RESEARCH ARTICLE

Current status and distribution of commercially exploited medicinal and aromatic plants in upper Gori valley, Kumaon Himalaya, Uttaranchal

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Estimation of population status and biomass availability of 14 threatened medicinal and aromatic plant species (TMAPS) extracted and traded from the higher altitudes of Kumaon Himalaya was carried out. We used stratified random samples covering distinct landscape units or habitats. These TMAPS were distributed in nine different habitat types and had habitat-specific distribution. On the basis of their status and level of pressure at a local scale, we have grouped them into six categories and a conservation approach has been suggested.

OUT of the ca. 17,500 flowering plant species found in India, over 1600 are used in traditional medicinal system[1]. Revival of the traditional medicine system in India and abroad has put extra pressure on the forests, especially the medicinal plants. Habitat degradation, unscientific harvesting and over-exploitation to meet the demands of illegal trade in medicinal plants have led to the extinction of more than 150 plant species in the wild[2,3]. At least 90% of the plant species used in the herbal industry today are extracted from the wild, majority of which comes from the sub-alpine and alpine zones of the Himalaya. Some of the species, which are in great demand from various pharmaceutical companies include *Picrorhiza kurrooa, Podophyllum hexandrum*, *Nardostachys grandiflora*, *Dactylorhiza hatagirea*, *Aconitum heterophyllum,* and *Saussurea costus*. Most of these species have been listed in Appendix I and II of CITES. It is believed that excessive anthropogenic pressures are the main cause of decline in the population and availability of these medicinal plants in the Himalayan region[4,5]. Quantitative information on the micro-habitat preferences and population status of these species is virtually lacking from the Himalayan region. Studies on these aspects of commercially useful plants would be very vital in understanding the ecology of such species and formulating the conservation plans for the areas. We conducted an ecological survey of 14 threatened medicinal and aromatic plants (TMAPS) in upper catchment of Gori river in Kumaon Himalaya, which is considered to be one of the major centres of illegal trade in medicinal plants. This paper deals with the broad findings of the survey *vis-à-vis* conservation implications.

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Study area and methods

Intensive surveys for TMAPS were carried out in Johar and Ralam valleys located between 30°05′–30°30′N latitude and 80°05′–80°25′E longitude (Figure 1) in the upper catchment of river Gori Ganga in district Pithoragarh. The study area extends from the Tibetan border down the Gori valley as far as the Pilthi Gad coming from Ralam valley joins it. On the eastern side, it is bounded by Darma valley and on the western side it forms the boundary of the Nanda Devi Biosphere Reserve (NDBR). Differences in climatic conditions coupled with a wide altitudinal range (1000–7500 m asl) provide a great diversity of landscapes, which have resulted in diverse flora and fauna[6,7]. The resident ethnic communities such as *Shaukas*, *Darmees*, *Barpatias* and *Jimdars* have a traditional bondage with the plants[8].

Field methods: selection, sampling and population estimation

Fourteen TMAPS which have high trade and conservation value, were selected for the present study (Table 1). The population survey of these species was carried out from May 2001 to August 2001. A total of four months were spent in the field by the two senior authors. As most of the species have extremely high site fidelity and habitat requirements[9], assessment of TMAPS within various strata of habitats gives the reliable population estimates. Hence, various habitats were identified based on altitude, topography, presence of perennial water channels and physiognomy of vegetation. In each habitat, 20 m × 2 m belt transects were laid, as these are useful for studying the distribution of species along an environmental or habitat gradient[10]. In each belt, the number and species of different medicinal herbs were

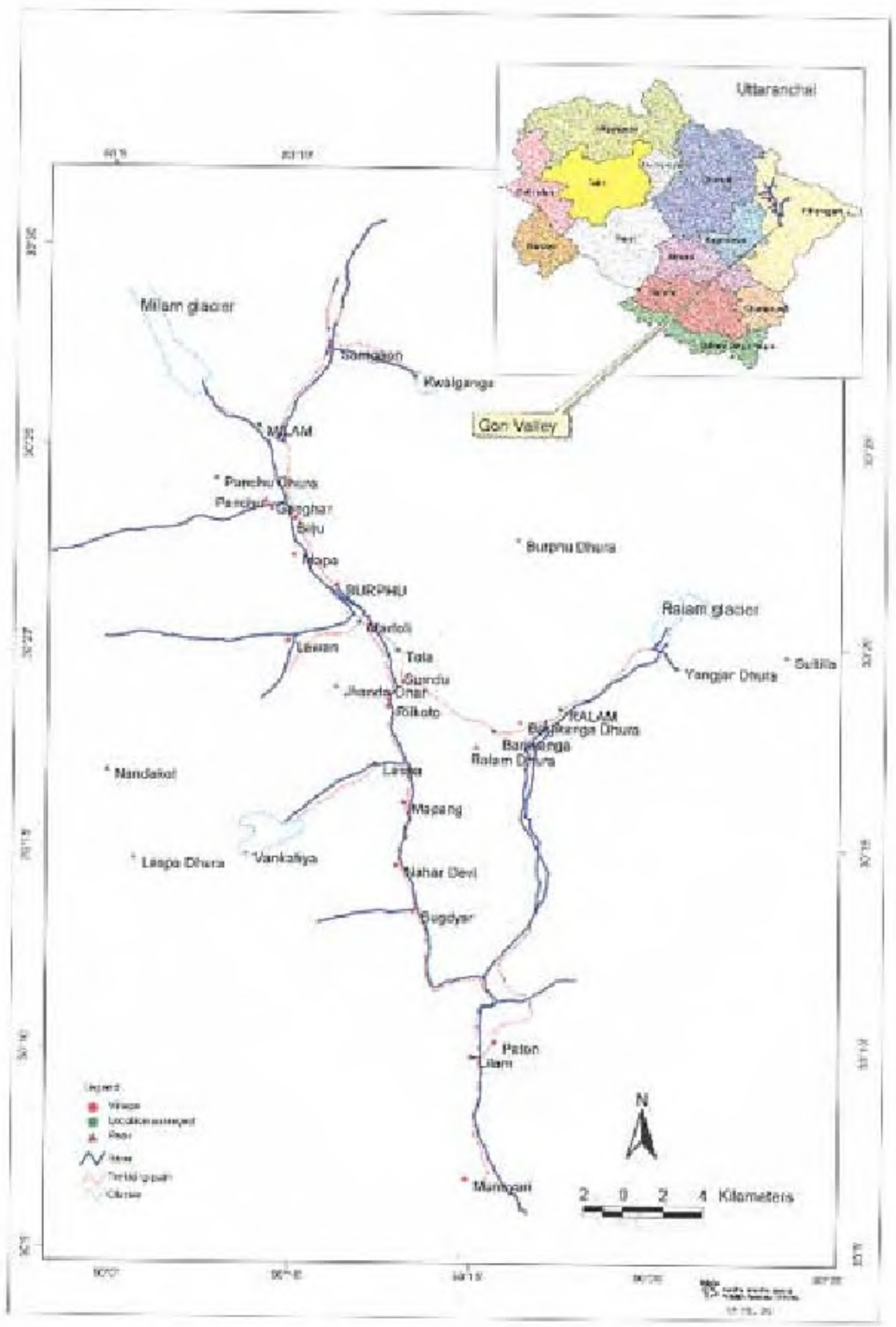

Figure 1. Map showing upper Gori valley and locations surveyed.

Table 1. TMAPS selected for population estimates in the wild

Species	Local name	Altitude (m)	Habitat	Part extracted	Legal status		
					RDB	PN	CITES
Aconitum heterophyllum	Atees	2400–4000	F, Sh, Ogs	Root	–	–ve	–
Allium stracheyi	Jimbu	3000–3500	Rs, Ogs	Leaf	V	–	–
Arnebia benthamii	Lal jadi	3000–4300	Os, Sh	Root	–	–ve	–
Bergenea stracheyi	Ghee-pati	3300–4500	As	Rhizome	–	–ve	–
Carum carvi	Thoya	2800–3200	Cul, Mr	Seed	–	–	–
Chaerophyllum villosum	Ginjuri	2100–3600	Sh, F	Root	–	–	–
Dactylorhiza hatagirea	Hathpanja	2800-4000	Os, Mr	Root	–	–ve	II
Jurinea macrocephala	Dhup-lakkad	3000–4300	Os	Root	–	–ve	–
Nardostachys grandiflora	Masi	3600–4800	Rs	Rhizome	V	–ve	II
Picrorhiza kurrooa	Kutki	3300–4300	Rs	Rhizome	V	–ve	II
Pleurospermum angelicoides	Chipi	3600–4800	As	Root	–	–	II
Podophyllum hexandrum	Ghyu-churpun	2400–4500	F, Os	Root	–	–ve	II
Rheum moorcroftianum	Taturi	3600–4700	Os	Root	–	–ve	–
Rheum australe	Dolu	3000–4200	Rs	Root	–	–ve	–

Os, Open slopes; Sh, Shrubberies; As, Alpine slopes; Rs, Rocky slopes; F, Forest; Ogs, Open grassy slopes; Mr, Marshland; Cul, cultivated; RDB, Red Data Book; PN, Public notice regarding negative list of export issued by Department of Commerce; CITES, Convention on International Trade of Endangered Species of Fauna and Flora; V, vulnerable.

counted. For the rhizomatous species such as *P. kurrooa*, each flowering shoot was counted as one individual[10]. For the assessment of availability of biomass of the TMAPS, harvest method was followed[11]. Inside each belt 1 m × 1 m quadrats (three in number) were laid. Different species were dug out from these quadrats and the fresh and sun-dried weights of their roots or rhizomes were recorded.

Analyses

Density of each TMAPS was calculated in different habitat types. Diversity and richness of TMAPS were calculated within each habitat type using the computer software, STATECOL[12]. Species were ordinated along different environmental variables using the computer software, CANOCO[13] (Canonical Community Ordination). Available biomass (kg/ha) of each TMAPS was calculated in each habitat and compared among different habitats.

Table 2. Habitat types in the study area

Habitat	Characteristics
Moist rock	Moist rocky outcrops, rocky crevices and rocks along water channels.
Dry rock	Dry rocky outcrops, dry landslide areas and rocky slopes without water channels.
Scree slope	Very high-altitude glacial moraines and landslide areas.
Gaps within scrub	Gaps formed between scrub patches and meadow area surrounded by scrub on all sides.
Under scrub	Under the canopy of scrubs such as *Rhododendron anthopogon*, *Juniperus* spp. and *Betula utilis*.
Grassland	Areas ≤ 45 degree slope and dominated by *Danthonia cachemyriana*.
Steep grassy slope	Areas > 45 degree slope and dominated by *D. cachemyriana*.
Undulating meadow	Undulating areas dominated by herbaceous plants.
Marshy meadow	Meadows along water channels and seepage areas.

Results

Distribution and diversity of medicinal herbs

The surveyed TMAPS (14) were found within nine habitat types (Table 2). Species such as *Rheum, Pleurospermum* and *Nardostachys* were confined to very high alpine zones (3900 m asl), whereas *Dactylorhiza hatagirea*, *Aconitum heterophyllum*, *Arnebia benthamii* and *Jurinea macrocephala* were found even in the lower alpine zones (3000 m asl). Canonical community ordination showed that though altitude influenced the distribution of TMAPS, microtopographic features such as presence and absence of water, canopy cover and slope inclination played a significant role in their distribution (Monte Carlo test, $P = 0.01$, F-ratio = 9.33). Species diversity also varied with the habitat types. It was found that undulating meadows (between 3400–4000 m asl) had highest species diversity. However, species richness was highest in the moist rocky habitat. It was observed that where species diversity was lowest (grassland), concentration of dominance was highest (Figure 2). Concentration of dominance, the value of which ranges between 0 and 1, indicates patterns of species dominance. Areas dominated by single or few species have

values closer to 1 and vice versa. On the basis of species diversity moist rocks, under scrub and undulating meadows were the best habitat types, whereas scree slopes, steep grassy slopes and marshy meadows had low species diversity.

Population status and biomass availability

It was found that population of different TMAPS varied in different habitats (Table 3). *A. benthamii* and *Allium stracheyi* had higher densities in steep grassy slopes and *A. heterophyllum*, *J. macrocephala* in undulating meadows. *D. hatagirea*, *Chaerophyllum villosum* and *Carum carvi* had higher density in marshy meadows, whereas *N. grandiflora* and *R. moorcroftianum* had higher densities in scree slopes. This reveals that though some species may be present in a variety of habitats, their populations would be high in a particular habitat. Certain species, viz. *A. benthamii*, *N. grandiflora* and *P. angelicoides* had patchy distribution even in their favoured habitat. *D. hatagirea*, *J. macrocephala*, *A. heterophyllum* and *P. kurrooa* had more or less regular distribution in their specific habitats. A high standard error in case of certain species in habitats other than their favoured ones further highlights their patchy and habitat-specific distribution. A comparative account of the present study with other studies[4,14,15] (Table 4) reveals that most of the TMAPS had low population in the present area compared to the protected areas, e.g. Valley of Flowers (VOF) and NDBR. This could be mainly due to over-exploitation and habitat degradation in the present study area.

Most of the medicinal plants are sold to the 'middle men' or contractors in terms of their dry weight. Hence available biomass of TMAPS was calculated as dry weight in different habitats. Available biomass of TMAPS also varied in different habitats. *A. benthamii* had highest biomass (664 kg/ha) in steep grassy slopes, while *D. hatagirea* had lowest available biomass (0.06 kg/ha) in under scrub habitat. Though *D. hatagirea*, *P. kurrooa* and *N. grandiflora* had good densities in their habitats, their available dry weight was low (Table 5) due to smaller root/rhizome size and high moisture content (Figure 3). Thus to get maximum dry weight of these species, a large number of individuals are extracted. It can be inferred from the above-mentioned results that these TMAPS had very localized and patchy distribution. Hence, population and biomass estimates cannot be extrapolated for the entire area unless the specific habitats are delineated and extent of the area is determined.

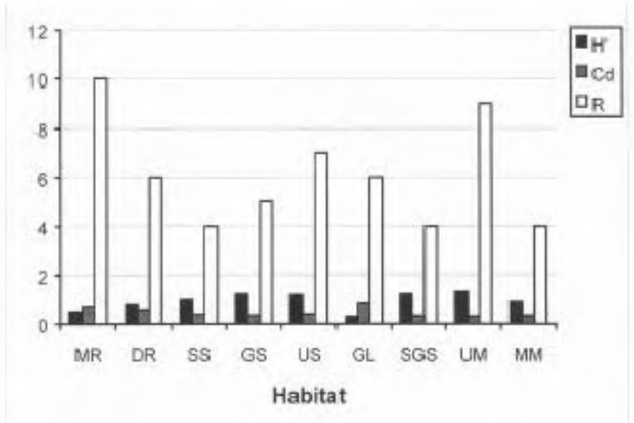

Figure 2. Pattern of species diversity (H′), concentration of dominance (Cd) and richness (R) along different habitats.

Figure 3. Sun-drying of *Dactylorhiza hatagirea*.

Discussion and conservation implications

Declining population of TMAPS in the wild due to over-exploitation has raised concern among various scientists, ecologists and conservationists[3,5,16,17]. Among the many factors involved in the depletion of a species from the wild, the most important is the small population size[18]. In some cases the population size of a species can inherently be low or at times anthropogenic pressures in the form of grazing, trampling and extraction result in the decline in population (Figure 4 *a* and *b*). We found that *B. stracheyi* and *P. hexandrum* had patchy or localized distribution within their habitats, whereas *C. villosum*, *C. carvi* and *D. hatagirea* were widely distributed. On the basis of their distribution pattern, population status and level of anthropogenic pressures (pers. obs.) in the present area, the surveyed TMAPS were grouped into six categories. Species of high trade value such as *A. heterophyllum*, *D. hatagirea*, *P. kurrooa* and *J. macrocephala* had good population in their specific habitats only; however, they are under heavy pressure due to demands in the market and were thus put under category 'restricted distribution and heavy pressure' (RDHP). Casual interviews with the local people during the four-month stay and

Table 3. Population (density/ha) of TMAPS in different habitats

Species	MR (47)	DR (13)	SS (32)	GS (7)	US (26)	GL (25)	SGS (21)	UM (69)	MM (28)
A. benthamii	333.3 ± 333.3	1562.5 ± 1562.5	–	650 ± 650	–	7816.43 ± 5578.22	16607.1 ± 6893.7	9500 ± 4635.8	–
A. heterophyllum	–	–	–	–	850 ± 850	4515 ± 3509.9	–	8602.9 ± 1937.6	–
A. stracheyi	3170.56 ± 2003.88	1937.5 ± 1119.7	–	–	–	–	8937.5 ± 1255.72	–	–
B. stracheyi	–	11162.5 ± 7871.6	–	–	–	–	–	–	–
C. carvi	–	–	–	–	–	–	–	–	934402.68 ± 40377.03
C. villosum	713250 ± 246750	–	–	–	–	258008 ± 168242	–	30000 ± 20992.8	167523.3 ± 101936.5
D. hatagirea	505 ± 438.76	–	–	4125 ± 625	50 ± 50	230 ± 217.72	–	432.36 ± 317.9	23194.17 ± 4510.9
J. macrocephala	2891.66 ± 2195.45	–	–	–	1916.7 ± 300.5	3349.3 ± 2242.4	5535.7 ± 2861.1	9580.7 ± 5957.1	3833.3 ± 2315.4
N. grandiflora	2641.66 ± 1275	58875 ± 58875	6833.33 ± 3585.7	–	–	–	–	136.4 ± 136.4	–
P. angelicoides	–	–	–	2240 ± 1607.44	2260.2 ± 1636.1	–	–	136.02 ± 121	–
P. hexandrum	1125 ± 1125	2750 ± 2750	–	–	–	–	–	–	–
P. kurrooa	129152.99 ± 123983	–	11998.33 ± 11441.1	850 ± 850	13890 ± 5189.9	–	–	–	–
R. australe	1283.88 ± 1063.62	737.5 ± 706.66	355± 339.6	150 ± 100	3500 ± 1860.23	125 ± 77.4	2964 ± 1174.42	39.78 ± 28.1	–
R. moorcroftianum	125 ± 125	–	3200 ± 547.9	–	50 ± 50	–	–	220.6 ± 220.6	–

MR, Moist rocks; DR, Dry rocks; US, Under scrub; GS, Gaps within scrub; SGS, Steep grassy slopes; GL, Grassland, MM, Marshy meadows; SS, Scree slopes; UM, undulating meadows. Values in parentheses represent number of transects.

Table 4. Population status (density/ha) of TMAPS: A comparative account

Species	Upper Gori valley[a]	Indian trans-Himalaya[b]	NDBR[c]	VOF[d]
A. stracheyi	4681.83	–	90000	–
C. carvi	934402.68	–	257	–
D. hatagirea	4756.1	161900	42000	10000
P. angelicoides	1545.4	–	283	–
B. stracheyi	11162.5	98500	–	8500
P. kurrooa	38972.83	70.6	–	45000
P. hexandrum	1937.5	25000	–	–
R. australe	1144.4	26600	–	2400
R. moorcroftianum	898.9	30900	–	–

[a]Present study (2001); [b]Kala[14]; [c]Maikhuri *et al.*[15]; [d]Kala *et al.*[4].

personal observations revealed that they earned Rs 60/kg for *P. kurrooa* to Rs 1500/kg for *A. heterophyllum*. Increased incentives and economic returns from the sale of TMAPS have made the collection of TMAPS as a specialized task. The period of collection has also increased from two months (August–September) to five months (May–September). People camp with their families in the wilderness to collect as much raw material as possible (Figure 5). As in most of the medicinal plants the rhizomes or roots are used, the entire plant was dug out. This has a negative effect on their biomass and regeneration in the wild. Besides, habitats of RDHP coincide with the grazing sites of sheep and goat, and hence overgrazing and overstocking have degraded their habitats at many places.

In Sikkim Himalaya, it has been reported that 6200 to 31000 kg of different TMAPS are extracted annually from the wild[19]. If similar trends exist in the present area, it is likely that the species with high market rates would decline more rapidly. According to an all-India trade survey of prioritized medicinal plant species, demands for some of these species have increased by 50%, whereas availability has declined by 26% (ref. 20). With such trends coming up, the status of these

Table 5. Available biomass (dry wt, kg/ha) of part used (in trade) in different habitats

Species	MR	DR	SS	GS	US	GL	SGS	UM	MM
A. benthamii	13.33 ± 13.33	78.13 ± 78.13	– –	26 ± 26	–	384.53 ± 278.24	664.29 ± 275.7	380 ± 185.43	–
B. stracheyi	–	1462.29 ± 1031.18	–	–	–	–	–	–	–
C. villosum	427.95 ± 148.1	–	–	–	–	154.8 ± 100.9	–	18 ± 12.6	NA
D. hatagirea	0.61 ± 0.53	–	–	4.9 ± 0.75	0.06 ± 0.06	0.3 ± 0.3	–	0.5 ± 0.3	100.51 ± 61.16
J. macrocephala	179.29 ± 136.1	–	–	–	118.84 ± 18.63	204.9 ± 139.4	343.21 ± 177.4	594 ± 369.34	27.83 ± 5.41
N. grandiflora	5.3 ± 2.6	117.75 ± 117.75	13.67 ± 7.17	–	–	–	–	0.27 ± 0.27	237.66 ± 143.55
P. angelicoides	–	–	–	105.2 ± 75.55	125.33 ± 95.74	–	–	6.38 ± 5.68	–
P. hexandrum	86.62 ± 86.62	211.75 ± 211.75	–	–	–	–	–	–	–
P. kurrooa	28.31 ± 19.88	–	20.39 ± 19.44	1.45 ± 1.45	23.61 ± 8.8	–	–	–	–
R. australe	202.86 ± 168.06	116.53 ± 111.6	56.09 ± 53.65	23.7 ± 15.8	553 ± 294	19.75 ± 12.25	468.36 ± 185.56	6.28 ± 4.4	–
R. moorcroftianum	18.75 ± 18.75	–	480 ± 82.18	–	7.5 ± 7.5	–	–	33.1 ± 33.1	–

Abbreviations are the same as given in Table 3.

Figure 4. ***a***, Extraction of TMAPS, and ***b***, Grazing, a threat to TMAPS.

Figure 5. Camping in alpine meadows for TMAPS extraction.

species would further worsen. Thus to conserve RDHP, species-specific conservation plots should be marked in the wild, and any extraction or exploitation from these plots should be banned.

A. benthamii, *R. australe*, *R. moorcroftianum* and *N. grandiflora* had restricted distribution and were extracted by local people in lesser quantities for self-consumption. Thus they are categorized as 'restricted distribution and low pressure' (RDLP) species. Though some of these species such as *N. grandiflora* and *A. benthamii* also have market value, it was observed that these were not much extracted in the present area and

therefore had a good population. The habitat of RDLP was also intact, as it is not easily accessible to livestock and people. For these species, spatial and temporal rotational harvesting should be promoted among the local people.

It was found that *B. stracheyi* and *P. hexandrum* had very patchy and localized distribution in their respective habitats. These were found at one or two locations only, and their extraction was very limited. Thus these were grouped under 'localized distribution and low pressure' (LDLP) category. Thus further explorations should be carried out to assess their status and distribution.

P. angelicoides was found mostly in the gaps within the alpine scrub and was extracted heavily by the local people for self-consumption; this seems to have affected its population in the wild (pers. obs.). Its habitat also overlapped with the grazing sites and was easily accessible to both livestock and human beings. Hence the species was categorized as 'restricted distribution and locally under high pressure' (RDLHP).

C. villosum was the only species which had a wide distribution range and also high pressure. Thus it was kept under the category 'wide distribution and high pressure' (WDHP). The species has a limited trade and was mostly extracted by the local people for self-consumption, as a subsidiary food.

In certain villages in the study area, viz. Laspa, Milam, Burfu and Ralam, local people have begun cultivation of *A. stracheyi* and *C. carvi*, and hence the pressure on the wild population is low. These species are therefore grouped in the 'under cultivation and low pressure' (UCLP) category. The cultivation efforts have yielded fruitful results in many parts of the Gori valley[21]. These should be promoted and propagated on a priority basis for all the species mentioned in the above three categories (RDLHP, WDHP and UCLP). Proper market should be developed for their disposal. Local people should be made aware of both *in situ* and *ex situ* conservation measures, which are essential to maintain the population status of TMAPS[22]. During the present survey it was found that certain locations, viz. Kwal Ganga, Laspa and Ralam in the upper Gori valley, harbour a vast diversity of TMAPS. These could be marked as control sites for future monitoring, to provide trends of population status and help in assessing the foreseeable future, keeping in view the present conditions[23]. The criterion developed here for the conservation of TMAPS at a local level and their habitat specificity should be kept in mind, when framing regional or global policies for their conservation.

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ACKNOWLEDGEMENTS. We thank the Director, Wildlife Institute of India for facilities. This study forms a part of WII-FES ongoing study on medicinal plants in Pithoragarh district. We are grateful to Chander da, Nayan da and villagers of Gori valley for their help and cooperation in the field. We also thank the unknown referee for his valuable suggestions and comments.

Received 27 November 2001; revised accepted 22 March 2002