimoga district, Karnataka. Indian J Trad Knowledge 10: 158-162

Shivarajan VV, Balachandran I. 1994. Ayurvedic drugs and their plant sources. Oxford & IBH Publishers, New Delhi

Shukla AN, Srivatsava S, Rawat AKS. 2010. An ethnobotanical study of medicinal plants of Rewa district, Madhya Pradesh. Indian J Trad Knowledge 9: 191-102

Warrier PK, Nambiar VPK, Kutty CR. 1994-1996. Medicinal Plants of India, Vol 1-V. Orient Longman Ltd., Madras

Yoganarasimhan SN. 1996. Medicinal plants of India, Vol I, Karnataka. Interline Publishers, Bangalore

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Plants utilization by the communities of Bharsar and adjoining area of Pauri Garhwal District, Uttarakhand, India

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ABSTRACT

Bisht AS, Sharma KD. 2014. Plants utilization by the communities of Bharsar and adjoining area of Pauri Garhwal District, Uttarakhand, India. Biodiversitas 15: 94-100. Garhwal Himalaya possesses luxuriant a varied vegetation with in the Himalaya region. Almost every plant has economic value in the form of shelter, food, water, medicine, fuel and industrial products and fodder. Surveys were conducted in entire Bharsar, Pauri Garhwal district of Uttarakhand, India in order to get information on traditional uses of plants by local inhabitants. A total of 169 plants were collected of which 40 species of vegetables, 19 species of forest and agroforestry, 24 species of ornamental flower, 71 species of less known medicinal plants and 15 species of agricultural crops were found economically important as they are used by the people frequently for various purposes.

Key words: Garhwal Himalaya, forestry, medicine, plant genetic resources, vegetables

INTRODUCTION

The Himalaya is the perennial source of attractions, curiosity and challenge to human intellect through the ages. Amongst several assets, the vegetation provides an everlasting and interesting field of investigation. The diversity, copiousness as well as uniqueness of the plant components in various habitats retained sound and aesthetic environment of the Himalaya. However, in the recent past couple of years, excessive exploitation of vegetation, unplanned land use, natural disasters and several developmental processes, accelerated deterioration of vegetation or loss of individual species since we do not possess the detailed botanical record for several of the localities or region. One of such botanical interests and little known region is the Bharsar in district Pauri, which sustain unique and rich genetic resources.

Plant genetic resources continue to play an important role in the development of agriculture, horticulture, forestry etc. World population is expected to increase from 7.0 billion to 9.1 billion by 2050 (WHO, 2012). The world needs astonishing increase in food production to feed this population. Plant genetic resources, constitutes the foundation upon which agriculture and world food securities are based and the genetic diversity in the germplasm collection is critical to the world's fights against hunger. They are the raw material for breeding new plant varieties and are a reservoir of genetic diversity.

In view with the multiple stresses and depletion of genetic resources and habitat, today's foremost concern of the globe in general and Himalayas in particular is the conservation of biological diversity, for which detailed description of plant genetic entities are essential. Keeping in view (i) the lack of earlier record, (ii) diversity and richness of the genetic resources in vast and varied stretch of land, (iii) the deterioration of mountain ecosystem and (iv) present day concern of biodiversity. An attempt is made to present the genetic resources account of the Bharsar region of district Pauri Garhwal, Uttarakhand.

MATERIALS AND METHODS

Study area

Pauri Garhwal is one of the thirteen districts of Uttarakhand, and is located between 29^0 20'-29^0 75' N latitude and 78^0 10'-78^0 80' E longitude, covering about 5540 Km^2 area. The district is the most fascinating segments of Himalaya, stretches from the Ram Ganga river that separates Pauri-Kumaon border in the East, and to the Ganga demarcating the Western border. Almora, Nainital (East), Chamoli, Tehri and Dehradun (North-West) and adjacent plains of Bijnor, Hardwar (South) districts, surround it. The whole area lies in between Kumaon and Himachal Pradesh Himalaya and considered as a part of North-Western Himalaya.

Bharsar is situated at about 60 Km from the district head quarter (Pauri) in the East-South direction on the road side area of Pauri-Thalisain-Ram Nagar National High way 121/41. The meaning of Bharsar in local dialect is 'flourished with natural wealth". Since the ancient time, it is famous for its vast reserve of biodiversity and geographically the temperate climate conditions of the region are quite congenial for the horticulture. It is bounded by the temperate evergreen forest towards North-East (Budha Bharsar), North-West (Chauri Khal), East-South

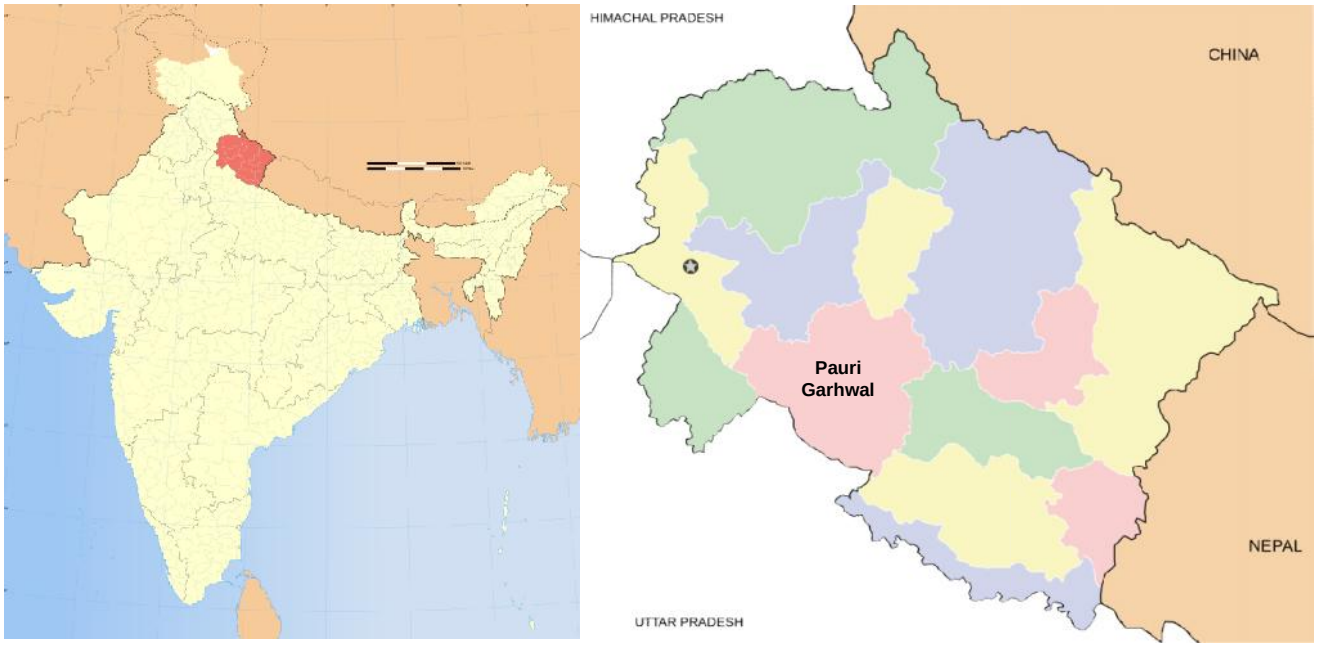

Figure 1. Study site in Pauri Garhwal district of Uttarakhand, India.

direction occupies terracing crop fields and village namely Dhulet, Sakniyana, Buransi, Nauntha, Sainji, etc.

Climate

In general, the climate of the Bharsar represents the mild summer, higher precipitation and colder or severe cold prolonged winter. The climate factors i.e. precipitation, temperature, relative humidity and wind, in association with elevation (valleys or mountain range from temperate zone), proximity to Great Himalaya, slope aspects, drainage, vegetation etc are responsible for the micro-climate of this area. Major output of precipitation is in the form of rain fall, besides occasional occurrence of due, hailstorm, fog, frost, snow fall etc. The South-East monsoon commences towards the end of June while the North-East monsoon causes occasional winter showers during November-February. During winter, snow fall is common in this region. During summer months, the valley has hot climate prevailing for few hours in a day, the maximum temperature during May-June is recorded between 30^0C-35^0C however, and nights are cool. December and January are the coldest months, the minimum temperature reaches to 1^0C to -4^0C. Relative humidity is normally highest during rainy season (July - August), often recorded near to saturation point (92-97%) in thickly forest in this zone, it gradually decreases towards December.

Soil

The soil texture, color and nature represent wide range of variations, depending upon geology, altitude, slope aspects, climate, vegetation and biological and chemical interactions. In general, the soil of the Himalaya on the slopes about 30^0 represents thin surface horizon. Such skeletal soil has medium to coarse texture, depending the core materials. The valley and gentle slopes have considerable soil depth, developed from colluviums the texture of such soil is generally coarse and least acidic. Decrease in soil pH with increase of elevation has been reported by some workers, possibly due to leaching out of calcium and magnesium from the surface and simultaneously in much higher altitude of great Himalaya, the trend is reversed. In majority of the places soil is rich in potassium, medium in phosphorous and poor in nitrogen contents, with the exception of some cultigens fields.

Procedures

The present investigation was a result of extensive and intensive field survey, conducted during August 2012 to July 2013. The specimen were collected by usual methods of collection, preservation and maintenance of specimen in herbarium with field notes viz. local name, habit, habitat, altitude range, color of flower, flowering and fruiting time, general availability, local use etc. The collected specimens were identified with the help of recent and relevant floras i.e. Gaur (1999) and Naithani (1985) various plant species have been gathered through personal interview of the local inhabitants.

RESULTS AND DISCUSSION

After extensive surveys conducted during 2011-2014 in Bharsar, Pauri district of Garhwal Himalaya, a total of 169 species collected and these species were recorded as economically important species based on genetic resource knowledge exists in the district. Species were further categorized into different groups as described *viz*. vegetables, fruits, medicinal plants, pulses etc. However, species used as supplementary foods, vegetables and as an edible fruits are described in this paper (Table 1).

Table 1. Enumeration of useful plants of Bharsar, Pauri district of Garhwal Himalaya, Uttarakhand, India

Botanical name	Family	English name	Vernacular name	Varieties
Vegetables				
Abelmoschus esculentus	Malvaceae	Lady's finger	Bhindi	Anamika, Pusa Sawani, Pusa Makhmali, Kiran, Aruna.
Beta vulgaris	Chenopodiaceae	Chukander	Sugar beet	Early Wonder', 'Detroit Dark Red', 'Ruby Queen', and 'Crosby'
Brassica chinensis	Brassicaceae	Chinese cabbage	Pakchoi	Baby,Shanghai
Brassica oleracea var. *capitata*	Brassicaceae	Cabbage	Bandh gobhi	Savoy, Napa, Navkranti, Pride of India
Brassica rapa	Brassicaceae	Turnip	Shalgham	
Capsicum annuum	Solanaceae	Capsicum	Simla mirch	California Wonder, Yellow Wonder, Nishant, Ganga, Bharat, Indira
Colocasia esculenta	Araceae	Taro	Arvi	
Colocasia himalayens	Araceae		Pindalu	
Cucumis sativus	Cucurbitaceae	Cucumber	Kheera	Balam Kheera, Pant Khera, Sheetal, Kalyanpur Green, Aman, Himagi
Cucurbita moschata	Cucurbitaceae	Pumpkin	Kaddu	
Cucurbita maxima	Cucurbitaceae	Red gourd	Metha Kaddu	
Cucurbita pepo	Cucurbitaceae	Field pumpkin	Chhappan Kaddu	Australian Green. Panjab Chhappan Kaddu-1, Early Yellow
Daucus carota	Apiaceae	Carrot	Gajar	Nantes (European carrot), RKC 1 to 6, Pusa Keshar, Pusa Medhali
Phaseolus vulgaris	Fabaceae	Common bean	Sem	Bharsar Local
Lablab purpureus	Fabaceae	Lablab bean	Patiya Sem	Pant Bean-2, Pusa Parvati, Pusa Himgiri, ABM-1
Lactuca sativa		Lettuce	Salad	
Lagenaria siceraria			Loki	
Luffa acutangula		Ridge gourd	Kali tori	
Luffa cylindrical		Sponge gourd	Ghiya tori,	
Lycopersicon esculentum	Solanaceae	Tomato	Tamatar	HS-101, Sweet-72, Pusa Hybrid-1 & 2, Pant Bahar, Pusa Divya, Arka Vishal, Manisha, Kashi, Amrit Rupali, GS-600
Momordica charantia		Bitter gourd	Karela	
Pisum sativum	Fabaceae	Pea	Matar	Arkel, PB-89, Pant Uphar, Ajad Matar, Pant Sabji Matar-3
Raphanus sativus	Brassicaceae	Radish	Muli	Doonagiri, Bharsar Local, BM 1-18, Japonica White. Punjab Pasand, Kashi Shrota
Solanum melogena	Solanaceae	Brinjal	Baingan	Bharsar Nav kiran, BPL-74, Pant Samrat, Pant Rhituraj, Pusa Utam, Pusa Upkar
Solanum tuberosum	Solanaceae	Potato	Aloo	Kufri Chandarmukhi, Kufri Ashoka, Kufri Jawahar, Chip Sona-1, Chip Sona-2
Spinacea oleracea	Chenopodiaceae	Spinach	Palak	BG, PH, Local, Algreen, Pusa Jyoti
Trichosanthes angunia	Cucurbitaceae	Snake gourd	Chachinda	
Trigonella foenum-graecum			Methi	TG-74, Kasoori Maithi, Maithi Local, Pant Ragni
Spices and condiments				
Allium cepa	Amaryllidaceae	Onion	Pyaz	Nasik Red, Pusa Ratna, Punjab Red Round, Arka Kirtiman, Arka Lalima, VL Onion-3
Allium sativum	Amaryllidaceae	Garlic	Lahsun	Jamuna Safed-1, Jamuna Safed-3, Pant Lohit
Amomum subulatum	Zingiberaceae	Cardamom	Bari Elachi	
Capsicum annuum var. *frutescens*	Solanaceae	Chill	Mirch	Pant C-1, Pusa Sadabahar, Punjab Lal
Coriandrum sativum	Apiaceae	Coriander	Dhania	
Curcuma domestica	Zingiberaceae	Turmeric	Haldi	
Metha arvensis	Lamiaceae	Mint	Paudina	
Zingiber officinale	Zingiberaceae	Ginger;	Adrak	
Fruits				
Actinidia arguta	Actinidiaceae	Kiwifruit	Kiwi	
Castanea sativa	Fagaceae	Chestnut	Chestnut	
Citrus aurantifolia	Rutaceae	Lime	Kagzinimbu	
Corylus jacquemontii	Corylaceae	Turkish hazelnut	Bhotiya Badam	
Juglans regia	Juglandaceae	Walnut	Akhrot	Govind, Rupa, Pratap

Malus domestica	Rosaceae	Apple	Seb	Golden Delicious, Vance Delicious, Red Chief, Oregon Spur, Royal Delicious, Top Red, Choubatiya Anupum, Rome Beauty
Pyrus communis	Rosaceae	Pear	Naspati	
Prunus persica	Rosaceae	Peach	Aru	Sharbati, Early Cream. Red June, Red Heaven, Early Glow, July Elberta
Prunus armeniaca	Rosaceae	Apricot	Chulu	Moorpark, Turkey, St. Ambrose, Kaisha, Nugget
Prunus domestica	Rosaceae	Plum	Alubukhara	Satsuma, Santa Rosa, Burbank,Kelsey, Santa Rosa, Titron, Satsuma, Mariposa, Jamuni, Kelsey,SantaRosa, Titron Blue Rock, Victoria
Punica granatum	Punicaceae	Pomegranate	Anar	
Agroforestry and social forestry				
Bauhinia variegata	Caesalpinaceae	Mountain Ebony	Guiral, Kuiral	
Celtis australis	Ulmaceae	European Nettle tree	Kharik	
Corylus Jacquemontii	Corylaceae	Turkish hazelnut	Bhotiya Badam	
Grewia optiva	Tiliaceae	Grewia	Bhimal	
Ficus palmate	Moraceae	Fig	Bedu	
Prunus cerasoides	Rosaceae	Wild Cherry	Panyyan	
Morus serrata	Moraceae	Himalayan Mulberry	Keemu, Sehtoot	
Ornamental plants				
Bellis perennis	Asteraceae	Daisy		
Calendula officinalis	Asteraceae	Pot Marigold	Marigold	
Chrysanthemum sp.	Asteraceae	Daisy	Guldawadi	
Columnea crassifolia	Gesneriaceae	Columnea		
Celosia cristata	Amaranthaceae	Cocks comb	Sarwari	
Dahlia imperialis	Asteraceae	Dahlia	Dahalia	
Gladiolus gandavensis	Iridaceae	Gladiolus	Gladiolus	
Helianthus annuus	Asteraceae	Sun Flower	Surajmukhi	
Helenium sp.	Asteraceae	Horse-heal		
Hibiscus rosa-sinensis	Malvaceae	China Rose	Gudhal	
Inula ensifolia	Asteraceae	Aster	Aster	
Lavatera trimestris	Malvaceae	Silver Cup	Silver Cup	
Meconopsis cambrica	Papaveraceae	Welsh poppy	Poppy	
Rosa spp.	Rosaceae	Rose	Gulab	
Rosa macrophylla	Rosaceae	Wild Rose	Van-Gulab	
Tagetes sp..	Asteraceae	Marigold	Gainda	
Tropaeolum majus	Tropaeolaceae	Nasturtium		
Zinnia elegans	Asteraceae	Zinnia;	Zinnia	
Medicinal and aromatic plants				
Aconitum heterophyllum	Ranunculaceae	Indian Aconite	Atis	Rhizome*
Acorus calamus	Araceae	Sweet flag	Bach	Rhizome*
Aloe vera	Liliaceae	Aloe	Gheet kumari	Leaves*
Ajuga bracteosa	Lamiaceae	Bugle	Neelkanthi	Leaf*
Artemisia nilagirica	Asteraceae	Mugwort	Kunja	Wholeplant*
Caryopteris foetida	Verbenaceae	Caryopteris	Karwi	Leaf*
Chrysanthemum cineraiaefolium	Asteraceae	Pyrethrum	Pyrethrum	Leaves*
Cinnamomum tamala	Lauraceae	Cinnamomum	Tejpat	Leaf, bark*
Hedychium spicatum	Zingiberaceae	Spiked ginger lily	Kapur Kachri	Rhizome*
Pelargonium graveolens	Geraniaceae	Geranium	Ratanjot	Leaves*
Picrorhiza kurroa	*Scro*phulariaceae	Picrorhiza	Kutki	Rhizome*
Podophyllum hexandrum	Berberidaceae	Himalayan mayappe	Van Kakadi	Rhizome*
Potentilla fulgens	Rosaceae	Silverweed	Bajardanti	Leaves*
Rauvolfia serpentine	Apocynaceae	Indian snake root	Sarpgandha	Roots*
Rosemary officinalis	Lamiaceae	Rosemary	Rosemary	Leaves*
Rubia cordifolia	Rubiaceae	Indian Madder	Majethi	Leaves*
Rumex hastatus	Polygonaceae	Rumex	Almoru	Leaves*
Saussurea costus	Asteraceae	Costus	Kuth	Leaves and roots*
Smilax aspera L.	Smilacaceae	Italian smilax	Kukurdada	Fruits*
Swertia chirayita	Gentianaceae	Chiretta	Chiraita	Leaf*
Thalictrum foliolosum	Ranunculaceae	Indian meadow	Mamiri	Roots
Urtica dioica	Urticaceae	Annual nettle	Bichu ghas	Leaves and rhizome*
Verbascum Thapsus	Scrophuliaceae	Aaron's rod	Akuluveer	Leaf*
Viola Tricolor	Violaceae	Viola	Banafsa	Leaf*
Withania somnifera	Solanaceae	Winter cherry	Ashgand)	Leaf*

Oil seed plants			
Brassica campestris	Brassicaceae	Mustard	Sarson
Brassica nigra	Brassicaceae	Black mustard	Kali Sarson
Helianthus annuus	Asteraceae	Sun flower	Surajmukhi
Linum usitatissimum	Linaceae	Flex	Alsi
Minor cereal crop plants			
Echinochloa frumentaceae	Poaceae	Japanese Barnyard Millet	Jhangora
Eleusine coracana	Poaceae	Finger Millet	Mandua
Panicum miliaceum	Poaceae	Hog Millet	Cheena
Setaria italica	Poaceae	Italian Millet	Koni/Kangani
Amaranthus caudatus	Amaranthaceae	Amaranthus	Ramdana
Amaranthus spinosus	Amaranthaceae	Amaranthus	Kantelu Marsu
Pulses			
Glycine max	Fabaceae	Soyabean	Bhat, Soyabean
Lens culinaris	Fabaceae	Lentil	Masur
Macrotyloma uniflorum	Fabaceae	Horse gram	Gahat or Kulthi
Vigna mungo	Fabaceae	Black gram	Urd
Vigna unguiculata	Fabaceae	Cowpea	Sonta, Lobia
Forest plants			
Aesculus indica	Hippocastanaceae	Himalayan Chestnut	Pangar
Alnus nepalensis	Betulaceae	Alder	Utees
Carpinus viminea	Betulaceae	Hornbeam	Chamkharik
Cedrus deodara	Pinaceae	Himalayan -Cedar	Deodar
Lyonia ovalifolia	Ericaceae	Lyonia	Anyar
Persea odoratissima	Lauraceae	Persea	Kaula
Pinus roxburghii	Pinaceae	Pine	Chir
Quercus floribunda	Fagaceae	Green Oak	Moru
Quercus leucotrichophora	Fagaceae	White Oak	Banj
Quercus semecarpifolia	Fagaceae	Brown Oak	Kharsu
Rhododendron arboreum	Ericaceae	Rhododendron	Burans
Taxus baccata	Cupressaceae	Yew-tree	Thuner

Note: (i) Naturally occurring vegetables are *Abelmoschus ficulneus* (Jangali bhindi), *Amaranthus dubius* Mart ex Thell. *Amaranthus viridis* Linn. (Jangli chaulai), *Bauhinia variegata* Linn. (Kachnar), *Chenopodium album* Linn. (Bathua), *Diplazium polypodiodes* Blume (Lingura), *Dioscorea belophylla* Royle (Tarur), *Ficus auriculata* Lour. (Timla), *Momordica balsamina* Linn. (Ban Kokora), *Oxalis corniculata* Linn. (Kati Booti), *Urtica dioica* Linn. (Bichhu Buti),*Zehneria umbellate* Thw. (Gwal Kakri). (ii) Wild Edible fruits are *Aesculus indica* Hiern,, *Ficus auriculata* Lour. (Timla), *Ficus palmata* Forssk. (Bedu), *Myrica esculanta* Thunb (Kaphal), *Pyracantha crenulata* Don. (Ghingaru), *Rubus fruticosus* L. (Kathula), *Rubus nepalensis* (Hook. f.) (Lal hisol), *Rubus niveus* Thunb (Kala hissar); *) plant used.

Discussion

The immense richness of botanical resources with statistics worldwide showed that only a very small fraction of plant resources has yet been utilized by the human race. Even whatever little known it is, it is mainly about some of the higher plants (Schultes 1963). India is recognized as one of the four major mega biodiversity of Asia. Majority of its forests are in Himalayan region, which although covers only 18% of the geographical area of the country, but accounts for more than 50% of India's forest cover and 40% of species endemism. The climatic, topographic and soil diversity of this region has resulted into the occurrence of several valuable and economically important plants. In India more than 3000 wild plants are used as subsidiary food and vegetables by various communities (Anon. 1994). It is estimated that in India about 800 species are consumed as food plants, chiefly by the tribal inhabitants (Singh and Arora 1978). Furthermore, 250 species can be developed as a new source of food in the near future (Anon. 1994). Over 170 species provide edible fruits and are consumed by the northeastern tribes. Mostly, it is the fleshy, sweet / sub-sweetish pulp of the fruit that is eaten raw and the tribes have screened the enormously rich flora of the seasonal rain-forest habitats and picked up edible types. Himalaya, one of the richest hot spots of biodiversity in the world, offers immense opportunities in various fields of biological domains and associated patterns of sustainable life support systems. Rich diversity occurs in Himalaya growing naturally under diverse environmental conditions, that is, from dry deciduous forest of north west to rain forest of north east and extending up to the alpine meadows, though the region occupied only 15% of geographical area of the country, but about 30% of the endemic species of Indian subcontinent are found in this region.

The Plants genetic resources is of immense importance such as what role do the plants gathered by local inhabitants of the region play in their economic life? If any plant products are bartered or sold; it is to show their quantification and also to indicate possibilities of value addition and entrepreneurship (Jain 2010). The Genetic resources surveys reveal that the people of the Bharsar region evolved the mechanism of utility of various

resources based on its availability. Some of the major species of plants used by people of the district for their varied requirements have been classified under different categories. The variability in term of utilization of various categories was also observed as a species is used for medicinal purpose by inhabitants of one villages /area, similar species was used as vegetable or for other purposes. *Eleusine corocana* (L.) Gaertn., *Setaria italic* (L.), *Echinochloa frumentacea* Link., *Sorghum halepense* (L.) *Amaranthus blitum* are major food grains after rice and wheat on many occasions including food scarcity. Some traditional uses such as making Chpatis and Laddu out of Amaranthus seeds are now at the verge of mislay and therefore, needs to conserve and for this value addition of these in addition to commercialization is required. Rawat et al. (2010) reported that the people of the Tones valley in Uttarakhand have well knowledge about the properties of various plants spread over 1000 - 4500 m and are known to derive their food requirements from a numbers of wild plants. *Paeonia emodi*, *Asparagus adscendens*, *Amaranthus viridis*, *Commelina maculate*, *Diplazium esculentum* are the major wild vegetables. In addition, vegetables like *Brassica oleracea*, *Lycopersicon esculentum*, *Solenum tuberosum* are common to diet of these people (Rawat et al. 2010). All these plants are widely used as vegetables in this area. In addition, *Diplazium* spp (Kuthara) is also reported as vegetables and it was not reported earlier from Uttarakhand. Similarly, some traditional recipes viz., Gunala (from leaves of Pinalu and Kadu), Badi, Raitha and Kaphali are although common recipes in the district, however not documented in the earlier literatures.

Similarly immature kernel of *Triticum aestivum* are used as Umi and is very delicious recipe which is used as Dal/vegetables is also documented. Badi is generally prepared for the period of scarcity of fresh vegetables especially winter as most of species used as vegetables are available only during May-November. Flowering buds of *Bauhinia variegata* are reported as vegetable in present study. Saikaia et al. (2010) also described that petals of *Bauhinia variegate* are used as vegetable in hill districts of Assam and in Arunachal reveals that people residing in hills have evolved more or less similar traditions.

Crops like *Fagopyrum tataricum*, *Amaranthus paniculatus*, *Triticum aestivum*, *Oryza sativa*, *Phaseolus vulgaris*, *Glycine max*, *Macrotyloma uniflorum*, *Phaseolus mungo* and *Pisum sativum* are common food items in Tones Valley as reported by Rawat et al. (2010). The some Species viz, *Phaseolus vulgaris*, *Glycine max*, *Macrotyloma uniflorum*, *Phaseolus mungo* and *Pisum sativum* as reported above are also very common crops used as pulses in the region also included in this study as they are widely cultivated. The wild as well as cultivated species of *Dioscorea* were used during famine in earlier past but now also used during festive occasions.

Medicinal Plants like *Aegle marmelos* (Bael), *Artemisia nilagirica*, *Asparagus racemosus* (Satavar), *Berberis aristata* (Kingora), *Bergenia ciliata* (Phasanbheda), *Centilla asiatica* (Brahmi), *Cinnamomum tamala* Nees & Eberm. (Tejpatta), *Gloriosa superba* (Kalihari), *Hedychium spicatum*. (Kapoor Kachri), *Meotheria heterophylla*. (Gwal Kakri), *Myrica esculenta* (Khaphal), *Ocimum sanctum* (Tulsi), *Origanum vulgarie* (Jungali Tulsi), *Picrorhiza kurroa* (Kutki), *Phodophyllum hexandrum*, *Potentilla fulgens* (Bajaradanti), *Prinsepia utilis* (Bhainkal), *Ranunculus sceleratus* (Kandeer), *Roscoea purpurea* (Kokoli), are used by local people in different therapeutics.

Conversely the forest plants are used in this region as Timber viz. *Abies pindrow Aesculus indica Cedrus deodara*, *Cupressus torulosa*, *Fraxinun Micrantha*, *Pinus roxburghii*, and as Fuelwood *Alnus nepalensis*, *Celtis australis*, *Cedrus deodara*, *Pinus wallichiana* , *Quercus floribunda*, *Quercus semicarpifolia and in this region the* Fodder plants are use such as *Celtis australis* Linn. *Cornus macrophylla*, *Ficus palmate*, *Fraxinun Micrantha* , *Grewia optiva*, *Quercus floribunda* .

Rawat et al. (2010) reported wild fruits such as *Hippophae rhamnoides*, *Fragaria nubicola* species of *Rubus* and *Duchesnea indica* as a common wild fruits to diet of people of Tones valley. Hippophae is widely used in Niti Valley as medicinal as the cake is used to cure severe cold and cough and throat infections and used as ingredients of Chutney (local jelly), pickle as reported by Dhyani et al. (2010). Similar uses of this plant were reported from Bharsar. Fruits of *Myrica esculenta* are now gaining popularity in town because of delicious taste and are being sold by local inhabitants. Similarly fruits of *Berberis* and *Rubus* have immense potential for value added entrepreneurship.

CONCLUSION

In general, it reveals that the region is a repository of vast plant genetic knowledge and many plants are used on daily basis to fulfill basic demands. Categories of supplementary food, vegetables, Medicinal and Aromatic plants and wild fruits provide an opportunity for bioprospecting for the discovery of new nutritional elements compounds in future.

REFERENCES

Anon. 1994. Ethnobotany in India: A Status Report. All India Coordinated Research Project in Ethnobotany. MOEF, GOI, New Delhi.

Atkinson ET. 1882. The Himalayan Gazetteer.Volume 2. Reprinted (1973). Cosmo Publication, New Delhi.

Barthwal BS. 1991. Forest flora of Pauri-Garhwal. [Ph.D.-Dissertation], HNB Garhwal University, Srinagar (Uttarakhand).

Bisht AS. 2005. Ecological studies of some important medicinal plants, their multiplication and conservation in Garhwal Himalaya, India. [Ph.D-Dissertation]. HNB Garhwal University, Srinagar (Uttarakhand).

Dabral SP. 1990. Uttarakhand Kaitihas. Veer Gatha Press, Dugadda UP, India. [Hindi]

Dhyani A, Nautiyal BP, Nautiyal MC 2010. Importance of Astavarga plants in traditional systems of medicine in Garhwal, Indian Himalaya. Intl J Biodiv Sci Ecosyst Serv Manag 6 (1-2): 13-19.

Dhyani D, Maikhuri RK, Misra S, Rao KS 2010. Endorsing the declining indigenous ethnobotanical knowledge system of Seabuckthorn in Central Himalaya, India. J Ethnopharmacol 127: 329-334.

Dhyani D, Maikhuri RK, Rao KS, Kumar L, Purohit VK, Sundriyal M, Saxena KG. 2007. Basic nutritional attributes of *Hippophae rhamnoides* (Seabuckthorn) populations from Central Himalaya, India. Curr Sci 92: 1148-1152.

Faulks PJ. 1958. An Introduction to Ethnobotany. Moredale Publications Ltd, London.

Friedman HS, Adler NE. 2001. The history and background of health psychology. Health Psychology. www.oup.com/us/pdf/Friedman/ch1.pdf.

Gaur RD. 1982. Dynamics of vegetation of Garhwal Himalaya. In: Paliwal GS (ed.). The Vegetational Wealth of the Himalaya. Puja Pub., Delhi.

Gaur RD. 1999. Flora of district Garhwal North-West Himalaya (with ethnobotanical notes). Pub. Transmedia, Srinagar, Garhwal.

Hammer K. 2003. A paradigm shift in the discipline of plant genetic resources. J Res Crop Evol 50: 3-10.

Hartwell JL. 1967-71. Plants used against cancer-a survey. Lloydia 30 (4): 379-436.

Kala SP, Gaur RD. 1982. A contribution to the flora of Gopeshwar (Chamoli Garhwal) UP. In: Paliwal GS (ed.) The Vegetational Wealth of the Himalaya. Puja Pub., Delhi.

Kiritikar KR, Basu BD. 1984. Indian Medicinal Plants. Lalit Mohan, Basu Pub., Allahabad, India.

Mehta PS, Negi KS, Ojha SN. 2010. Native plant genetic resources and traditional foods of Uttarakhand. Indian J Nat Prod Resour 1 (1): 89-96.

Naithani BD. 1984-1985. Flora of Chamoli. 2 Vols., BSI Pub., Howrah, India.

Raizada MB, Saxena HO. 1970. Flora of Mussoorie. Vol. I, Bishen Singh Mahendra Pal Singh Pub., Dehradun, India.

Roberto C. 1984. The Macdonald encyclopedia of Medicinal Plants. Macdonald & Co. Pub Ltd., London.

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Short Communication: A new variety of *Pholiota microspora* (Berk.) Sacc. (Agaricales) from Nepal

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ABSTRACT

Adhikari MK, Watanabe K, Parajuli GP. 2014. A new variety of Pholiota microspora *(Berk.) Sacc. (Agaricales) from Nepal. Biodiversitas 15: 101-103.* In the fall of late rainy season 2011, a new *Pholiota* (Fr.) P. Kumm. (Agaricales, Strophariaceae) was collected in the *Quercus* forest of Phulchowki (Kathmandu valley) along the trial line, on the dead log at an altitude of 2600m. The specimen gathered was quite small. It was brought to laboratory and cultivated in NARC, Pathology laboratory, Lalitpur. The mushroom has been identified as *Pholiota microspora* (Berk.) Sacc. var. *himalensis* var. nov..

Key words: Agaricales, *Pholiota microspora*, new variety, Nepal

INTRODUCTION

Pholiota (Fr.) P. Kumm., the mushroom, falls in the family Strophariaceae of Agaricales. Saccardo (1887) records 93 species. Arora (1986) and Lincoff (GL) (1980) records 25 species from America. Smith and Hesler (1968) reported 216 species of *Pholiota* from North America. Courtecuisse and Duhem (1994), Courtecuisse (2000) and Eyssartier and Roux (ER) (2011) record 19 species from France and Europe. "*Fungi of Northwestern China"* (2005) records 12 species. Phillips (P) (2006) records 11 species. Kirk et al. (2004) states about 150 species of *Pholiota* to prevail in the world, while Neda (2008) states to be 362 species of *Pholiota* in the world. Ikeda (2005) and Imazeki et al. (1988, revised 2012) record 12 species from Japan. Chehey (2013) enlists 78 species.

The Nepalese literatures (Adhikari, 1996, 2000, 2009, 2012) record six species of *Pholiota* viz. : *Pholiota limonella* (Pers.) Sacc. [= *Pholiota adiposa* (Batch.:Fr.) Kumm., *Pholiota aurivella* (Batsch:Fr) Kummer, treated as synonym in Eyssartier & Roux (2011)], *Pholiota gummosa* (Lasch.) Singer, *Pholiota microspora* (Berk.) Sacc. [= *Pholiota nameko* (T.Ito) S.Ito & S.Imai], *Pholiota squarrosa* (Weigel:Fr.) Kumm., *Pholiota squarrosoides* (Peck) Sacc. and *Pholiota terrestris* Smith.

Description of the fungus

Pholiota microspora (Berk.) Sacc. var. *himalensis* Adhikari & Watanabe var. nov. (Figures 1-3) (MB 808362)

Basidiocarp growing in cluster; in natural environment pileus orange brown to bright deep orange brown, darker in the centre, fading towards margin, scattered; stipe creamy white. The cultivated mushrooms have very light dull pale yellow to yellow brown pileus and white to creamy stipe.

Pileus 2-3.5 cm broad, fleshy, at first light yellow to yellow brown, orange brown at maturity, dark orange brown at the centre; margin fading to yellow brown, in full grown light brown, to fugacious brown, to bright deep orange brown, fading to dull yellow in age, margin wavy, not in rolled, smooth; at first convex, umbellate-hemispherical, slightly umbonate, becoming plane, viscid, glutinous; sometimes with remnants of veil; scales orange brown, very few, scattered, yellow to yellowish brown, which fall off, later becoming smooth. Pellicle thin, yellowish to yellowish brown, separable. Pileocystidia not found. Flesh white to slightly creamy. Stipe 5-6 cm long, 0.5 cm broad, stuffed hollow, slender, dry to slightly viscid, creamy white to yellowish, scaly with orange brown scales, fibrillose, composed of thin walled hyaline to brownish mycelium, up to 2 µm broad, Caulocystidia absent. Annulus cobwebby at first and later disappearing leaving black scar on the stipe. Lamellae mostly adnate to adnato-decurrent, white to creamy at first, becoming yellowish then brownish with age, crowded. Basidia 12-20x10-12 µm, clavate, hyaline, thin walled, 2 sterigmate. Sterigmata up to 1µm long, conical short. Pleurocystidia 18-22x10-12 µm, clavate to lageniform, thin walled, hyaline, smooth, in the hymenia surface or protruding slightly beyond hymenial surface. Cheilocystidia absent. Chrysocystidia not found. Basidiospores 3.5-5 (6)x3-4 µm, dull brown in print, mostly ovoid, ovoid-ellipsoid, one guttulate, at first hyaline then rusty brown, thick walled, smooth, without germ pore, inamyloid. Edibility unknown previously, but edible and has very faint aroma. Taste none to mild.

Figure 1. *Pholiota microspora*. var. *himalensis* var. nov. A. Basidiocarps (young) on *Quercus* log in natural habitat, B. Basidiocarps (full grown)

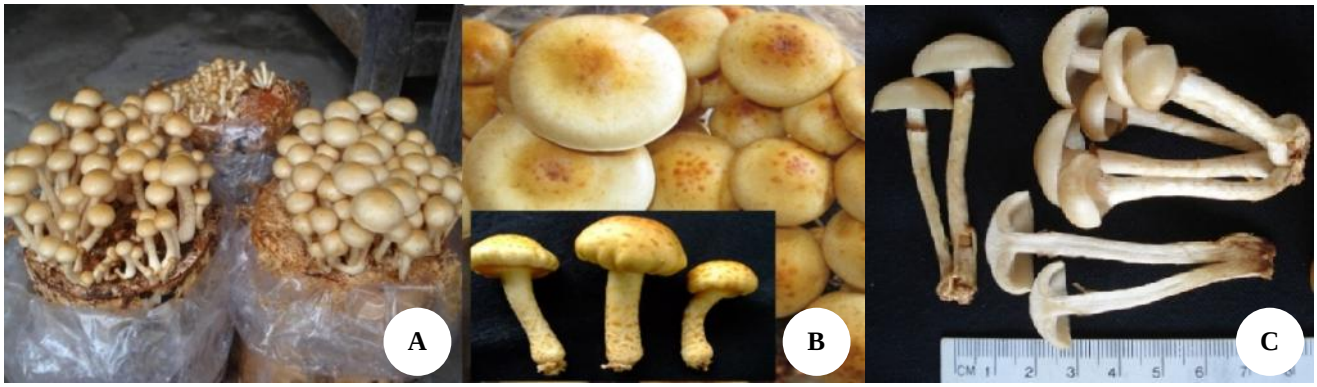

Figure 2. A. Showing cultivation of the species, B.C. Size of the cultivated Fruit body

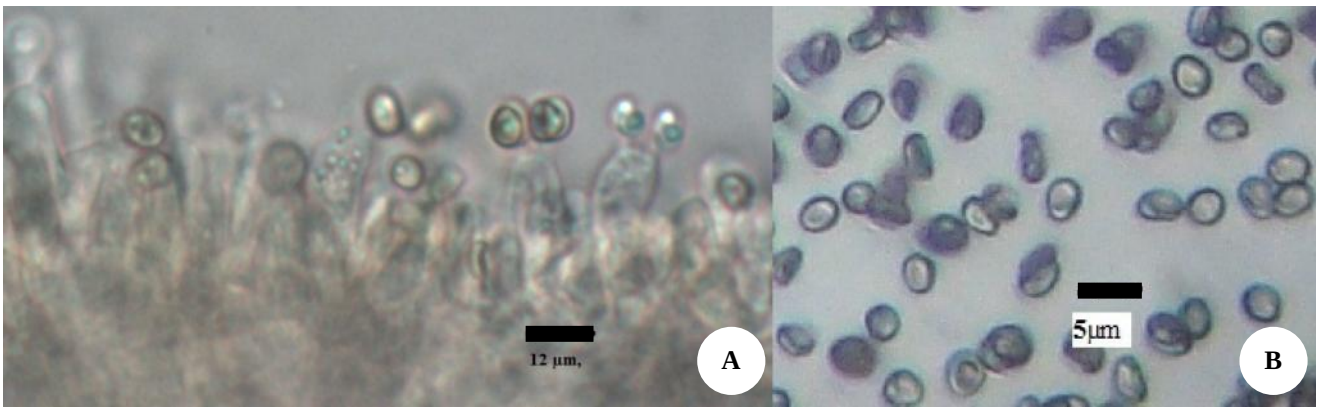

Figure 3. A. Cystidia and basidia, B. Basidiospores

Specimen examined

Nepal. Growing on *Quercus* dead wood log in natural condition, caespitose or gregarious, Phulchowki forest, 2068.6.13 (2011. Sept. 30), 2600 m, voucher deposited no. 552 Holotype (KATH, NARC & Kyushu University, Japan), Adhikari, Watanabe & Parajuli, and cultivated at Nepal Agricultural Research Council (NARC), Khumaltar, Lalitpur, Nepal.

Comments

The closely related species, which differ from the present species, are as follows. The thick walled spores are present in *Pholiota limonella*, *Pholiota flammans* (Batsch) P. Kumm., *Pholiota lubrica* (Pers.) Singer and *Pholiota alnicola* (Fr.: Fr.) Singer, but they differ in various characters.

The lignicolous *Pholiota* species are *Pholiota microspora* (Berk.) Sacc. [Syn. *Pholiota nameko* (T.Ito) S.Ito & S.Imai], *P. micromeres* Berk. & Br., *P. astragalina* (Fr.: Fr.) Singer, *P. limonella* (Peck) Sacc., *P. alnicola* (Fr.: Fr.)

Singer [= *Pholiota malicola*], *Pholiota flammans* (Batsch: Fr.) Kummer, and *Pholiota scamba* (Fr.: Fr.) Moser.

Pholiota micromeres differs from the present specimen in having glabrous, larger sized cap and stipe and adnate gills with 6 µm long spores. *Pholiota astragalina* (Fr.:Fr.) Singer differ from the present taxon in having larger saffron red cap (bitter in taste-Lincoff, edible –IOH), larger spores (6-7x3.5-4.5 µm), presence of pleurocystidia, cheilocystidia (18-52x6-13 µm) and chrysocystidia and growth on coniferous woods. *Pholiota limonella* is inedible having larger cap oblong spores (5-10x3.5-6 µm) with pore at tip, presence of pleurocystidia (23-37x10-13 µm) and cheilocystidia (42-62x7-13 µm) and growth both on coniferous and broad leaved trunks. *Pholiota alnicola* [edible-IOH; non edible-Arora, GL, ER; Poisonous-Nagasawa (2003)] has fibrillose, longer, rusty stipe. In *P. alnicola* both cap and stipe are without scales, spores are larger (7-10x4-5 µm), pleurocystidia are present, chrysocystidia are absent, taste is bitter and growth mostly on *Alnus* woods. *Pholiota flammans*, the edible one, has large umbonate scaly caps with brownish scales on stipe, presence of cheilocystidia (25-40x7-10 µm) and chrysocystidia in the gills, spores of 3.5-7x2.5-3 µm in size, radish like odor and growth on conifers. The presently described taxon also resembles with *P. scamba* in having similar size of cap and absence of cheilocystidia and chrysocystidia but differs in larger ovoid spores and growth in conifers. *Pholiota flavida* (Schaeff.) Singer has smaller spores and the fruit body is slightly aromatic. *Pholiota subochracea* (Smith) Smith & Hesler has viscid pale yellow cap with 5 cm long stipe and 5-6 µm spores.

Pholiota microspora (Berk.) Sacc. var. *himalensis* var. nov. differs from all the above species in its pileus colour and size, nature of stipe and scales, hymenium, cystidia and spores.

Pholiota microspora closely resembles with the presently described taxon at first sight but differs in possessing umber-brown pileus which is glutinous, smooth, larger and without scales; stipe is longer, solid, covered with mucus and without scales; cheilocystidia (36-43x10-11 µm) are present in the adnate-decurrent lamellae; spore is thick walled, ellipsoid-oval, 4-6x2.5-3µm; the taste and ordor pleasant, edible (Neda, 2008). But the present species grows on broad leaved forest composed of *Quercus* species, in isolated clusters; has small bright yellow to orange brown, orange brown scaly and sticky cap; creamy white stipe which is stuffed hollow with orange brown scattered scales; annulus cobwebby at first, later leaving black scar around the stipe; lamellae creamy to light brown, adnate to slightly adnate-decurrent, pleurocystidia present; and spores dull brown in print, smooth, ovoid, ovoid-ellipsoid, thick walled, 1guttulate. On the above basis, the present specimen is described as a new variety of *Pholiota microspora* (Berk.) Sacc., and the epithet is kept after its Himalayan habitat.

Latin diagnose

Pholiota microspora (Berk.) Sacc. var. *himalensis* Adhikari & Watanabe var. nov. (Figures 1-3)

Pileus 2-3.5 cm latus, carnosus, laete flavus, orantioflavus ad umbone, flavus ad marginem, farcto convexus, hemisphaericus, leviter umbonatus, plane posta, viscidus, glutinosus, vestigium velum interdum, paucus squamosus, orantioflavus, quorum lapsus promptus, posta becomascens laevis,

Margo undulates, nullo involutus, laevis. Stipite 5-6 cm longo, 0.5 cm latus, solido ad subcavus, tenuis, deccica ad subviscid, cremeus-albino ad lutescnte, brunneo squammae, fibrillosus, totum tenuis perietis hyalinus ad brunneus hyphae, usque ad 2 µm latae, Caulocystidia nullo. Annuus arachnoideus e postea evanescens cicatricibus circum in stipitis. Lamellis vulgo mostly adnatus ad adnato decurrentibus, albino ad cremeus ad fulvus brunneus, congestus, densus. Basidia 12-20x10-12 µm, clavata, hyalino, tenuis perietis, 2 sterigmatibus, usque 1µm longa. Pleurocystidia 18-22x10-12 µm, clavata ad lageniforme, hyalino. Cheilocystidia non visus. Chrysocystidia non visus. Basidiosporae 3.5-5 (6)x3-4 µm, vulgo ovalis ad ovalis-ellipsoideis, 1guttulatae, hyaline ad ferrugineo-brunneus, crassus perietis, laevis, obsque germ poris.

Habitat in arborum trucatis *Quercus*, caespitose, Phulchowki, 2600 m, Kathmandu vallis, Nepalia, 2011. Sept. 30, Holotypus no. 552, Adhikari, Watanabe & Parajuli.

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REFERENCES

Adhikari MK. 1996. Biodiversité des Basidiomycetes au Népal: etude systematique et biogeographique. Specialité Ecologie-Mycologique. Thése du Doctorat de L'Université present devant l'Université Paul Sabatier, Toulouse, France.

Adhikari MK. 2000. Mushrooms of Nepal. Edited by G. Durrieu, P.U. Printers Battishputali, Kathmandu, Nepal.

Adhikari MK. 2009. Researches on the Nepalese mycoflora: Revised account on the history of mycological explorations mushrooms of Nepal. Kathmandu.

Adhikari MK. 2012. Researches on the Nepalese mycoflora-2: Checklist of macrofungi (mushrooms). K.S. Adhikari, Kathmandu.

Arora D. 1986. Mushrooms Demystified. 2nd ed. Ten Speed Press, Berkely.

Chehey B. 2013. SIMA [The Southern Idaho Mycological Association]. www.simykos.org/SystemList/qryWholeList1Page23.htm [last updated June 13, 2012]

Courtecuisse R, Duhem B. 1994. Guide des Champignons de France et D'Europe. Delachaux et Niestle, Paris, France

Courtecuisse R. 2000. Photo guide des champignons de France et D'Europe. Chanticleer Press, Delachaux et Niestle, Paris, France.

Eyssartier G, Roux P. 2011. Le guide des champignons France et Europe. Cedex, Belin, Paris.

Ikeda Y. 2005. Mushrooms and toadstools pictured book of Hokuriku. Japan.

Imazeki R, Otani Y. and Hongo,T. 1988. Fungi of Japan. (revised 2011). Yama-Kei Publ Co. Ltd. Tokyo, Japan.

Kirk PM., Cannon PF., David JC, Staplers JA. 2004. Ainsworth & Bisby's Dictionary of the fungi. 9th ed. CAB International, New York.

Lincoff G. 1980. The Audubon Society Field Guide to North American Mushroom. Alfred S Knopf. Inc Chanticleer Press, New York.

Nagasawa E. 2003. Poisonous fungi in Japan. Gakusuikenqusha, Tokyo.

Neda H. 2008. Correct name for "nameko". Mycoscience 49:88-91

Phillips R. 2006. Mushrooms. Pan MacMillan, London.

Saccardo PA. 1887. Sylloge de fungarum. 5: 736-781. Pavia

Smith AH, Hesler LR. 1968. The North American Species of Pholiota. Hafner Publ Co, New York.

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Short Communication: A new record of *Giganthias immaculatus* Katayama, 1954 (Perciformes: Serranidae) from Indonesia

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ABSTRACT

Peristiwady T, Makatipu PCh, Du J. 2014. A new record of Giganthias immaculatus *Katayama, 1954 (Perciformes: Serranidae) from Indonesia. Biodiversitas 15: 104-107.* Three specimens of *Giganthias immaculatus* Katayama, 1954, were collected from Bitung, North Sulawesi, in October 2009, November 2009 and June 2012. The morphological data for *G. immaculatus* are similar to those for *G. serratospinosus* White & Dharmadi, 2012; those species share the following characters: dorsal fin rays IX, 11-13, anal fin rays III, 8 and lateral line high arched. However, the former is clearly distinguishable from G. *serratospinosus* by pectoral-fin rays 16 or 17 (vs. 13 or 14 for G. *serratospinosus*); gill rakers (10) + (21-24) (vs. 10 + 20 for *G. serratospinosus*). It also differs in the following: body depth, head length, predorsal length, preanal length, upper-jaw length, interorbital width. Initially, this species was collected from Izu-Õshima, Japan. Other localities of capture for this species are: Ago Bay, Shimacho Goza, Shima City, Mie Pref., Tomari, Okinawa, Japan and Taiwan and now recorded also off Bitung, Sulawesi Island, Indonesia.

Key words: Anthiinae, *Giganthias immaculatus*, Indonesia, new record, Serranidae

INTRODUCTION

Fishes of the genus *Giganthias* Katayama, 1954 are moderate size species living in hard-bottom habitats beyond scuba-diving depths are rarely catch by divers, gillnetting or trawling. The present specimen was taken by vertical hand-line together with the others target deep-water groupers (*Epinephelus*), big eye (*Priacanthus*) and snappers (*Pristipomoides* and *Etelis*).

The genus *Giganthias* belongs to the subfamily Anthiinae of the family Serranidae, although Katayama (1960) placed it in a separate subfamily, the Giganthiinae. This genus is characterized by a combination of the following characters: nine dorsal-fin spines, serrated tip to third dorsal spine and pelvic spine, a supplementary maxillary and a very highly arched lateral line (Katayama 1954). Sub-family Giganthiinae currently consists of one genus, with two species. In the world, two species of *Giganthias* have been reported, *Giganthias immaculatus* Katayama, 1954 from Ryukyus, Japan (Katayama 1954; Masuda et al. 1984; Nakabo 2002), from Taiwan (Lee 1990) and *G. serratospinosus* White and Dharmadi, 2012 from Indonesia (White and Dharmadi 2012).

During the ichthyofaunal survey in Bitung, North Sulawesi, Indonesia, three specimens of *Giganthias immaculatus* were collected from Bitung. The species has been previously known only from the Ryukyu Islands and Taiwan, then the Indonesian specimen, herein described, represent the first record of the species outside Japan and Taiwan and bring the total number of species of this genus recorded from Indonesia to two species.

Materials and Methods

Three specimens of *Giganthias immaculatus* were collected from off Girian, Bitung, North Sulawesi, Indonesia. The present specimens were taken by vertical hand-line from the depth of more than 150 m together with other deep-water groupers, big eye and snappers. Methods of counting and measuring followed Randall and Heemstra, 2006 with additional measurements of all dorsal and anal fins spine and rays length measuring as distance from tip and base of spine and suborbital width measuring as least distance between orbit and jaws. All measurements were made with digital calipers to the nearest 0.01 mm. Cyanine blue was used to examine and scale counts.

Standard and head lengths are abbreviated as SL and HL, respectively. Institutional codes follow Eschmeyer (2013) with additional abbreviations as follow: LBRC-F (The Reference Collection of LIPI Bitung, Technical Implementation Unit for Marine Biota Conservation, Indonesian Institute of Sciences, Bitung, North Sulawesi, Indonesia. Institutional acronyms for types and comparative material are those of Leviton et al., 1985.

Giganthias immaculatus Katayama, 1954

(Figure 1; Table 1).

Giganthias immaculatus Katayama, 1954: 57, fig.1 (type locality: off Izu-Õshima, Japan): Katayama in Masuda et al. 1984: 132, pl.119 (off Izu-Õshima, Japan); Lee 1990: 64 (Taiwan), Nakabo 1993:634 (Japan); Randall *in* Randall & Lim 2000: 610, Nakabo 2002: 733 (Izu Isls., Ryukyu, Japan), White and Dharmadi 2012: 65; Zongguo and Mao 2012: 150.

Figure 1. Color photograph of *Giganthias immaculatus* Katayama, 1954, LBRCF 1380, 205 mm SL, Bitung, North Sulawesi, Indonesia.

Table 1. Proportional measurements of *Giganthias immaculatus* from Japan and Bitung, Indonesia. Minimum and maximum measurements are presented as percentages of SL and HL, mean value between brackets.

Parameters	**NSMT P18654(1) Holotype**	**Japanese specimens**	**Indonesian specimens**
Dorsal rays	IX-11	IX (11-13)	IX (11-13)
Anal rays	III-8	III (8)	III (8)
Pectoral rays	17	16-17	16-17
Pelvic-fin rays	I-5	I (5)	I (5)
Gill-rakers	-	10+20	10+(21-24)
Scales in Lateral line	44	41-43	39-41
Scales above lateral line	7 or 8	6-8.5	6-8.5
Scales below lateral line	18-19	16.5-18	16.5-18
In SL			
Body depth	44.8	42.1 - 47.6 (44.7)	43.4 - 46.5 (45.4)
Body width	20.3	18.8 - 23.2 (20.8)	20.1 - 21.7 (20.7)
Head length	35.5	34.3 - 39.8 (36.0)	38.1 - 39.6 (39.0)
In HL			
Snouth length	26.4	24.9 - 26.6 (25.9)	24.7 - 40.3 (31.2)
Orbit diameter	30.9	30.9 - 32.6 (31.3)	28.1 - 34.6 (31.6)
Interorbital width	36.6	34.0 - 39.5 (36.9)	33.8 - 36.9 (35.3)
Upper-jaw length	53.5	47.9 - 54.4 (51.9)	47.1 - 52.3 (49.6)
Caudal-peduncle depth	42.0	38.8 - 44.3 (42.0)	34.0 - 41.5 (36.9)
First dorsal spine	12.2	12.2 - 14.2 (13.1)	12.1 - 12.6 (12.3)
Second dorsal spine	20.5	20.5 - 24.2 (22.9)	21.9 - 27.2 (23.9)
Third dorsal spine	28.4	28.4 - 33.6 (31.7)	29.3 - 33.4 (31.4)
Fourth dorsal spine	29.2	29.2 - 33.4 (31.5)	33.5 - 36.8 (34.7)
Last dorsal spine	26.6	26.6 - 33.1 (29.2)	22.2 - 29.4 (25.8)
First dorsal ray	41.8	41.8 - 43.1 (42.5)	38.4 - 42.6 (40.5)
Longest dorsal ray	52.3	42.8 - 53.3 (49.4)	40.9 - 48.5 (44.3)
Last dorsal ray	25.2	25.2 - 33.1 (29.1)	26.9 - 33.0 (29.9)
First anal spine	14.9	14.9 - 19.0 (16.7)	15.0 - 15.5 (15.2)
Second anal spine	27.2	26.4 - 29.0 (27.5)	26.3 - 29.0 (27.6)
Third anal spine	27.4	25.4 - 28.3 (27.0)	25.3 - 29.4 (27.3)
Longest anal ray	47.9	45.1 - 53.7 (48.9)	40.8 - 47.4 (44.3)
Pelvic-spine length	43.9	43.9 - 50.9 (47.6)	41.8 - 50.8 (45.1)

Material examined: *Giganthias immaculatus*: NSMT-P 18654 (formerly KFC 1534), holotype, 252 mm SL, off Izu-Õshima, Japan, collected by S. Igarashi, October 1952; FRLM 03665: 205.5 mm SL, Ago Bay, Shimacho Goza, Shima City, Mie Pref., Japan, 7 September 1982, collected by Seishi Kimura and others; LBRCF 1380, 205 mm SL, Girian Fish Market, Bitung, Indonesia, T. Peristiwady, 25 November 2009; LBRCF 1803, 214 mm SL, Girian Fish Market, Bitung, Indonesia, T. Peristiwady, 17 October 2009; LBRCF 2910, 250.5 mm SL, Girian Fish Market, Bitung, Indonesia, T. Peristiwady, 20 June 2012; ; URM-P 3764, 239.95 mm SL, Fish landing Okinawa Island, Yoshino, June 1982; URM-P 39792, 267.95 mm SL; fish market of Okinawa Pref. Fishery Cooperation, Tomari, Okinawa, Japan, Fujioka, 10 April 1999;

***Description*:** Dorsal-fin rays IX, 10-13, filament between spine incised, 4th dorsal-fin spine longest, 3rd ray longest, all dorsal rays branched, the last rays joint to its base; anal-fin rays III, 8; 2nd spine longest; 2nd, 3rd or 4th anal ray longest, all anal rays branched, the last rays joint to its base; pectoral-fin rays 16-17, uppermost and lowermost un-branched; pelvic-fin with I spine and 5 branched rays; lateral-line complete, lateral-line scales 39-41, scales above lateral line 7-9, scales below lateral line 17-18; circumpeduncular scales 25; gill rakers 10+(21-24).

Body oblong and moderately elongated, its depth 2.2-2.3 (2.2) in SL; body compressed, the width 2.1-2.3 (2.2) in body depth; head length 2.1-2.5 (2.4) in SL; eye large, orbit diameter 2.9-3.6 (3.2) in HL; snout short, 2.5-4.0 (3.3) in HL; interorbital slightly convex, the least width 2.7-3.0 (2.8) in HL; caudal-peduncle depth 2.4-2.8 (2.7) in HL; caudal-peduncle length 1.6-1.9 (1.7) in HL. Mouth large, the maxilla extending just to a vertical line at mid pupil, the upper-jaw length 1.9-2.1 (2.0) in HL; mouth terminal, forming an angle of about 50° to horizontal axis of head and body, lower jaw rather projecting; anterior tip of upper and

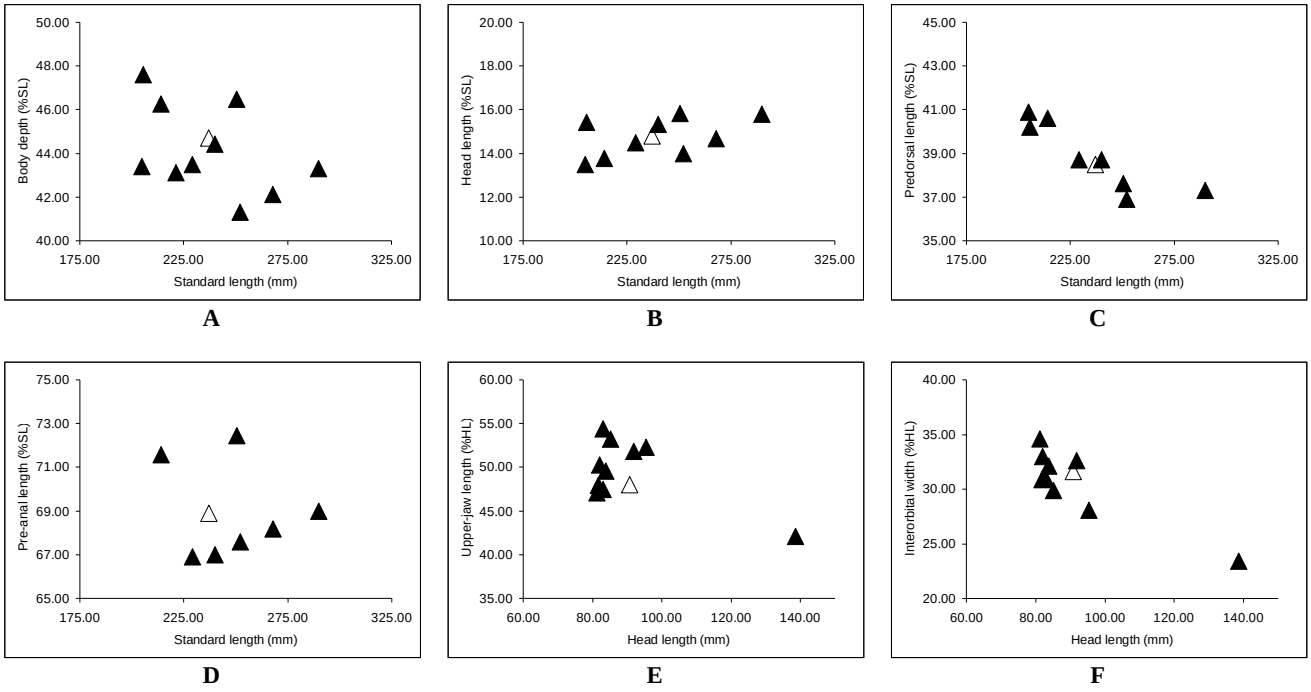

Figure 2. Ratio of body depth (A), head length (B), predorsal length (C), preanal length (D), upper-jaw length (E) and interorbital width (F) of *Giganthias immaculatus* (▲) and *G. serratospinosus* (Δ). Data *G. serratospinosus* recalculated from White and Dharmadi, 2012.

lower jaws with elevated patch of large conical teeth, posterior base of lower jaw with a elevated patch of large conical teeth, patch of villiform teeth on vomer and palatines with conical teeth.

Nostrils located directly anterior to eyes at about above a horizontal line of upper level of pupil, the anterior with a short flap, posterior nostril posterodorsal to anterior nostril and large. Opercle with three flat spines, upper opercular spine blunt and covered by scale, the middle spine pointed reaching posterior edge of fleshy opercle; lowest spine shorter than two upper spine; posterior margin of preopercle with serration and margin of interopercle smooth, angle of preopercle without serrae;

Scales ctenoid; scales progressively smaller anteriorly on head; predorsal area scaled to about level of anterior nostril, preorbital, lips, throat and mandible scaled; small scales basally on soft portions of dorsal, smaller scales on caudal fin extending at about posterior margin; small scales on basal of pectoral fins.

Lateral line high arched below the fifth dorsal spine. Origin of dorsal fin over upper second opercular spine, dorsal fin continuous and not really incised at junction of spines and soft rays, the four anterior dorsal spines stout, two anterior tips of dorsal spine with coarse serration, third and fourth spine not smooth; first dorsal spine 0.4-0.6 (0.5) length of second dorsal spine, fourth dorsal spine longest, 2.7-3.0 (2.9) in HL; soft rays not forming filament, the third rays longest, 2.1-2.4 (2.30) in HL, last two branched rays joint in the base; origin of anal fin below base of first or second dorsal rays; anal spines smooth without serration, anal spines short and stout, first anal spine about half length of second; second and third anal spine about same length; second, third or fourth anal soft ray longest, 3.0-3.7 (3.4) in HL; caudal fin forked, the lobes not tapering, the fin length 3.2-3.4 (3.3) in SL; caudal concavity 2.6-3.1 (2.8) in HL; pectoral fins long and pointed, asymmetric, reaching anus, 1.2-1.3 (1.2) in HL; pelvic-fin stout, anterior tip of spine with serration, second ray of pelvic fins longest.

***Color when fresh (Fig.1)*:** Head and body deep pink dorsally grading to paler ventrally; nape and around orbit yellowish; nape to back below spinous dorsal spine yellow, several yellow blotches on head, anterior to eye, upper lip and maxilla to suborbital space; and as a bar on preopercular margin; dorsal fin pale pink, soft portion of dorsal fin yellow distally, membranes of the spinous portion whitish; pelvic and anal spine pinkish, pectoral and caudal fin pinkish orange, posterior margin of caudal fn whitish.

Color in preserved specimens: Head and body pale brownish uniformly.

***Distribution*:** The present specimen was taken by handline together with the target deep-water groupers (*Epinephelus*), big eye (*Priacanthus*) and snappers (*Pristipomoides* and *Etelis*). Initially this species was described as new species from Izu-Õshima, Japan (Katayama 1954). This species from other locations was reported from Ago Bay, Shimacho Goza, Shima City, Mie Prefecture; Okinawa, Japan (Nakabo 2002) and Taiwan (Lee 1990) and now recorded also in Bitung, Sulawesi Island, Indonesia.

Comparison with other species: The meristic data of *Giganthias immaculatus* Katayama, 1954 is similar to *G. serratospinosus* White and Dharmadi, 2012 in sharing the following characters: dorsal fin soft rays X, 11-13, anal fin soft rays III, 8 and lateral line high arched. However, the

former is clearly distinguishable from G. *serratospinosus* by pectoral rays 16-17 (vs. 13-14 for G. *serratospinosus*); gill rakers (10) + (21-24) (vs. 10-20 for *G. serrato-spinosus*). It also differs in the following characteristics: body depth, head length, predorsal length, preanal length, upper-jaw length, interorbital width as shown Figure 2. Color image of *G. immaculatus* and *G. serratospinosus* from Lombok, Indonesia allowing a comparison of the fresh coloration of the two species. The color of these two species of genera *Giganthias* is very similar.

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REFERENCES

Eschmeyer WN. 2013. Catalog of fishes. California Academy of Sciences. http://re-search.calacademy.org/research/ichthyology/catalog/ fishcatmain. asp [25 March 2013].

Katayama M. 1954. A new serranid fish found in Japan. Japanese J Ichthyol 3: 56-61.

Katayama M. 1960. Serranidae. In: Fauna Japonica. Biogeographic Society of Japan, Tokyo.

Lee SC. 1990. A revision of the serranid fish (family Serranidae) of Taiwan. J Taiwan Mus 43: 1-72.

Leviton AE, Gibbs RH Jr., Heal E, Dawson CE. 1985. Standards in herpetology and ichthyology: part 1. Standard symbolic codes for institutional resource collections in herpetology and ichthyology. Copeia 1985: 802-832.

Masuda H, Amaoka K, Araga C, Uyeno T, Yoshino Y. 1984. The fishes of the Japanese Archipelago. Tokai University Press, Tokyo.

Nakabo T. 2002. Fishes of Japan with pictorial keys to the species, English edition. 2nd ed. vol. 1. Tokai University Press, Tokyo.

Nakabo T. 1993. Fishes of Japan with pictorial keys to the species, Japanese edition. 1st ed. Tokai University Press, Tokyo.

Randall JE, Heemstra PC. 2006. Review of the Indo-Pacific fishes of the genus *Odontanthias* (Serranidae: Anthiinae), with descriptions of two new species and a related genus. Indo-Pacific Fishes 38: 1-32.

Randall JE, Lim, KKP. 2000. A checklist of the fishes of the south China sea. Raffles Bull Zool, Suppl 8: 569-667.

White, WT, Dharmadi. 2012. *Giganthias serratospinosus*, a new serranid (Perciformes: Serranidae: Anthiinae) from the island of Lombok in Indonesia. Zootaxa 31: 61-66.

Zongguo H, Mao L. 2012. An illustrated guide to species in China's Seas Vol. 6. Ocean Press, Beijing [Chinese].

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