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Assessment of fuel resource diversity and utilization patterns in Askot Wildlife Sanctuary in Kumaun Himalaya, India, for conservation and management

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Summary

A general decrease in abundance of wild plant species used as sources of fuel suggests that more detailed information is urgently needed on species-level trends and their conservation. Such studies have not been carried out so far in India and elsewhere; we therefore quantified the species-wise extraction of fuel from a site (Gori Ganga Valley) in Askot Wildlife Sanctuary in the Kumaun Himalaya. In all, 31 species (26 trees and 5 shrubs) were used as fuel, of which 14 were native to the Himalaya. Utilization patterns, distributions, probabilities of use (PU), resource use indices (RUI), preferences and availabilities in forest communities of these species were determined. Use pattern did not vary much amongst low altitude villages (Similarity: 52–74%), whereas along the vertical (elevational) gradient it varied considerably (Similarity: 15–31%). *Woodfordia fruticosa* (L.) Kurz, *Pinus roxburghii* Sarg., *Quercus leucotrichophora* A.Camus, *Macaranga pustulata* King ex Hk. f., *Quercus lanuginosa* Don, *Engelhardtia spicata* Bl. and *Mallotus philippensis* (Lamk.) Muell. contributed most to collections, while *Pyracantha crenulata* (Don) Roem., *Syzygium cuminii* (L.) Skeels, *Alnus nepalensis* Don and *Bauhinia vahlii* Wt. & Arn. were in lesser demand. *W. fruticosa*, *P. roxburghii*, *M. pustulata*, *Casearia elliptica* Willd., *E. spicata*, *M. philippensis, Q. leucotrichophora* and *Phoebe lanceolata* (Nees) Nees showed high values of PU and RUI, indicating high pressure. High density of *P. roxburghii*, *Rhododendron arboreum* Sm., *Q. lanuginosa*, *Q. leucotrichophora*, *Lyonia ovalifolia* (Wall.) Drude, *C. elliptica* and *M. pustulata* amongst trees and *Maesa indica* A.DC., *P. crenulata* and *W. fruticosa* amongst shrubs exhibited high density but the remaining species showed low density indicating their possible depletion. Intensive management of natural habitats of species highly-preferred for fuel, diversification of choice of species from natives to non-natives, large scale propagation of highly preferred taxa and plantation of seedlings in the degraded, uncultivated and marginal lands through peoples' participation should promote conservation and management of fuel resources.

Keywords: diversity, preference, probability, communities, conservation

Introduction

In India, fuelwood continues to be the primary source of domestic energy. According to Anon. (1985), the requirement for firewood will be 300–330 million tonnes in 2000 as against 30–40 million tonnes of recordable production. The estimates for fuelwood demand in the country range from 96–157 million tonnes annually, including a rural demand of 80–128 million tonnes; this implies an annual consumption level of 148–242 kg per capita (Bhattacharya & Nanda 1992). However, the per capita annual consumption of dry wood in various parts of the Himalaya has been reported to be much higher, ranging between 500 and 1200 kg (Campbell & Bhattarai 1984; Berthet-Bondet *et al*. 1986; Singh 1989; Metz 1990).

In the Kumaun Himalaya, about 80% of the total human population (of 2 943 199) live in the rural areas (Anon. 1991). Unlike many urban centres of the region and plains of the country, the alternative sources of fuel are not easily available, hence the population almost totally depends upon wood resources. Most of this demand is met from the neighbouring forests. However, a small quantity of fuel is also obtained from the trees growing in agroforestry systems. Unfortunately, the source (forests) of these resources are continuously being degraded (Shah 1982; Khoshoo 1987) and continual biomass extraction (i.e. fuel and fodder) is considered a major reason for such depletion (Singh 1998).

The information available on the fuel resources of the Himalaya is scattered (Rawat & Pangtey 1987; Pangtey *et al*. 1988, 1989; Pande *et al*. 1990; Samant *et al*. 1993, 1995, 1996; Samant 1995; Dhar *et al*. 1997, 1998). The issues related to fuelwood as a resource have been addressed to some extent (Singh *et al*. 1988), but there has been no attempt to interrelate availability, quantity extracted and inhabitants' preferences, yet this is important if resource sustainability and conservation are to be addressed. The objectives of the present study have been to: (1) study the distribution and utilization patterns of fuel species; (2) assess the annual quantity collected; (3) analyse inhabitants' preferences for species, probabilities of use and resource use indices; (4) assess the status of fuel species in the forests/communities; and (5) sug-

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gest conservation strategies based on the existing status and utilization trend of the plants.

Methods

Study area and trends of fuel collection

Askot Wildlife Sanctuary (20°46′45″–30°27′45″N and 81°01′53″–80°16′25″), located in the north of the Pithoragarh district in Kumaun Himalaya, covers an area of approximately 600 km^2 (Fig. 1) and a wide altitudinal range (600–6905 m). The undulating topography, diversity in climate and soil offer a high diversity of species, habitats and communities. The vegetation of the area mainly comprises subtropical, temperate, subalpine and alpine types.

The area has 109 villages with a population of about 58 967, of which >30% belong to Schedule Castes and Schedule Tribes (Anon. 1991). Amongst the tribes, Rajee and Bhotia are well-known ethnic groups. Most inhabitants of the area are dependent on forests for fuel, fodder and other resources (Dhar *et al.* 1997).

In our surveys during 1993–97 it was observed that fuelwood collection starts at the end of November and finishes by the end of February. Based on these observations, we assume that the inhabitants collect fuel for about 90 days and considered these as total collection days (TCD). The dry fuelwood is stored in lots (>20 bundles) and utilized subsequently in the year, but at the end of each collecting season, inhabitants also cut large branches and logs and leave them on the forest floor to ensure subsequent availability of dry wood during the year.

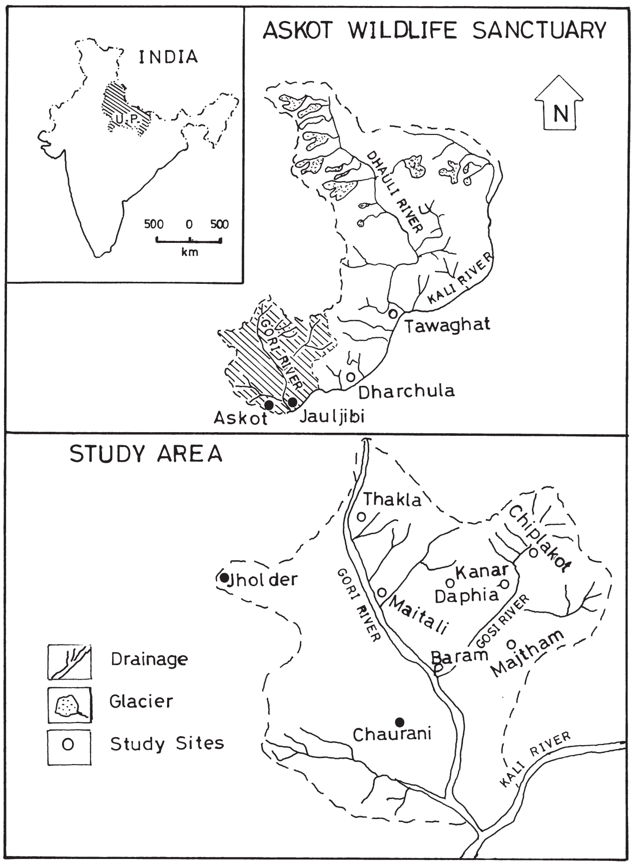

Figure 1 Diagrammatic maps showing the location of the Askot Wildlife Sanctuary and of study area within it, Uttar Pradesh, India.

Informal interviews (with heads of 10 families) in each village revealed that on average two people per day were involved in fuel collection from each household. Thus, the number of households in each village were multiplied by 2 to give an idea of total population responsible (TPR) for collection in each village.

Site selection, sampling and species identification

In the Gori Ganga Valley, a site in Askot Wildlife Sanctuary representative in terms of floristic diversity (Dhar *et al.* 1997; Samant *et al.* 1998), ethnicity and resource use (Dhar *et al.* 1998), six villages were selected. Villages were located at distances of 5 km from each other. Four villages (Baram, Lumti, Mori and Chhoribagar) were in the altitude range (900–1100 m), the other two being higher, namely Chopta (1400 m) and Maitli (2000 m).

A village survey was conducted in February 1996 to identify and quantify the fuel resource. The collection was brought in bundles to the village, mostly by adults. Ten such bundles were randomly selected each day in each village for five consecutive days. The species collected in each sample were separated by local names, and the weight of each species measured using a spring balance. Samples of each species were identified with the help of florulas and research papers (Gupta 1968; Osmaston 1978; Naithani 1984, 1985; Samant 1987; Pangtey *et al.* 1988; Purohit & Samant 1995), the list of the fuel species for each village was prepared from pooled information of all the samples. The biogeographical affiliations of the species were characterized following Anon. (1883–1970) and Samant *et al.* (1998).

Data analysis

The information generated from samples was pooled for each village. For individual species, mean amount collected (kg sample^{-1} day^{-1}; kg household^{-1} day^{-1}; kg household^{-1} year^{-1}), probability of use (PU) and resource use index (RUI) were calculated as follows:

$$\text{Mean collection (kg) of the species, } A = \frac{T}{N} \quad (1)$$

where T = total collection in all samples, and
N = number of samples;

Mean collection sample^{-1} day^{-1},

$$Cs = \frac{\sum_{i=1}^{n=6} A\,TPR_i}{\sum_{I=1}^{n=6} TPR_i} \quad (2)$$

where A = mean collection of the species, and TPR_i = total population responsible for collection in the *i*th village;

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$$\text{Mean collection household}^{-1}\ \text{day}^{-1},\ Cd = 2\,Cs \qquad (3)$$

$$\text{Mean collection household}^{-1}\ \text{year}^{-1},\ Cy = 90\,Cd \qquad (4)$$

where 90 was the total collection days per year;

$$\text{Probability of use, PU} = \frac{\sum_{i=1}^{n=6} F_i\,P_i}{\sum_{i=1}^{n=6} P_i} \qquad (5)$$

where F_i = frequency of collection of a species in the *i*th village; P_i = population of the *i*th village.

$$\text{Resource Use Index, RUI} = Cy\,PU \qquad (6)$$

where Cy = mean collection household^{-1} year^{-1}.
Similarity in fuelwood consumption across the villages of different altitudinal zones was determined using Sorenson's Index of similarity (Muller-Dombois & Ellenberg 1974),

$$IS = \frac{2C}{A+B}\,.\,100 \qquad (7)$$

where C = amount of fuel collection common in the villages (A and B); A = collection of fuel in village A, and B = collection in village B.

Phytosociological analysis

To understand the patterns of fuel species availability, a detailed phytosociological investigation was conducted in forests under continuous use in the study area. Inhabitants largely used fuel from only four of the forest communities, namely *Macaranga*-mixed, Chir-pine (*Pinus roxburghii*), Banj-oak (*Quercus leucotrichophora*) and Rianj oak (*Quercus lanuginosa*) of the seven identified communities in Gori Ganga Valley (Dhar *et al*. 1997). Three sample plots (each 0.5 ha) were selected at random from those locations which were regularly accessible to village inhabitants. Within each marked plot, 10 (10 × 10 m) quadrats for trees and 20 (5 × 5 m) quadrats for shrubs, seedlings and saplings were randomly laid. Numbers of individuals of each species and diameter at breast height (dbh; 1.37 m) for tree individuals were recorded in quadrats. Amongst trees, individuals below 10 cm dbh were considered recruits, i.e. seedlings and saplings. Density was calculated for each size class following Misra (1968). Plot density was pooled for each forest.

Results

Diversity, distribution and utilization patterns

In all, 31 species (26 trees, 5 shrubs) were used as fuel in the area (Table 1), of which 14 species were native to Himalaya (Table 2). Maximum numbers of species were used in

Table 1 Human population statistics and number of fuel species used in the study villages of Askot Wildlife Sanctuary.

Village (altitude in metres)	*Total population*	*No. of households*	*Population responsible for collection*	*Fuel species collected*
Low altitude villages				
Baram (900)	388	60	120	21
Lumti (1000)	444	65	130	13
Mori (1050)	164	27	54	13
Chhoribagar (1100)	239	39	78	12
Mid altitude village				
Chopta (1400)	35	5	10	8
High altitude village				
Maitli (2000)	276	38	76	16
Total	*1546*	*234*	*468*	*31*

Table 2 Index of similarity (%) in the quantum collection of fuel resource in the villages of Askot Wildlife Sanctuary.

Villages	*Baram*	*Chopta*	*Maitli*	*Lumti*	*Mori*	*Chhoribagar*
Baram	100	31.33	15.22	62.94	53.81	52.77
Chopta		100	20.57	28.54	44.58	47.94
Maitli			100	11.10	23.77	20.77
Lumti				100	69.71	57.14
Mori					100	74.21
Chhoribagar						100

Table 3 Mean collection rate, probability of use and resource use index values for fuel species in Askot Wildlife Sanctuary. Biogeographical affinity: Reg. Himal. = Himalayan Region; Ind. Or. = Indian Oriental; As. Trop. = Tropical Asia; Austr. = Australia; As. et Austr. Trop. = Asia and Tropical Australia; As. Trop. et Subtrop. = Tropical and Subtropical Asia; As. et Afr. Trop. = Asia and Tropical Africa.

Species name	*Local name*	*Biogeographical affinity*	*Mean collection (kg sample^{-1} day^{-1})*	*Mean collection (kg household^{-1} day^{-1})*	*Expected mean collection (kg household^{-1} year^{-1})*	*Probability of use (PU)*	*Resource use index (RUI)*
Alnus nepalensis Don	Outees	Reg. Himal.	0.07	0.14	12.60	0.04	0.50
Bauhinia vahlii Wt. & Arn.	Malu	Ind. Or.	0.09	0.18	16.20	0.03	0.49
B. variegata L.	Kweral	Ind. Or., Burma, China	0.27	0.54	48.60	0.13	6.32
Berberis aristata DC.	Chuthar	Ind. Or.	0.49	0.98	88.20	0.12	10.58
Callicarpa arborea Roxb.	Guwal	As. Trop.	0.31	0.62	55.80	0.13	7.25
Casearia elliptica Willd.	Pipri	As. Trop., Austr.	1.21	2.42	217.80	0.39	84.94
Castanopsis tribuloides (Sm.) A.DC.	Katonj	Reg. Himal., Burma	0.12	0.24	21.60	0.03	0.65
Cornus oblonga Wall.	Kanaki	Reg. Himal.	0.46	0.92	82.60	0.12	9.91
Emblica officinalis Gaertn.	Aonla	As. Trop.	0.73	1.46	131.40	0.08	10.51
Engelhardtia spicata Bl.	Bijaysar, Mawa	Reg. Himal., Malaya	1.58	3.16	284.40	0.36	102.38
Eurya acuminata DC.	Dhwair	Reg. Himal., Malaya	0.82	1.64	147.60	0.27	39.85
Glochidion velutinum Wt.	Bhair	Ind. Or.	0.62	1.24	111.60	0.19	21.20
Lyonia ovalifolia (Wall.) Drude	Ayar	Reg. Himal., Japan	1.21	2.42	217.80	0.18	39.20
Macaranga pustulata King ex Hk. f.	Ramal	Reg. Himal.	2.35	4.70	423.00	0.56	236.88
Mallotus philippensis (Lmk.) Muell.	Ruin	As. et Austr. Trop.	1.55	3.10	279.00	0.34	94.86
Maesa indica A. DC.	Bakaria	Ind. Or., Malaya	0.42	0.84	75.60	0.23	17.39
Myrica esculenta Buch.-Ham. ex Don	Kaphal	As. Trop. et Subtrop.	0.57	1.14	102.60	0.05	5.13
Ougeinia oojeinensis (Roxb.) Hochr.	Sanan	Ind. Or.	0.62	1.24	111.60	0.27	30.13
Persea duthiei (King ex Hk. f) Kosterm.	Kaul	Reg. Himal.	0.26	0.52	46.80	0.05	2.34
Phoebe lanceolata (Nees) Nees	Kaule	Ind. Or., Burma	1.03	2.06	185.40	0.30	55.62
Pinus roxburghii Sarg.	Chir, Sal	Reg. Himal.	4.41	8.82	793.80	0.71	563.60
Pyracantha crenulata (Don) Roem.	Ghingaru	Reg. Himal.	0.01	0.02	1.80	0.04	0.07
Quercus glauca Thunb.	Phaliant	Reg. Himal., Japan	0.25	0.50	45.00	0.04	1.80
Q. lanuginosa Don	Rianj	Reg. Himal.	1.63	3.26	293.40	0.07	20.54
Q. leucotrichophora A. Camus	Banj	Reg. Himal.	2.93	5.86	527.40	0.34	179.32
Rhododendron arboreum Sm.	Burans	Reg. Himal., Ceylon	1.09	2.18	196.20	0.14	27.47
Syzygium cuminii (L.) Skeels	Jamun	As. et Austr. Trop.	0.07	0.14	12.60	0.03	0.38
Terminalia chebula Retz.	Harar	As. Trop.	0.69	1.38	124.20	0.27	33.53
Toona ciliata Roem.	Tun	Malaya, Austr.	0.20	0.40	36.00	0.11	3.96
Wendlandia exserta (Roxb.) DC.	Terchun	Ind. Or.	0.64	1.28	111.60	0.09	10.04
Woodfordia fruticosa (L.) Kurz	Dhaul	As. et Afr. Trop.	9.28	18.56	1670.40	0.78	1302.91

Baram (21 spp.), Maitli (16 spp.), Lumti and Mori (13 spp. in each). Amongst low altitude villages, the pattern of species collection and amount consumed did not vary very greatly (Similarity 52–74%; Table 2). The major part of the fuel in this zone came from *Woodfordia fruticosa*, *P. roxburghii*, *Phoebe lanceolata*, *Mallotus philippensis*, *Q. leucotrichophora*, *Engelhardtia spicata*, *Casearia elliptica* and *Macaranga pustulata*. In contrast, use pattern varied considerably across the altitudinal gradient (Similarity 15–31%; Table 2). *P. roxburghii*, *Q. leucotrichophora*, *W. fruticosa*, *M. philippensis* and *Lyonia ovalifolia* contributed most to the collection in Chopta at mid altitude, and *Q. lanuginosa*, *Rhododendron arboreum*, *L. ovalifolia*, *Myrica esculenta, Berberis aristata* and *Q. leucotrichophora* contributed most to collections in Maitli, which was the village at greatest altitude studied (Table 3).

Diversity in species preference, their distribution in different communities, altitude range, dominant elements of communities and uses of fuel resource for the entire area are given (Table 4).

Probability of use

Probability of use (PU) was highest for *W. fruticosa* (0.78), followed by *P. roxburghii* (0.71), *M. pustulata* (0.56), *C. elliptica* (0.39), *E. spicata* (0.36), *M. philippensis* (0.34), *Q. leucotrichophora* (0.34), *P. lanceolata* (0.30), *Ougeinia oojeinensis* (0.27), *Eurya acuminata* (0.27), *Terminalia chebula* (0.27) and *Maesa indica* (0.23) respectively, with the remaining species showing PU < 0.20 (Table 3). High values of PU reflected increased pressure on the species and low values reflected low preference or low availability in the wild.

Resource use index

W. fruticosa, *P. roxburghii*, *M. pustulata*, *Q. leucotrichophora*, *E. spicata*, *M. philippensis*, *C. elliptica*, *P. lanceolata*, *E. acuminata*, and *L. ovalifolia* showed high resource use indices (RUI), suggesting their frequent use and indicating high anthropogenic pressure on these taxa (Table 3). The RUI was very low for *Alnus nepalensis*, *Bauhinia vahlii*, *Pyracantha crenulata*, *Syzygium cuminii*, *Quercus glauca*, *Persea duthiei* and *Castanopsis tribuloides,* suggesting their low acceptability as fuel.

Availability and status of fuel resource

Amongst 10 top-ranking fuel species, eight (*W. fruticosa, P. roxburghii, M. pustulata, E. spicata, C. elliptica, M. philippensis*) occupied low to mid-altitude forests, such as *Macaranga*-mixed deciduous and Chir-pine (Table 3). The other two, namely *Q. leucotrichophora* and *L. ovalifolia* occupied mid to high-altitude forests (Banj-oak, Rianj-oak and Chir-pine).

Considering the density distribution in different size classes as an indicator of availability and status, the population structures of native and non-native species in the identified communities were prepared (Figs 2 & 3). Of the 31 fuel species, *B. vahlii* and *Bauhinia variegata* were not recorded in the forest communities identified. This indicated that they were either distributed sporadically or restricted to certain pockets and were not fully sampled in the plots. Amongst the priority native species, *P. roxburghii* (384 trees, 504 saplings, 332 seedlings ha^{-1}) in the Chir-pine community exhibited greater availability and substantial density of recruits. Similarly, *M. pustulata* in the *Macaranga*–mixed community (173 trees, 74 saplings, 91 seedlings ha^{-1}), and in the Banj-oak community (5 trees, 20 saplings, 10 seedlings ha^{-1}), suggested continuing recruitment (Fig. 2). *Q. leucotrichophora* also exhibited an even population structure in all four communities; in the Banj-oak community, the density of *Q. leucotrichophora* (340 trees, 55 saplings, 90 seedlings ha^{-1}) was particularly high. *R. arboreum* in the Banj-oak and Rianj-

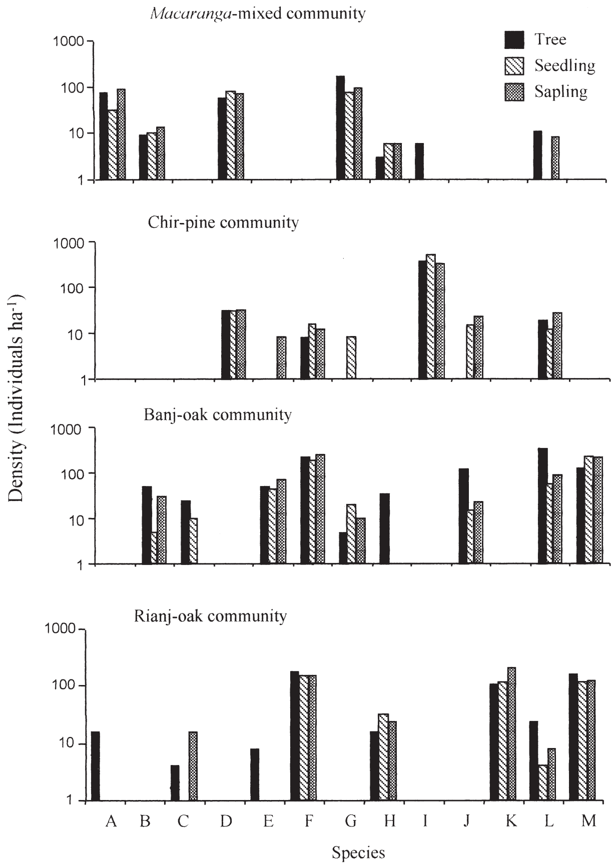

Figure 2 Population structure of the native tree species providing the fuel resource in Askot Wildlife Sanctuary. Tree species: A = *Alnus nepalensis*; B = *Castanopsis tribuloides*; C = *Cornus oblonga*; D = *Engelhardtia spicata*; E = *Eurya acuminata*; F = *Lyonia ovalifolia*; G = *Macaranga pustulata*; H = *Persea duthiei*; I = *Pinus roxburghii*; J = *Quercus glauca*; K = *Q. lanuginosa*; L = *Q. leucotrichophora*; M = *Rhododendron arboreum*.

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Table 4 Preference (1 indicates most preferred), community type, altitudinal range, co-occurring dominants and uses of fuel species in the Askot Wildlife Sanctuary. Uses: Md = Medicinal; Ed = Edible; Fd = Fodder; Hb = House building; At = Agricultural tools; Rel = Religious; Pisc = Piscicidal; Misc = Miscellaneous.

Species name	*Preference*	*Community type/s*	*Altitude range (m)*	*Dominant elements*	*Uses*
Woodfordia fruticosa (L.) Kurz	1	*Macaranga*-mixed, Chir-pine, Banj-oak	1200–1600	*Macaranga pustulata*, *Pinus roxburghii*, *Quercus leucotrichophora*	Md, Ed, Fd
Pinus roxburghii Sarg.	2	*Macaranga*-mixed, Chir-pine	1000–2000	*M. pustulata*, *Engelhardtia spicata*, *P. roxburghii*	Md, Hb
Macaranga pustulata King ex Hk. f.	3	*Macaranga*-mixed, Chir-pine	800–1800	*M. pustulata*, *P. roxburghii* *Q. leucotrichophora*	Fd, Hb
Quercus leucotrichophora A.Camus	4	*Macaranga*-mixed, Chir-pine, Banj-oak, Rianj-oak	1500–2500	*M. pustulata*, *P. roxburghii*, *Quercus lanuginosa*, *Lyonia ovalifolia*	Md, Ed, Fd, Hb, At
Engelhardtia spicata Bl.	5	*Macaranga*-mixed, Chir-pine	800–1600	*M. pustulata*, *E. spicata*, *P. roxburghii*	Fd, Pisc
Mallotus philippensis (Lamk.) Muell	6	*Macaranga*-mixed, Chir-pine	800–1500	*M. pustulata*, *E. spicata*, *P. roxburghii*	Fd, Misc
Casearia elliptica Willd.	7	*Macaranga*-mixed, Chir-pine	800–1500	*M. pustulata*, *E. spicata*, *P. roxburghii*	At, Fd
Phoebe lanceolata (Nees) Nees	8	*Macaranga*-mixed	800–1800	*M. pustulata*, *E. spicata*, *Alnus nepalensis*	Fd
Eurya acuminata DC.	9	Chir-pine, Banj-oak, Rianj-oak	1400–2500	*P. roxburghii*, *Q. leucotrichophora*, *Q. lanuginosa*	Fd, Misc
Lyonia ovalifolia (Wall.) Drude	10	Chir-pine, Banj-oak, Rianj-oak	1500–2500	*P. roxburghii*, *Q. leucotrichophora*, *Q. lanuginosa*	Md, Pisc
Terminalia chebula Retz.	11	*Macaranga*-mixed, Chir-pine	800–1600	*M. pustulata*, *E. spicata*, *P. roxburghii*	Md, Ed, Fd, Hb
Ougeinia oojeinensis (Roxb.) Hochr.	12	Chir-pine	1000–1600	*P. roxburghii*, *Terminalia chebula*, *Glochidion velutinum*, *Emblica officinalis*	Md, Ed, Fd, At, Misc
Rhododendron arboreum Sm.	13	Banj-oak, Rianj-oak	1500–3500	*Q. leucotrichophora*, *Q. lanuginosa*, *Q. semecarpifolia*	Md, Ed
Glochidion velutinum Wt.	14	Chir-pine	1000–1600	*P. roxburghii*, *T. chebula*, *G. velutinum*	Fd
Quercus lanuginosa Don	15	Rianj-oak	1800–2600	*Q. lanuginosa*, *Rhododendron arboreum*, *L. ovalifolia*, *Q. floribunda*	Fd, Hb
Maesa indica A.DC.	16	*Macaranga*-mixed Chir-pine	800–1400	*M. pustulata*, *E. spicata*, *P. roxburghii*	Fd, Ed
Berberis aristata DC.	17	Rianj-oak	1800–2500	*Q. lanuginosa*, *R. arboreum*, *L. ovalifolia*	Md, Ed
Emblica officinalis Gaertn	18	*Macaranga*-mixed	800–1500	*M. pustulata*, *E. spicata*, *A. nepalensis*	Md, Ed, Fd, Rel
Wendlandia exserta (Roxb.) DC.	19	*Macaranga*-mixed, Chir-pine, Banj-oak	800–1800	*M. pustulata*, *P. roxburghii*	Fd
Cornus oblonga Wall.	20	Banj-oak, Rianj-oak	1800–2600	*L. ovalifolia*, *Q. leucotrichophora*, *Q. lanuginosa*, *R. arboreum*	–
Callicarpa arborea Roxb.	21	*Macaranga*-mixed	1000–1500	*M. pustulata*, *A. nepalensis*, *E. spicata*	Fd
Bauhinia variegata L.	22	–	1000–1800	–	Fd, Md, Ed
Myrica esculenta Buch-Ham. ex Don	23	Banj-oak, Rianj-oak	1400–2200	*Q. leucotrichophora*, *Q. lanuginosa*, *R. arboreum*, *L. ovalifolia*	Md, Ed
Toona ciliata Roem.	24	*Macaranga*-mixed	800–1200	*M. pustulata*, *E. spicata*, *A. nepalensis*	Hb
Persea duthiei (King ex Hk.f.) Kosterm	25	*Macaranga*-mixed, Banj-oak, Rianj-oak	1500–2600	*M. pustulata*, *Q. leucotrichophora*, *Q. lanuginosa*	Fd
Quercus glauca Thunb.	26	Chir-pine, Banj-oak	800–2000	*P. roxburghii*, *Q. leucotrichophora*	Fd, At
Castanopsis tribuloides (Sm.) A.DC.	27	*Macaranga*-mixed, Banj-oak	800–2000	*M. pustulata*, *Q. leucotrichophora*, *L. ovalifolia*	Fd, Hb, Ed, At
Alnus nepalensis Don	28	*Macaranga*-mixed, Rianj-oak	1000–2500	*M. pustulata*, *Q. lanuginosa*, *R. arboreum*	Fd
Bauhinia vahlii Wt. & Arn.	29	–	800–1200	–	Fd, Ed, Rel
Syzygium cuminii (L.) Skeels	30	*Macaranga*-mixed	1000–1500	*M. pustulata*, *E. spicata*	Md, Ed, Hb
Pyracantha crenulata (Don) Roem.	31	*Macaranga*-mixed, Chir-Pine, Banj-oak	1000–2000	*M. pustulata*, *P. roxburghii*, *Q. leucotrichophora*	Ed,At

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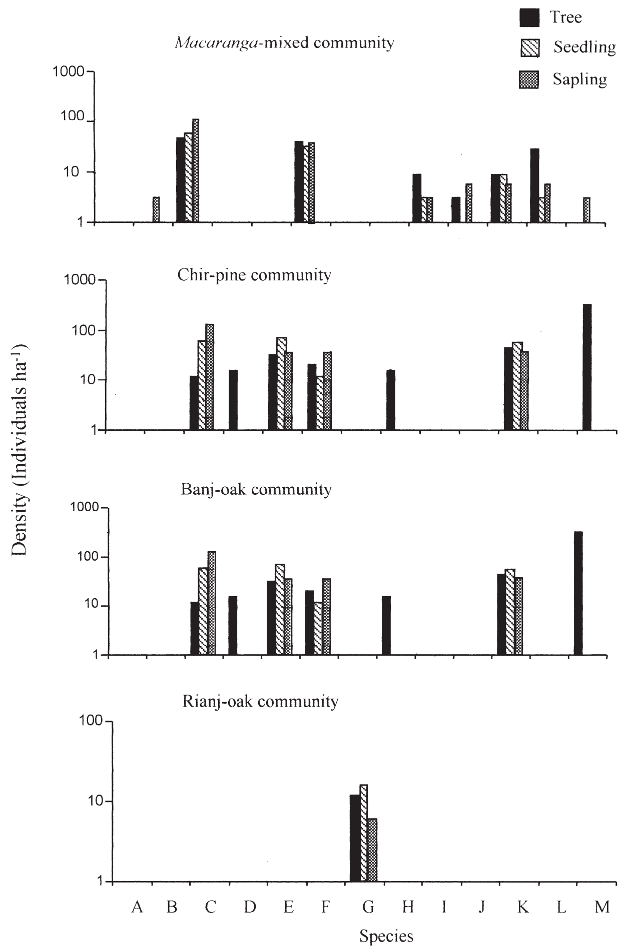

Figure 3 Population structure of non-native tree species of fuel resource in Askot Wildlife Sanctuary. Tree species: A = *Bauhinia variegata*; B = *Callicarpa arborea*; C = *Casearia elliptica*; D = *Emblica officinalis*; E = *Glochidion velutinum*; F = *Mallotus philippensis*; G = *Myrica esculenta*; H = *Ougeinia oojeinensis*; I = *Phoebe lanceolata*; J = *Syzygium cuminii*; K = *Terminalia chebula*; L = *Toona ciliata*; M = *Wendlandia exserta*.

oak, *L. ovalifolia* in the Chir-pine, Banj-oak, and Rianj-oak, communities, and *A. nepalensis* in the *Macaranga*-mixed forests, also exhibited strong recruitment (Fig. 2).

Amongst the preferred non-native trees, *M. philippensis* and *C. elliptica* showed individuals in all size classes in the *Macaranga*-mixed and Chir-pine communities. Density data indicated low availability of *O. oojeinensis, P. lanceolata, S. cuminii, Emblica officinalis, M. esculenta, Cornus oblonga, C. tribuloides* and *P. duthiei* (Figs 2 & 3).

Amongst shrubs, the high density of *Maesa indica* (1050 individuals ha^{-1}), and *P. crenulata* (1600 individuals ha^{-1}) in the *Macaranga*-mixed community, and of *W. fruticosa* in the Chir-pine (1210 individuals ha^{-1}) and Banj-oak (470 individuals ha^{-1}) indicated the present availability for fuel purposes.

Most of these species were also sources of fodder, timber, house building, agricultural tools and other uses; a few of them had medicinal and food (edible) value (Table 3).

Discussion

There have been very few studies on fuel-resource plants of the Indian Himalaya (Shah 1982; Khoshoo 1987; Singh *et al.* 1988; Singh 1989) and such studies have been largely confined to measurement of availability of fuel resource in different altitudinal zones. Pertinent information for conservation includes levels of annual collection, relative importance as fuel, population status including likely impact of fuelwood collection on species and communities. The present study was to contribute to such information.

The diversity of use of fuel species depends on the wood quality, accessibility, availability and also the human population of the surrounding villages (Singh *et al.* 1988). The present study clearly shows that the species richness of available resources, accompanied by large human population, contributed to a diversity of species collected (Table 1). For instance, in the study area, *Macaranga*-mixed and Rianj-oak (*Q. lanuginosa*) communities were relatively rich in woody components (Dhar *et al.* 1997), and the large villages in their vicinity used a relatively large number of species as fuel. In contrast, the mid-altitude village Chopta in the species-poor Chir-pine (*P. roxburghii*) community, utilized few species (Table 1). Moreover, increased species choice did reduce the species focused collection intensities, which by and large concentrated on few taxa. This can be attributed to the choice of good quality fuel, accessibility and availability. For example, low-altitude villages had easy access to *W. fruticosa*, which provides good quality wood and retains heat for a longer time according to villagers; all these factors contributed to the higher demand for this species. Similarly, at high altitude *Q. lanuginosa* was easily available, has hard wood and the high quality coal producible from it made it the most preferred resource. According to the inhabitants' own assessment of fuel quality, eight of the ten top ranking fuel species (the exceptions being *W. fruticosa* and *Q. leucotrichophora*) were considered poor as fuel. All the preferred taxa (except *P. lanceolata*) exhibited substantial recruitment in their respective forest communities, suggesting that availability of the resource is the most important contributing factor determining the inhabitants' choice. Further, diversity in utilization of species broadly followed the patterns of changes in forest vegetation across the altitudinal gradient. At low altitude along the Gori Ganga River, the vegetation remained mostly uniform (i.e. *Macaranga*-mixed), and the villages exhibited high similarity in fuel use. Whereas, along the altitudinal gradient, the forest communities (i.e. *Macaranga*-mixed, Chir-pine, Banj-oak and Rianj-oak) differed greatly, hence the villages along this gradient exhibited great differences in resource use.

The PU and RUI of species depended partly on the frequency of collection in the study villages, species with high PU and RUI having high collection pressure (Table 3). The

RUI reflected the relative importance of species as a resource and included both pressure (quantity collected) and preference. Species with high mean collection and PU exhibited high RUI. The multiple utility of some of the species enhanced pressures on them.

The non-availability of *B. variegata* and the low density and poor distribution of *O. oojeinensis*, *P. lanceolata*, *S. cuminii*, *C. tribuloides*, *C. oblonga*, *E. officinalis*, *M. esculenta* and *P. duthiei* in the identified communities reflected generally low availability of these species (Figs 2 & 3). Although not included in Figure 3, *B. vahlii* was also absent. Continuous exploitation of these species for fuel and other purposes is likely to have contributed to their depletion. Despite sufficient recruitment in most of the high ranking species, the high proportion as saplings, for example in *Q. lanuginosa* in the Rianj-oak forest indicates that the species is not being allowed to reach tree size.

Conservation and management perspectives

Various societies utilize their natural resource base depending on their perception, experience and response to patterns of resource use (Gadgil 1991; Samant & Dhar 1997). The present trends of fuel resource collection in the area indicate that the inhabitants perceived their resource base to be unlimited. Studies on biomass production in central Himalayan forests suggest that in this region fuelwood consumption is well below the carrying capacity of forests, provided the entire wood production of the region is considered (Singh & Singh 1992). Therefore, it may at first appear that no resource use restraints are desired. However, the demographic profile of existing resources shows that resource availability is finite and probably sensitive to current levels of resource use. For example, the dominant taxa in *Q. leucotrichophora* and *Q. lanuginosa* communities reflected possible changes in forest structure and composition as a consequence mostly of biomass removal (Dhar *et al*. 1997). In this respect, it is essential to develop some means of restraining resource use for these communities. One way could be through bringing down the level of harvest of dominant taxa through strict regulations. In the case of fuel collection from oak communities this might be achieved by encouraging increased consumption of less-preferred and widely-available species such as *R. arboreum* (rank 13; Table 4) and *L. ovalifolia* (rank 10), which were currently of lesser interest. The existing trends of greater preference for trees as fuel resource (27 spp.) are not a healthy approach to resource use, contributing to greater pressure on a particular group as they do. The pressure might be diverted to easily-available shrub resources (richness 9–14 in studied forests, Table 4; Dhar *et al*. 1997).

The rehabilitation of degraded, uncultivated and marginal lands through development of plantations for seedlings and saplings of high-quality fuel species in the respective villages might reduce pressure on wild plants in the natural habitats. However, Singh *et al*. (1988) opined that such efforts could only meet the firewood needs of the population at the existing level, and on a long-term basis would only be a temporary relief, in view of the increasing human population in the region.

The study area as such supports a high proportion of non-native taxa (66%) and proliferation of several non-native taxa is a consequence of deliberate introduction and/or promotion by the inhabitants (Dhar *et al*. 1997; Samant *et al*. 1998). The inhabitants are utilizing > 55% non-natives as fuel, but the extraction intensities on these in most cases are considerably lower than on native species. This practice indirectly contributes to the relative protection of non-native taxa. This phenomenon over the course of time could lead to long-term changes in ecosystem processes (Vitousek 1986; Ramakrishnan & Vitousek 1989).

Fuelwood is necessary to satisfy basic household requirements for cooking and space heating in the region. Considering the remoteness of the area and existing trends of development we do not see any possible alternatives, such as cooking gas or electricity in the near future. Therefore, the inhabitants will have to rely on the woody species to meet their fuel demand. About 52% of the total area is under forests which are the major source of fuel for local inhabitants. At present, fuel resource is easily available in most parts of the Sanctuary and inhabitants view it as a source of free energy and their fuel consumption habits remain wasteful or faulty. As a result, the many resource species are under heavy pressure. Considering that in reality the existing resource base is finite, inhabitants knowingly or unknowingly have unsustainable fuel-use practices and remoteness of the area hinders provision of alternative energy sources by the government, the following measures seem appropriate to sustain the fuel resource for posterity:

- Enforcement of strict protected area rules for intensive management in identified sites, especially those subject to greater pressure.
- Diversification of choice of fuel species from frequently used to less used and from natives to non-natives.
- Practically feasible propagation packages for the most preferred species and their dissemination to local inhabitants.
- Greater awareness amongst the inhabitants of the available stock, accompanied by conservation programmes such as community forestry and agroforestry.
- Education of local inhabitants about less wasteful habits of firewood consumption (Pant & Singh 1987; Singh *et al*. 1988). For example, improved *chullas* (cooking and heating utensils) have been successful in reducing firewood consumption in other parts of the region. Education and awareness amongst rural inhabitants could further improve their level of acceptance of modern improvements in cookware, for example, pressure cookers and alternative energy sources like solar energy.

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