Threat Assessment and Prioritization of High-Value Medicinal Plants In Pindari Valley, Nanda Devi Biosphere Reserve, India

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Abstract
The communication assesses the high-value medicinal plants reported in Pindari Valley, Nanda Devi Biosphere Reserve, Uttarakhand, using a score-based method for prioritization and conservation. A total of 42 high-value medicinal plants were assessed, prioritized and scored on the basis of rapid threat assessment. Maximum threat was recorded for Aconitum heterophyllum followed by Picrorhiza kurrooa and Nardostachys jatamansi given their limited number of individuals observed in the study area as well as high utilization patterns. Minimum threat status was recorded for Epilobium angustifolium, where the species was found in higher density in its natural habitat. Among the recorded species, 64% were observed growing in grassland/alpine pastures and open/alpine slopes. 55% of species were native/endemic to Himalaya and 48% were extracted by the inhabitants. Underground portions (roots/rhizomes/tubers) of 40% of the species were utilized leading to destruction in natural habitat. Out of 42 medicinal plants, 16 species have been prioritized for conservation and recognized in different threat categories and most of these species are collected from natural habitat without scientific knowledge. Conclusion of the study might helpful for identifying threatened plants in the region so as to initiate sustainable use and conservation practices of high-value medicinal plant resources.

Introduction
The mighty Himalaya contains a plenitude of medicinal plants and its habitants possess the knowledge of traditional medicinal plants. Indian Himalaya region (IHR) harbors about 1748 (23.4% of India) plant species recognized for their medicinal values. The higher diversity of medicinal plants in IHR is represented by the occurrence of...

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a variety of native (31%), endemic (15.5%) and threatened elements (14% of total Red Data Book plants of IHR). The need of medicinal plants is continuously increasing at local and global levels. Due to the high demand of medicinal plants in the Himalayan region, about 90% are collected from the wild and around 70% are unscientifically harvested/extracted from wild which enhances the loss on medicinal plant diversity.

Ever increasing demand of medicinal plants along with the habitat destruction, the world is experiencing the principal challenge of minimizing loss of biodiversity by conservation efforts. Further, few conservationists have tried prioritization of conservation efforts due to higher number of extinction rate. Number of medicinal plant species is now described under different threat categories and in the immediate future, many species may warrant the declaration of a threatened status until adequate scientific data are available. Therefore, the key challenge in the sustainability of medicinal plants is to synthesize the data on availability of medicinal plants and prioritization of certain species that require immediate conservation action.

A number of studies have been conducted on the utilization of medicinal plants in the IHR, viz, Dhar et al., Bisht et al., Kala, Maikhuri et al., Chandra Sekar and Srivastava, Chandra Sekar and Rawat, Negi et al., Bisht et al., Joshi and Chandra Sekar. However, the Pindari region is not having the data-set on diversity of medicinal plants, utilization and conservation efforts. In view of above, we studied the diversity of medicinal plants in Pindari Valley, a buffer zone region of Nanda Devi Biosphere Reserve, Uttarakhand.

**Objectives of The Study**

Keeping all the above in mind and the high use value and conservation importance of medicinal plants, the present attempt has been made to: (i) prepare an inventory of locally occurring medicinal plants through primary survey and secondary literature sources; (ii) identify and score the threatened and high-value medicinal plants (THMPs) based on their ecological (habitat, nativity, endemism and threat status) and socioeconomic values (plant part used, use value, user group and extraction trend); (iii) Prioritize the threatened high-value medicinal plants; (iv) suggest sustainable utilization and conservation strategies for the THMPs.

**Materials and Methods**

**Study Area**

Pindari Valley (a buffer zone of Nanda Devi Biosphere Reserve) is situated in the Bageshwar district of Uttarakhand, Western Himalaya (Figure 1). The total area of the Park is 339.39 km² at latitude 30°15’ N and longitude 79°13’ to 80°02’ E. It lies between the Nanda Devi and Nandakot peaks and the presence of glacier extends from 3600 to 5000 m. The Pindar Valley is named after the Pindar river which emerges from the Pindari Glacier. The valley remains completely covered with snow for six
months (early October to March). The entire valley has been considered for documentation of medicinal plant diversity. People traditionally collecting the medicinal plants from the valley resurveyed for recording the presence of medicinal plants. Further, the similar habitats nearby the traditional collection area were also surveyed for getting additional information on availability.

Questionnaire Survey/Interviews
A semi-structured questionnaire survey was conducted in two villages namely, Jaitoli and Khati of Pindari Valley in the years 2016-2018 (Figure 1). A total of 42 informants were selected randomly from 32 households for obtaining the utilization patterns. Further, the informants and Vaidyas (Medicine men) were also accompanied in the field for correct identification of particular plants, apart from house-hold interview. The complete information on medicinal plants, i.e., parts used and their habitat were collected. The information further cross checked with elderly people / Vaidyas repeatedly for confirming the utilization patterns.

An Approach for Rapid Threat Assessment (Rta) and Prioritization
For threat assessment, a list of Threatened and High-value Medicinal Plants (THMPs) was developed and rapid threat assessment (RTA) was carried out using Rapid Vulnerability Assessment method followed by Cunningham, and has been employed successfully by Shrestha and Shrestha and Pandey et al.

We followed an analytical method to prioritize the species of THMPs based on globally standardized criteria. To assess each species, we have used a total of seven ecological & socioeconomic criteria (i.e., habitat, plant part used, use value, user group, extraction trend, nativity, endemism and threat status). An appropriate numerical score ranging from 1 to 4 was assigned to each of these criteria (1 for low and 4 for high threat). The prioritized species were based on the sum of the scores assigned to each of these criteria (Table 1) as explained in Box 1.

Box 1. Criteria Used and their Detailed Explanation

Habitat
Habitat of the species was assessed on the basis of field observation during the field surveys and species were scored for the above mentioned four categories. Habitats like gravel, rocky and stony slopes are very fragile, species in these habitats were considered vulnerable to even the slightest human intervention and therefore scored at 4 (high threat). While, species in grasslands, alpine pastures and open/alpine slopes were ranked least vulnerable (score 1) as they have a large habitat range.

Plant Part Used
The plant part used means the part or parts of a specific species used for the treatment of diseases. The part of the plant used can influence the sustainability of a medicinal plant species and lead to a decrease in their population. For example, species having whole plant, root and/or rhizome with medicinal properties were prone to be more vulnerable while leaf bearing species as an essential part of the preparation of medicine were prone to be less vulnerable. Thus, plant part used was also scored (Table 1).

Use Value
The use value of a species related to the number of diseases for the treatment of which a specific medicinal plant species is being used. The use value defines the relative importance of the species in treating various diseases. A higher use value for a specific species was pointed to a higher collection pressure in natural areas of that plant species and therefore a higher degree of threat. Here, the medicinal uses were categorized into four classes and a different score was given to each class (Table 1).

User Group
Data on user groups of different medicinal plants were evaluated through interviews with local people/harvesters, traders, District Forest Officers and local authorities of Pindari Valley. These groups and their scores are tabulated in Table 1.

Extraction Trend
The extraction trend information was taken by interviewing the local people and Vaidyas of the study area. These scores are listed in Table 1.

Nativity and Endemism
Nativity and Endemism was assessed with the help of regional flora such as Flora of British India; Flora of the District Garhwal; Flora of Gangotri National
Various specialized online databases such as e-flora of China (www.efloras.org/browse.aspx?flora_id=2), e-flora of Pakistan (www.efloras.org/browse.aspx?flora_id=5), and Tropicos (www.tropicos.org) were consulted. During the present study, the threatened medicinal plant species were classified into four categories on the basis of the geographic scale. Consequently, different scores were assigned to each species (Table 1).

Table 1: Threat assessment criteria, categories and assigned scores for high-value medicinal plants of Pindari Valley (see Materials and methods for detailed explanation)

| S. No. | Criteria          | Category                                                                 | Score |
|--------|-------------------|--------------------------------------------------------------------------|-------|
| 1.     | Habitat           | (a)- Gravel/soil, boulder stony/rocky slopes                             | 4     |
|        |                   | (b)- Moist, marshy, shady, glacial moraine land                          | 3     |
|        |                   | (c)- Riverine, shrubberies, riverbeds                                    | 2     |
|        |                   | (d)- Grasslands/ alpine pastures, open/alpine slopes                     | 1     |
| 2.     | Parts used        | (a)- Whole plant (both underground and aerial portions)                  | 4     |
|        |                   | (b)- Underground portions (Roots/Rhizomes/tubers)                       | 3     |
|        |                   | (c)- Bark, stems, fruits, flowers, bulbs, seeds                          | 2     |
|        |                   | (d)- Leaves, resin, latex                                                | 1     |
| 3.     | Use value         | (a)- More than 6 uses                                                    | 4     |
|        |                   | (b)- 4-5 uses                                                            | 3     |
|        |                   | (c)- 2-3 uses                                                            | 2     |
|        |                   | (d)- 1 use                                                              | 1     |
| 4.     | User group        | (a)- Local people + local exchange + trade                              | 4     |
|        |                   | (b)- Local people + trade                                                | 3     |
|        |                   | (c)- Local people + local exchange                                      | 2     |
|        |                   | (d)- Local people                                                        | 1     |
| 5.     | Extraction trend  | (a)- Commercial + self                                                   | 4     |
|        |                   | (b)- Commercial                                                         | 2     |
|        |                   | (c)- Self-use                                                            |        |
|        |                   | (d)- No use                                                             |        |
| 6.     | Nativity/ Endemism| (a)- Native/endemic to India                                             | 4     |
|        |                   | (b)- Native/endemic to Himalaya                                         | 3     |
|        |                   | (c)- Native/endemic to Himalaya and surrounding countries               | 2     |
|        |                   | (d)- Cosmopolitan                                                       |        |
| 7.     | Threat status     | (a)- Status in 3 categories or more                                      | 3     |
|        |                   | (b)- Status in 2 categories                                              | 2     |
|        |                   | (c)- Status in 1 category                                               | 1     |
|        |                   | (d)- Not assigned                                                       | 0     |

To get the final score, a complete list was created and the values of the relevant categories of each species were represented. The species were categorized into four threat categories as shown below (category I representing the most threatened and category IV the least threatened category) on the basis of the final score. For prioritization we used only three categories (Category I, II, & III) for developing effective conservation priorities.

Threat category I ≥28
Threat category II 20–24
Threat category III 15–19
Threat category IV <15

Results
In the present study 42 species of High-value Medicinal Plants (HMPs) were documented on the basis of survey, ethnobotanical utilization and trade / market value (Table 2, Figure 2). Identified HMPs belong to 37 genera and 24 families. *Asteraceae* and *Ranunculaceae* are represented by 05 species each; *Polygonaceae* by 04 species; *Apiaceae*, *Boraginaceae*, *Rosaceae*, *Primulaceae*, *Orchidaceae*, *Papaveraceae*, *Melanthiaceae* by 02 species each; whereas single species represented *Amaryllidaceae*, *Balsaminaceae*, *Berberidaceae*, *Caprifoliaceae*, *Ericaceae*, *Caryophyllaceae*, *Gentianaceae*, *Lamiaceae*, *Liliaceae*, *Violaceae*, *Plantaginaceae*, *Onagraceae* and *Orobanchaceae* (Table 2).

| S. No. | Plant species                     | Family           | Habitat          | Endemic                  | Threat Status | No. of used parts | Parts used |
|--------|-----------------------------------|------------------|------------------|--------------------------|---------------|-------------------|------------|
| 1.     | *Aconitum heterophyllum* Wall. ex Royle | Ranunculaceae     | Rocky slopes     | Native/ endemic to Himalaya | NA            | CR    | EN    | NA    | 6 Wp, Rt |
| 2.     | *Aconitum violaceum* Jacq. ex Stapf | Ranunculaceae     | Open alpine slopes | Native/ endemic to Himalaya | NA            | VU    | VU    | NA    | 5 Wp, Rt |
| 3.     | *Allium humile* Kunth             | Amaryllidaceae    | Open alpine slopes | Native/ endemic to Himalaya | NA            | NA    | NA    | NA    | 1 Lf     |
| 4.     | *Anaphalis contorta* (D. Don). Hook. f | Asteraceae       | Grasslands      | Native/ endemic to Himalaya and surrounding countries | NA            | NA    | NA    | NA    | 1 Fl     |
| 5.     | *Anaphalis triplinervis* (Sims) C.B. Clarke | Asteraceae       | Grasslands      | Native/ endemic to Himalaya and surrounding countries | NA            | NA    | NA    | NA    | 1 Fl     |
| 6.     | *Androsace sarmentosa* Wall.      | Primulaceae       | Grasslands      | Native/ endemic to Himalaya | NA            | NA    | NA    | NA    | 1 Lf     |
| 7.     | *Anemone obtusiloba* D. Don       | Ranunculaceae     | Grasslands      | Native/ endemic to Himalaya and surrounding countries | NA            | NA    | NA    | NA    | 1 Rt     |
| 8.     | *Anemone rivularis* Buch.-Ham. ex DC. | Ranunculaceae     | Grasslands      | Native/ endemic to Himalaya and surrounding countries | NA            | NA    | NA    | NA    | 1 Rt     |
| 9.     | *Angelica glauca* Edgew.          | Apiaceae          | Rocky slopes    | Native/ endemic to Himalaya | NA            | EN    | EN    | NA    | 1 Rt     |
| 10.    | *Arnebia benthamii* (Wall. ex G. Don) I.M. Johnst. | Boraginaceae   | Rocky slopes    | Native/ endemic to Himalaya and surrounding countries | NA            | CR    | NA    | NA    | 4 Rt     |
| 11.    | *Bistorta affinis* (D. Don) Greene | Polygonaceae      | Grasslands      | Native/ endemic to Himalaya and surrounding countries | NA            | NA    | NA    | NA    | 1 Rt     |
| 12.    | *Corydalis cashmeriana* Royle     | Papaveraceae      | Open alpine slopes | Native/ endemic to Himalaya and surrounding countries | NA            | NA    | NA    | NA    | 2 Rt     |
| No. | Species Name                  | Family            | Habitat Description                                                                 | Conservation Status | Distribution | Number | Genera | Infra-genera | Status  |
|-----|--------------------------------|-------------------|---------------------------------------------------------------------------------------|---------------------|-------------|--------|--------|-------------|---------|
| 13  | Cynoglossum nervosum          | Boraginaceae      | Alpine pastures native/ endemic to Himalaya                                          | NA                  | NA          | NA     | NA     | NA          | 2       |
| 14  | Dactylorhiza hastagarea       | Orchidaceae       | Moist, shady areas native/endemic to Himalaya and surrounding countries              | NA                  | CR          | NA     | NA     | II          | 5       |
| 15  | Epilobium angustifolium L.    | Onagraceae        | Grasslands cosmopolitan native/ endemic to Himalaya and surrounding countries        | NA                  | NA          | NA     | NA     | 1           | Lf      |
| 16  | Fritillaria roylei Hook.      | Liliaceae         | Alpine boulders native/ endemic to Himalaya                                          | NA                  | EN          | NA     | NA     | NA          | 3       |
| 17  | Gaultheria trichophylla       | Ericaceae         | Alpine pastures native/endemic to Himalaya and surrounding countries                 | NA                  | NA          | NA     | NA     | 1           | Fr      |
| 18  | Gentiana stipitata Edgew.     | Gentianaceae      | Stony slopes native/ endemic to Himalaya                                             | NA                  | NA          | NA     | NA     | 1           | Rt      |
| 19  | Impatiens sulcata Wall ex Benth. | Balsaminaceae | Alpine pastures native/ endemic to Himalaya                                          | NA                  | NA          | NA     | NA     | 2           | Fl      |
| 20  | Jurinea dolomiae Boiss.       | Asteraceae        | Rock crevices native/ endemic to Himalaya                                            | NA                  | EN          | NA     | NA     | 3           | Rt      |
| 21  | Malaxis muscifera (Lindl.) Kuntze | Orchidaceae     | Shady-moist areas native/ endemic to India                                           | NA                  | EN          | VU     | NA     | 3           | Rt      |
| 22  | Meconopsis aculeata Royle     | Papaveraceae      | Rock crevices & alpine boulders native/ endemic to Himalaya                          | NA                  | EN          | NA     | NA     | 3           | Fl      |
| 23  | Nardostachys jatamansi. (D. Don) DC | Caprifoliaceae | Rocky slopes native/ endemic to Himalaya                                           | VU                  | CR          | CR     | NA     | 2           | Rt      |
| 24  | Oxyria digyna (L.) Hill.      | Polygonaceae      | Open alpine slopes native/ endemic to Himalaya                                      | NA                  | NA          | NA     | NA     | 2           | Lf      |
| 25  | Paris polyphylla Smith        | Melanthiaceae     | Moist shady areas native/ endemic to Himalaya                                       | NA                  | EN          | NA     | NA     | 5           | Wp      |
| 26  | Pedicularis hoffmeisteri Klutz. | Scrophula -riaceae | Grasslands native/ endemic to Himalaya                                             | NA                  | NA          | NA     | NA     | 2           | Rt      |
| 27  | Pedicularis pectinata Wall. ex Benth. | Orobanchaceae | Grasslands native/ endemic to Himalaya                                             | NA                  | NA          | NA     | NA     | 1           | Lf      |
| 28  | Persicaria polystachya (Wall. ex Meisn) Gross | Polygonaceae | Grasslands native/ endemic to Himalaya and surrounding countries                | NA                  | NA          | NA     | NA     | 1           | Lf      |
| 29  | Picrorhiza kurrooa Royle ex Benth. | Plantaginaceae | Alpine boulders native/ endemic to Himalaya                                       | VU                  | CR          | NA     | II     | 4           | Rt      |
| 30  | Potentilla atrosanguinea Lodd  | Rosaceae          | Grasslands native/ endemic to Himalaya and surrounding countries                  | NA                  | NA          | NA     | NA     | 1           | Lf      |
| No. | Species                        | Family         | Habitat         | Status            | Part Used | Trade Value and Harvesting of THMPs |
|-----|--------------------------------|----------------|-----------------|-------------------|-----------|-------------------------------------|
| 31. | *Potentilla cuneata* Wall. ex Lehmann | Rosaceae       | Grasslands      | Native/endemic to Himalaya | Lf        | Cost up to Rs. 5000 per Kg. |
| 32. | *Primula macrophylla* D. Don     | Primulaceae    | Open slopes     | Native/endemic to Himalaya and surrounding countries | Lf        | Cost of approximately Rs 3600 per Kg. |
| 33. | *Ranunculus hirtellus* Royle     | Ranunculaceae  | Grasslands      | Native/endemic to Himalaya | Wp        | Cost of Rs 4500 per Kg. |
| 34. | *Rheum australe* D. Don          | Polygonaceae   | Open slopes     | Native/endemic to Himalaya | Rt        | Cost of Rs 3600 per Kg. |
| 35. | *Selenium elatum* (Edgew.) Hiroe | Apiaceae       | Open slopes     | Native/endemic to Himalaya | Lf        | Cost of Rs 2500-3000 per Kg. |
| 36. | *Silene vulgaris* (Moench) Garcke | Caryophyllaceae | Grasslands      | Native/endemic to Himalaya and surrounding countries | Fl        | Cost of Rs 2200 per Kg. |
| 37. | *Sinopodophyllum hexandrum* T.S. Ying | Berberidaceae  | Moist-shady areas | Native/endemic to Himalaya | Rt        | Cost of Rs 2200 per Kg. |
| 38. | *Tanacetum dolichophyllum* Kitam. | Asteraceae     | Open slopes     | Native/endemic to Himalaya | Fl        | Cost of Rs 2200 per Kg. |
| 39. | *Taraxacum officinale* Weber     | Asteraceae     | Open slopes     | Cosmopolitan       | Rt        | Cost of Rs 2200 per Kg. |
| 40. | *Thymus linearis* Benth         | Lamiaceae      | Grasslands      | Native/endemic to Himalaya | Sd        | Cost of Rs 2200 per Kg. |
| 41. | *Trillium govanianum* Wall. ex D. Don | Melanthiaceae | Alpine boulders | Native/endemic to Himalaya | Fr        | Cost of Rs 2200 per Kg. |
| 42. | *Viola pilosa* Blume             | Violaceae      | Moist, shady areas | Native/endemic to Himalaya and surrounding countries | Lf        | Cost of Rs 2200 per Kg. |

**Abbreviations**

**Threat Status:** CR= Critically Endangered; EN= Endangered; LC= Least Concern; VU= Vulnerable; NT= Near Threatened; NA= Not Evaluated; CAMP= Conservation Assessment and Management Plan; CITES= Convention on International Trade in Endangered Species; IUCN= International Union for Conservation of Nature; RDB= Red Data Book.

**Plant parts used:** Wp= Whole plant; Rt= Root, Lf= leaf; Fl= Flower; Fr= Fruit; Sd= Seed; Tu= Tuber.

**Trade Value and Harvesting of THMPs**

Sixteen species of THMPs are traded actively in the study area and *Aconitum heterophyllum* was recorded to be the highest with a cost up to Rs. 5000 per Kg. *Picrorhiza kurrooa* was the second highest traded species in the study area with a cost of about Rs. 4500 per Kg. Similarly, both *Dactylorhiza hatagirea* and *Paris polyphylla* were traded at the cost of approximately Rs 3600 per Kg. Few important species like, *Angelica glauca* fetched about Rs 2500-3000 per Kg and *Trillium govanianum* was sold at a price about Rs 2200 per Kg.

**Rapid Threat Assessment**

As per the Rapid Threat Assessment Score system opted in the study, the maximum aggregate score
recorded for *Aconitum heterophyllum* (25) clearly indicate the highest threat categorization because of high extraction pressure, maximum number of uses and whole plant being used to treat various diseases and ailments in the study area. This was followed by *Picrorhiza kurrooa* with score 24, *Nardostachys jatamansi* with score of 23 and the four species *Dactylorhiza hatagirea*, *Angelica glauca*, *Sinopodophyllum hexandrum*, *Malaxis muscifera* the score of 21 each. *Epilobium angustifolium* scored the minimum (06) and can be considered as least threatened plant due to facing minimum extraction pressure and used to treat few diseases among the medicinal plants of Pindari Valley (Table 3). Out of the total recorded HMPs, 16 plant species were categorized under different threat categories of CAMP; 06 species are under IUCN; 03 species (*P. kurrooa, D. hatagirea, S. hexandrum*) are in the CITES (Appendix II) and 02 species (*P. kurrooa and N. jatamansi*) are in RDB (Table 2). Moreover, among the HMPs one species i.e., *Aconitum heterophyllum* was placed under the threat category I, whereas 08 species fell into threat category II, 07 species listed under threat category III and remaining 26 species were placed under least threat category IV (Table 3).

### Table 3: Scores for high-valued medicinal plants

| S. No. | Plant species                  | Score (Habitat) | Score (Threat Status) | Score (Endemic) | Score (Use value) | Score (Parts used) | Score (User Group) | Score (Extraction trend) | Total Score | Threat Category |
|--------|--------------------------------|-----------------|-----------------------|-----------------|-------------------|-------------------|---------------------|-------------------------|-------------|-----------------|
| 1.     | *Aconitum heterophyllum* Wall. ex Royle | 4               | 3                     | 2               | 4                 | 4                 | 4                   | 4                       | 25          | I               |
| 2.     | *Picrorhiza kurrooa* Royle ex Benth. | 4               | 3                     | 3               | 3                 | 3                 | 4                   | 4                       | 24          | II              |
| 3.     | *Nardostachys jatamansi* (D. Don) DC | 4               | 3                     | 3               | 2                 | 3                 | 4                   | 4                       | 23          | II              |
| 4.     | *Dactylorhiza hatagirea* (D. Don) Soo | 3               | 2                     | 2               | 3                 | 4                 | 4                   | 3                       | 21          | II              |
| 5.     | *Angelica glauca* Edgew.          | 3               | 3                     | 3               | 2                 | 1                 | 3                   | 4                       | 21          | II              |
| 6.     | *Sinopodophyllum hexan-drum* (Royle) T.S. Ying | 3               | 3                     | 3               | 3                 | 3                 | 4                   | 3                       | 21          | II              |
| 7.     | *Malaxis muscifera* (Lindl.) Kuntze | 3               | 4                     | 2               | 2                 | 3                 | 3                 | 4                       | 21          | II              |
| 8.     | *Paris polyphylla* Smith          | 3               | 2                     | 1               | 3                 | 4                 | 4                   | 3                       | 20          | II              |
| 9.     | *Jurinea dolomiae* Boiss.         | 4               | 3                     | 1               | 2                 | 3                 | 3                 | 4                       | 20          | II              |
| 10.    | *Arnebia benthamii* (Wall. ex G. Don) I.M. Johnst. | 4               | 2                     | 1               | 3                 | 3                 | 3                 | 3                       | 19          | III             |
| 11.    | *Fritillaria roylei* Hook.        | 4               | 3                     | 1               | 2                 | 3                 | 3                 | 3                       | 19          | III             |
| 12.    | *Aconitum violaceum* Jacq. ex Stapf | 3               | 3                     | 2               | 3                 | 4                 | 2                   | 2                       | 17          | III             |
| 13.    | *Meconopsis aculeata* Royle, Wall. ex D. Don | 4               | 3                     | 1               | 2                 | 2                 | 2                 | 2                       | 16          | III             |
| 14.    | *Trillium govanianum* Wall. ex D. Don | 4               | 3                     | 0               | 2                 | 2                 | 2                 | 3                       | 16          | III             |
| 15.    | *Thymus linearis* Benth.          | 1               | 3                     | 0               | 3                 | 2                 | 3                 | 4                       | 16          | III             |
| 16.    | *Rheum australe* D. Don           | 1               | 3                     | 1               | 3                 | 3                 | 2                 | 2                       | 15          | III             |
| 17.    | *Gentiana stipitata* Edgew.       | 4               | 3                     | 0               | 1                 | 3                 | 1                 | 1                       | 13          | IV              |
| 18.    | *Oxypria digyna* (L.) Hill.       | 1               | 3                     | 0               | 2                 | 1                 | 2                 | 2                       | 11          | IV              |
| 19.    | *Viola pilosa* Blume              | 3               | 2                     | 0               | 1                 | 1                 | 2                 | 2                       | 11          | IV              |
| 20.    | *Cynoglossum nervosum* Benth.     | 1               | 3                     | 0               | 2                 | 3                 | 1                 | 1                       | 11          | IV              |
| 21.    | *Pedicularis hoffmeisteri* Klotz. | 1               | 3                     | 0               | 2                 | 3                 | 1                 | 1                       | 11          | IV              |
| 22.    | *Ranunculus hirtellus* Royle      | 1               | 3                     | 0               | 1                 | 4                 | 1                 | 1                       | 11          | IV              |
23. Bistorta affinis (D. Don) Greene 1 2 0 1 3 2 2 2 11 IV
24. Allium humile Kunth 1 3 0 1 1 2 2 2 10 IV
25. Gaultheria trichophylla Royle 1 2 0 1 2 2 2 10 IV
26. Corydalis cavanatica Royle 1 2 0 2 3 1 1 10 IV
27. Tanacetum dolichophyllum (Kitam.) Kitam. 1 3 0 2 2 1 1 10 IV
28. Taraxacum officinale Weber 1 1 0 3 3 1 1 1 10 IV
29. Impatiens sulcata Wall. 1 3 0 2 2 1 1 1 10 IV
30. Silene vulgaris (Moench) Garcke 1 2 1 2 2 1 1 10 IV
31. Anemone obtusiloba D. Don 1 2 0 1 3 1 1 1 9 IV
32. Anemone rivularis Buch. -Ham. ex DC. 1 2 0 1 3 1 1 1 9 IV
33. Androsace sarmentosa Wall. 1 3 0 1 1 2 1 9 IV
34. Selinum elatum (Edgew.) Hiroe 1 3 0 2 2 1 1 1 9 IV
35. Anaphalis triplinervis (Sims) Sims ex C.B. Clarke 1 2 0 1 2 2 1 1 8 IV
36. Anaphalis contorta (D. Don) Hook. f. 1 2 0 1 2 1 1 8 IV
37. Potentilla cuneata Wall. ex Leh. 1 3 0 1 1 1 1 1 8 IV
38. Potentilla atrorubens Lodd 1 2 0 1 1 1 2 2 8 IV
39. Pedicularis pectinata Wall. ex Benth. 1 2 0 1 1 1 1 1 7 IV
40. Persicaria polystachya (Wall. ex Meisn) Gross 1 2 0 1 1 1 7 IV
41. Primula macrophylla D. Don 1 2 0 1 1 1 1 7 IV
42. Epilobium angustifolium L. 1 1 0 1 1 1 1 6 IV

The threat assessment reported that 64% of the HMPs of Pindari Valley grow in grasslands/alpine pastures, open/alpine slopes while 55% HMPs are native/endemic to Himalaya (Figure 3). In present study area, 48% of these HMPs are harvested by local people (Figure 3). For the preparation of medicines, different parts of HMPs are used (i.e., roots, rhizomes, inflorescences, leaves, bulbs, fruits and tubers) (Table 2). It is obvious that 40% plants utilized the underground portions (e.g., roots, rhizomes, tubers) may harm the life cycle. Further, 12% plant used as whole plants (in combination of both above and below ground portions) for different medicinal purposes, also affects the life of plant. The remaining 48% plants exploited for leaves, seeds, flower, etc. and can be considered sustainable. Around 64% plants are categorized in Least Concern category, but 5% plants have considered in Critically Endangered category (Figure 3).

Prioritisation of THMPs
Based on seven selected categories of Rapid Threat Assessment (RTA), such as habitat, plant used,
use value, user group, extraction trend, nativity/endemism, threat status, a total of 16 plant species were identified and placed in three categories on the basis of their cumulative score (Figure 4).

Different parts of HMPs (i.e., roots, rhizomes, inflorescences, leaves, flowers, fruits, and tubers) are used for the preparation of medicines (Table 2).

It is obvious that 40% plants utilized the underground portions (e.g., *Aconitum heterophyllum*) fell under the most threatened category i.e., I. The species
under category II of threat having higher scores were *P. kurrooa*, *N. jatamansi*, *D. hatagirea*, *A. glauca*, *S. hexandrum*, *M. muscifera*, *P. polyphylla* and *J. dolomiaeae*. The species under threat category III were *A. benhamii*, *F. roylei*, *A. violaceum*, *M. aculeata*, *T. govanianum*, *T. linearis* and *R. australae*.

**Discussion**

This study revealed extensive information on the high use value of medicinal plants for the first time coupled with information on the level of threat, available conservation initiatives and prioritization based on importance of THMPs in the Pindari valley. Further, it exposes the therapeutic potential of 42 plant species having high potentials to cure different diseases. Among these enumerated plants, 54% (23 plants) were collected as whole plants or their underground parts extracted from the wild for use in herbal medicines and possess immense threat to natural vegetation.38,37 Nine of these species, viz. *Aconitum heterophyllum*, *Arnebia benthamii*, *Angelica glauca*, *Dactylorhiza hatagirea*, *Fritillaria roylei*, *Meconopsis aculeata*, *Picrorhiza kurrooa*, *Sinopodophyllum hexandrum*, and *Thymus linearis* have been already prioritized for conservation in the Indian Himalayan State of Uttarakhand,22,28 and two species namely, *Aconitum violaceum* and *Angelica glauca* were categorized in IUCN categories. It is noticeable that 55% of the total prioritized species are native/endemic to Himalaya and 2% species are native/endemic to India. Due to the limited information on these endemic and threatened plants, the conservationists put more attention to authentic documentation, assessment and sustainable utilization towards conservation.38

The continuous increasing demand for these species in the pharmaceutical industries has been known from other regions of Himalaya and resulted depletion of wild resources.32,28 If the same situation like overexploitation proceeds, many species may reduce and eventually disappear from, their natural habitats. This especially applies to medicinal plants found in alpine Himalaya with multiple uses.39,40 Some very prominent medicinal plants in this region namely, *Aconitum heterophyllum*, *Angelica glauca*, *Dactylorhiza hatagirea*, *Malaxis muscifera*, *Paris polyphylla* and *Picrorhiza kurrooa* are already declining in population38 in mountain regions.1,16,40,41,42,43,44,45,46,47,48

As per the present threat categorization, *Aconitum heterophyllum* is the most threatened species which is falling under threat category I. It is one of the most preferred species of the region, possess high medicinal use39,45 as well as trade value.49 Thus, the harvesting pressure is predominant threat factors for the species of category I. Further, the species under threat category II having higher scores were *Picrorhiza kurrooa*, *Nardostachys jatamansi*, *Dactylorhiza hatagirea*, *Angelica glauca*, and *Sinopodophyllum hexandrum*. All these species are preferred not only by residents of the Pindari Valley but also in other parts of Himalayas.24,25 Although some of these species are prohibited for collection, besides of this local people are totally dependent on these medicinal plants due to lack of the healthcare facility in the higher altitude region. All these five species under category II are extracted for their underground parts and are sometimes harvested without leaving any remains of whole plant due to unavailability of scientific knowledge, which prevents further regeneration.21 Hence, the species of category II mainly suffer from unscientific harvesting for frequently utilization by locals. In third category (category III) recorded by *Arnebia benthamii*, *Fritillaria roylei*, *Aconitum violaceum*, *Meconopsis aculeata*, *Trillium govanianum*, *Thymus linearis* and *Rheum australe* are identified as a least threatened species in the study area, in view of less demand in market as well as local level.

The results of this study could direct the local government and stakeholders in determining which species should be targeted at conservation. Nearly two-thirds of the existing priority species in this part of the world have not been evaluated in compliance with IUCN guidelines and therefore deserve urgent conservation assessment.50,51,52 Further, awareness on medicinal plants and conservation education to the local people needs to be provided for better understanding and sustainable utilization of these high-value medicinal plants.

**Conclusion**

The study revealed a total of 42 high-value medicinal plant species based on rapid threat assessment. Outcomes of the study suggested: (i) *Aconitum heterophyllum* with the highest score indicates that this species confronts the highest degree of threat among all the species. (ii) the
study concluded that the demand of species, like *Aconitum heterophyllum*, *Angelica glauca*, *Dactylorhiza hatagirea*, *Nardostachys jatamansi*, *Sinopodophyllum hexandrum* and *Paris polyphylla* were high for various therapeutic purpose as well as trade value and needs major prioritization and conservation attention. (iii) providing awareness is an important tool for conservation as proper awareness among the local people is highly required. The threatened species can be promoted through cultivation in local village area for household utilization may also reduce some pressure from wild. Further, the advance scientific techniques by using biotechnology can also be substituted for mass propagation and plantation in natural habitat for conservation. This study is an initial attempt to identify the endangered plant species, as also to draw the attention of conservation biologists, policymakers and researchers to implement conservation measures for these highly valuable plants.

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**Conflict of Interest**

The authors do not have any conflict of interest.

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