Assessment of Structure and Composition of Vegetation in and around a Hydroelectric Project Area in Alaknanda Valley of Western Himalaya, India.

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Abstract
The present study assessed the structure and composition of vegetation in and around the Vishnugad-Pipalkoti hydroelectric project area and identified the impacts of proposed hydroelectric project on floral biodiversity. The study was carried out in six sites. Out of selected sites, four study sites various project construction activities viz. dam, power house, adits, roads and colony etc. were proposed. The rest two sites were situated in the influence and catchment area of project. Stratified random sampling method was adopted for field survey using various sizes of quadrats for different vegetation layers. Maximum number of species was recorded at project adit site (53 spp.) and minimum number of species was observed at tail race channel (TRC) of project (36 spp.). The total tree density varied from 440 plants/ha to 810 plants/ha and value of the total tree basal area ranged between 18.38 to 35.11 m²ha⁻¹ in the study sites. Maximum tree density of 240 plants/ha with a total basal cover of 14.40 m²/ha was recorded for Pinus roxburghii species. The total density of shrub layer was recorded between 3200 (plants/ha) to 5440 (plants/ha). A well-developed herb layer recorded in the present study. Species diversity was observed higher at sites situated far from human habitation and lower at sites situated near villages due anthropogenic pressure. ANOVA analysis revealed significant differences in Shannon-wiener diversity index (F= 16.88, p<0.01) and Simpson diversity index (F= 9.42, p<0.01) for all vegetation layers in the study sites. Diversity index (H') ranged from 1.33 to 2.34 for tree layer, from 2.20 to 2.68 for shrub layer and for herb layer between 2.64 to 3.11.Hydropower project development will create some direct and indirect impact on floral diversity in the study sites. Sound implementations of forest management and protections measures are urgently required for the conservation of vegetation wealth of the region.

Keywords: Himalaya, hydropower, floral biodiversity, conservation, sustainable development

Introduction
Forests are biologically diverse systems, representing some of the richest biological areas on planet. They offer a variety of goods and services and play an important role in economy of the nations (CBD). As per World Bank estimates, more than 1.6 billion people depend on forests for their livelihoods worldwide. Forest degradation and loss of biodiversity as a result of deforestation, fragmentation, climate change and excessive anthropogenic pressures have caused much concern among the conservationists in the recent years. Forests are also being degraded and fragmented rapidly in the Himalayan region (Singh 2006). The Indian Himalayan Region (IHR) spread from Arunachal Pradesh state in the east to Jammu and Kashmir state in the west covering 5,33,604 km² geographical area (16.2% of India’s geographical area), holds a special place in the mountain ecosystem of the world (Anon. 2006). The forest of IHR supports nearly 50% of the total flowering plants of which 30% are endemic to the region (Khosshoo 1992). The occurrence of 21 forest types due to wide elevational range, rainfall and topographic gradients throughout the Himalayan range is in itself an indication of diverse habitats (Champion & Seth1968). The Himalayan vegetation shows remarkable variation from tropical dry deciduous forests in the foothills to alpine meadows above the timberline (Singh & Singh 1992). Review of existing floral biodiversity information of IHR reveals that there are approximately 18,440 plant species (Singh & Hajra 1996) out of which 1748 medicinal plants (Samant et al. 1998), 675 wild edibles (Samant & Dhar 1997), 279 fodder species (Samant 1998), 155 sacred plants (Samant & Pant 2003), 118 essential oil plants with medicinal values (Samant & Palni 2001).

In addition to rich and unique biological elements of IHR, it is blessed with vast water resources. The IHR is known as a ‘water tower of the earth’ and provides water to a larger part of the Indian subcontinent. Approximately 10–20% of the area is covered by glaciers, while 30–40% remains under seasonal snow cover varying from 0.48±0.43 to 2.20±1.25 million km² (Bahadur 2004). Keeping in view...
the rich water potential in the IHR, Government of India (GOI) has commenced hydropower development for rapid socio-economic development of the country, to cater domestic energy demand and to reduce rapidly growing greenhouse gases. GOI aims to construct 292 dams throughout the Indian Himalaya over the next several decades (Grumbine & Pandit 2013).

Researchers have observed that development of hydropower power projects create profound complex, varied, and multiple impacts on ecosystems worldwide (Goldsmith & Hildyard 1984). As per Pandit and Grumbine (2012) assessment nearly 90% of Indian Himalayan valleys would be affected by dam building and 27% of these dams would affect dense forests. Forest loss due to direct submergence and habitat degradation from dam building could lead to loss of 22 angiosperm and 7 vertebrate taxa by 2025 in the IHR. Hydropower projects directly affects the structure and composition of vegetation of a region particularly due to submergence of forest area (Balakrishnan & Abraham 1988, Singh et al.2011; Grumbine & Pandit, 2013), alteration of river flow (Nilsson et al. 1997, Quinn et al. 2005; Rajvanshiet al. 2012), road construction (Kanwal & Joshi 2010, Panwar et al. 2010), muck disposal (Sharma et al. 2007) and various other allied construction activities. Economically important and ethnobotanical plants species are also affected from hydropower development (Awasthi et al. 1999, Dixit & Greevan 2000, Samant et al. 2007, Kanwal & Joshi 2011, Sigdelet al. 2013, Kanwal & Joshi 2015).

Uttarakhand state is one of the prominent states of IHR. It occupies 53,483 km² geographical area which constitutes 1.63% of the land area of the country (Anon. 2011). Uttarakhand state is well known for its rich natural resources and varied ecosystems types. This state uniquely endowed with glaciers and rain fed monsoon rivers following the natural incline/gradient has good hydro power potential and is thus recognized as a future Energy State (Joshi 2007). The total identified hydropower potential of the state is about 18,175 MW out of which only 3426.4 MW (19.04%) has been harnessed so far, 1640 MW (9.11%) is in the different stages of development and about 12931.70 MW (71.85%) hydropower potential is yet to be developed (Anon. 2014). The state is also endowed with a rich array of forest types from tropical to alpine. The recorded forest area of the Uttarakhand is about 34,651 km², which constitutes 64.79% of the state’s geographical area (FSI 2011). These forests can be further categorized into reserved forests (68.74%), protected forests (0.36%) and unclassed forest (30.9%).

Forest play very essential role in day to day life of dependent communities. However, in the recent couple of years excessive exploitation of forest resources, unplanned land use, natural disasters and several developmental processes have accelerated deterioration of forest and biodiversity of this Himalayan state (Kanwal & Joshi 2010). Impacts of hydropower development on structure and composition of vegetation in Indian subcontinent remain largely unknown (Panwar et al. 2010). In the absence of information on existing biological diversity and assessment of anthropogenic pressures the management agencies are unable to take any action towards long term conservation. Therefore, documentation on current habitat structure and resource distribution and richness is necessary to estimate their loss (Singh et al. 2011). Keeping in view the development of hydropower projects in Himalayan region and their likely impact on forest and plant biodiversity, the present study was carried out in the Vishnugad-Pipalkoti area of Chamoli district of Uttarakhand State. The aim of present study is to document the structure and composition of vegetation and to evaluate the impacts of Vishnugad-Pipalkoti Hydroelectric project on vegetation of the area.

Materials and Methods

Study area

The Vishnugad-Pipalkotiarea is situated in Alaknanda Valley of Chamoli district of Uttarakhand state. The study area is lies between 30° 30’ 50” to 30° 25’ 31”N and 79° 29’ 30” to 79° 24’ 56”E in Chamoli district (Figure 1). The Vishnugad-Pipalkoti area represents the eastern part of the Garhwal Himalaya. The area has highly diversified ecological region, and covers a wide range of climatic conditions under altitudinal variation. The river Alaknanda is a major tributary of the holy river Ganges. It originates at an elevation of 3641 masl from Alakpuri glacier (Bhagirath Kharak and Satopanth) and confluence with Bhagirath at Devprayag and flows as the Ganga (Agarwal et al.2010). M/s Tehri Hydro Development Corporation India Limited (THDCIL) is developing Vishnugad-Pipalkoti Hydroelectric Project (VPHEP) on river Alaknanda in Chamoli District (EIA 2007). The Vishnugad-Pipalkoti Hydro Electric Project (VPHEP) has been designed as a 444 MW (4 x 111), run-of-river water diversion scheme. The project has been involved construction of a 65 m high diversion dam across river Alaknanda river, near Helong village (30°30’50”N and 79°29’30”E).

The climate of the project area can be divided into four main seasons i.e. winter ranging season from December to February followed by pre-monsoon or mild summer season from March to May. The Temperature in the area varies with elevation. It rises rapidly after March and the month of July is the hottest month of the year with mean daily maximum temperature going up to 27-28°C. The months of December and January are the coolest months of the year, with mean daily minimum temperature as low as 4 to 5°C. The average annual rainfall is about 125 c.m. per annum. The maximum rainfall is received in the months of July and August. On an average, there are about 88 rainy days (i.e. days with rainfall of 2.5 mm) in a year. The average ‘humidity’ is about 61% Apart from the monsoon months, humidity is around 50-55% throughout the year. The soil of study area is sily to clayey loam and is very fertile. In the forest margins the soil are stony, completely immature and extremely poor. The forest cover of the Chamoli district is about 2695 km², out of which 427 km² is very dense forest, 1586 km² is moderately dense forest and 682 km² is open forest (FSI Report, 2009). The major forest types occur in the study area are Tropical dry deciduous, Subtropical Pine, Subtropical dry evergreen, Himalayan moist

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temperate, Himalayan dry temperate, Sub-alpine and Alpine forests. These forests are primary livelihood source for the rural population and source of fresh water for both urban and rural population.

Fig 1: Location map of Vishnugad-Pipalkoti Hydroelectric Project Area

Methodology

As suggested by Beanlands and Duinker (1984), before undertaking the biodiversity and ecological impact assessment, it was essential to define the boundaries of the extent of impacts of the project. Since the boundaries define extent of the influence of the developmental activity, they also establish the limits of the cause-effect relationships. The boundaries considered in VPHE project were the directly impacted area (DIA) or project affected area, the influence area and the free draining catchment area. The area to be directly affected by project development was taken as the directly impacted area. It was an area within 1km all around the various project units and constructions sites. The influence zone was the area within a 10 km radius from the periphery of reservoir and other appendances of the project. The catchment area between the proposed dam site to the next proposed dam site in the upstream was considered as the free draining catchment area. The study was conducted in the project area since July 2007 and March 2010 during different seasons.

After thorough reconnaissance survey, six sites were identified for vegetation sampling in study area. Out of selected sites, four study sites various project construction activities viz. dam, power house, adits, roads and colony etc. were proposed. The rest two sites were situated in the influence and catchment area of project. Site I, Site II, Site III, Site IV were located near tail race channel (TRC) of project near birahi ganga river, power house of project, between dam site and power house site (near maina nadi adit site), near dam site of project, respectively. Whereas, Site V and VI were located near upstream of dam site and catchment area of project, respectively. Sampling points were selected in different forest communities keeping in view the slope, aspect, and elevation of the area.

Stratified random sampling method was adopted for field survey using various sizes of quadrats for various life forms in the study area (Roy et al 1999). The size and number of quadrats needed were determined using the species-area curve (Mishra 1968) and the running mean method (Kershaw 1973). The phytosociological analysis of tree species was done by randomly placed ten, 10m x 10m quadrats. Each, 10m x 10m quadrat was subdivided into two 5mx5m sub-quadrat for examining the shrubs and four 1mx1m sub-quadrat for herbs, respectively. Trees with > 31.5 cm CBH (circumference at breast height i.e., 1.37 m from the ground) were individually measured for CBH and species were identified. CBH was taken for the determination of tree basal area and calculated as \( \pi r^2 \), where \( r \) is the radius. Tree basal area of a species was the multiple of mean tree basal area and density. Total basal area (TBA) was the sum of basal area of all species present in the stand. Tree basal area was used to determine the relative dominance of a species. Sample of plant species were also collected and identified with the help of standard taxa florals and research papers (Kanjilal 1928, Naithani1984, Gaur et al. 1993)

The tree, shrub, and herb layers were quantitatively analysed separately for species richness, density, diversity, and frequency following Curtis and McIntosh (1950).

The IVI for the tree species was determined as the sum of the relative density, relative frequency and relative dominance (Phillips 1959).
Species diversity was determined by using Shannon-Weiner index (H’) (Shannon and Weinner 1963).

\[ H' = -\sum \left( \frac{n_i}{N} \right) \ln \left( \frac{n_i}{N} \right) \]

Concentration of dominance was measured by Simpson’s index (Simpson 1949).

\[ \lambda = \sum \left( \frac{n_i}{N} \right)^2 \]

Species richness (SR) was calculated following Margalef (1958):

\[ R' = \frac{S - 1}{\ln N} \]

Evenness index (Hill 1973) was also calculated based on the density of the species recorded.

\[ E = \frac{H'}{\ln S} \]

Where, \( S = \) Total number of species, \( N = \) Total number of individuals of all the species, and \( n_i = \) number of individuals of the ith species.

The data were analysed for analysis of variance (ANOVA) following Steel and Torrie (1981) in Microsoft excel-2007.

**Results**

**Structure and composition of vegetation**

Phytosociological analysis of study area indicated that total tree density varied from 440 no/ha to 810 no/ha. The value of the total tree basal area ranged from 18.38 to 35.11 m$^2$/ha in the study sites. Tree density and basal area values were recorded maximum at site III (maina nadi adit site). Very limited human interference was observed at this site. Site III was dominated by 14 tree species with *Pinus roxburghii*, *Alnus nepalensis*, *Toona ciliata*, *Lyonia ovalifolia* and *Cupressus torulosa* as main associate species(Table 1).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Site I</th>
<th>Site II</th>
<th>Site III</th>
<th>Site IV</th>
<th>Site V</th>
<th>Site VI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of species</td>
<td>36</td>
<td>48</td>
<td>53</td>
<td>47</td>
<td>50</td>
<td>41</td>
</tr>
<tr>
<td>Tree species</td>
<td>5</td>
<td>12</td>
<td>14</td>
<td>11</td>
<td>9</td>
<td>6</td>
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<tr>
<td>Shrub species</td>
<td>13</td>
<td>20</td>
<td>18</td>
<td>17</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>Herb species</td>
<td>18</td>
<td>16</td>
<td>21</td>
<td>19</td>
<td>24</td>
<td>20</td>
</tr>
<tr>
<td>Tree density (ha$^{-1}$)</td>
<td>520</td>
<td>680</td>
<td>810</td>
<td>710</td>
<td>670</td>
<td>440</td>
</tr>
<tr>
<td>Basal area m$^2$/ha$^{-1}$</td>
<td>18.38</td>
<td>26.77</td>
<td>35.11</td>
<td>27.17</td>
<td>22.77</td>
<td>24.53</td>
</tr>
<tr>
<td>Shrub density (ha$^{-1}$)</td>
<td>3640</td>
<td>5440</td>
<td>4460</td>
<td>4760</td>
<td>3460</td>
<td>3200</td>
</tr>
<tr>
<td>Herb density (ha$^{-1}$)</td>
<td>126250</td>
<td>139750</td>
<td>162250</td>
<td>152500</td>
<td>196500</td>
<td>157750</td>
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</table>

Maximum tree density of 240 plants/ha with a total basal cover of 14.40 m$^2$/ha was shown by *Pinus roxburghii* species. Dam site (site IV) of project was dominated by *Pinus roxburghii*. The maximum density and total basal cover (170 plants/ha and 9.86 m$^2$/ha) were recorded for *Pinus roxburghii* followed by *Alnus nepalensis* (120 plants/ha with TBC 3.96 m$^2$/ha), *Cupressus torulosa* (90 plants/ha with TBC 2.25 m$^2$/ha and *Melia azedarach* (70 plants/ha with TBC 2.31 m$^2$/ha) at site IV. *Pinus roxburghii* (IVI=168.25), *Cedrus deodara* (IVI=113.94), *Quercus leucotrichophora* (IVI=81.44), *Rhododendron arboreum* (IVI=68.05), *Pinus wallichiana* (IVI=57.23), *Alnus nepalensis* (IVI=55.76) were emerged as the dominant tree species in all six study sites (Table 2).

**Table 2:** Phytosociological attributes (density, abundance, frequency, total basal area and importance value index) of tree species in the studied six sites of Vishnugad-Pipalkoti area.

<table>
<thead>
<tr>
<th>Species name</th>
<th>A</th>
<th>F (%)</th>
<th>D ha$^{-1}$</th>
<th>TBA (m$^2$/ha)</th>
<th>IVI</th>
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<tbody>
<tr>
<td><strong>Site I</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pinus roxburghii</em></td>
<td>3.43</td>
<td>70</td>
<td>240</td>
<td>14.4</td>
<td>168.25</td>
</tr>
<tr>
<td><em>Alnus nepalensis</em></td>
<td>5</td>
<td>30</td>
<td>150</td>
<td>1.5</td>
<td>55.76</td>
</tr>
<tr>
<td><em>Cupressus torulosa</em></td>
<td>2</td>
<td>30</td>
<td>60</td>
<td>1.2</td>
<td>36.82</td>
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<tr>
<td><em>Ficus semicordata</em></td>
<td>3</td>
<td>10</td>
<td>30</td>
<td>0.6</td>
<td>15.28</td>
</tr>
<tr>
<td><em>Toona ciliata</em></td>
<td>2</td>
<td>20</td>
<td>40</td>
<td>0.68</td>
<td>23.89</td>
</tr>
<tr>
<td><strong>Site II</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pinus roxburghii</em></td>
<td>2.75</td>
<td>80</td>
<td>220</td>
<td>13.28</td>
<td>103.00</td>
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<th>Vol. 6 No. 1</th>
<th>ISSN: 2277-193X</th>
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<tr>
<td>Cupressus torulosa</td>
<td>1.8</td>
<td>50</td>
<td>90</td>
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<tr>
<td>Mallotus philippensis</td>
<td>2</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Toona ciliata</td>
<td>1.25</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>Sapindus insigne</td>
<td>1.33</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Melia azedarach</td>
<td>1.67</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Alnus nepalensis</td>
<td>2</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Other species</td>
<td>6.5</td>
<td>100</td>
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**Site III**

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<tr>
<td>Pinus roxburghii</td>
<td>3.83</td>
<td>60</td>
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<tr>
<td>Cupressus torulosa</td>
<td>3.67</td>
<td>30</td>
<td>110</td>
</tr>
<tr>
<td>Mallotus philippensis</td>
<td>2.33</td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>Albizia lebbeck</td>
<td>1.33</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Melia azedarach</td>
<td>1.5</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Cinnamomum tamala</td>
<td>1.67</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Anogeissus latifolius</td>
<td>2</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Other species</td>
<td>12</td>
<td>120</td>
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**Site IV**

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<tr>
<td>Pinus roxburghii</td>
<td>2.43</td>
<td>70</td>
<td>170</td>
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<tr>
<td>Alnus nepalensis</td>
<td>2.4</td>
<td>50</td>
<td>120</td>
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<tr>
<td>Cupressus torulosa</td>
<td>2.25</td>
<td>40</td>
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<tr>
<td>Melia azedarach</td>
<td>1.75</td>
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<td>Sapindus insigne</td>
<td>2</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Albizia lebbeck</td>
<td>2</td>
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<td>40</td>
</tr>
<tr>
<td>Other species</td>
<td>7.66</td>
<td>110</td>
<td>160</td>
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**Site V**

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<tr>
<td>Quercus leucotrichophora</td>
<td>2.57</td>
<td>70</td>
<td>180</td>
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<tr>
<td>Rhododendron arboreum</td>
<td>2.33</td>
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<td>140</td>
</tr>
<tr>
<td>Lyonia ovalifolia</td>
<td>2</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>Alnus nepalensis</td>
<td>2.33</td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>Myrica esculenta</td>
<td>1.5</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Other species</td>
<td>5.5</td>
<td>100</td>
<td>140</td>
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**Site VI**

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<th>Vol. 6 No. 1</th>
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<td>Cedrus deodara</td>
<td>2.5</td>
<td>60</td>
<td>150</td>
</tr>
<tr>
<td>Pinus wallichiana</td>
<td>1.8</td>
<td>50</td>
<td>90</td>
</tr>
<tr>
<td>Cupressus torulosa</td>
<td>1.75</td>
<td>40</td>
<td>70</td>
</tr>
<tr>
<td>Abies pindrow</td>
<td>2</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Picea smithiana</td>
<td>1.33</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Aesculus indica</td>
<td>3</td>
<td>10</td>
<td>30</td>
</tr>
</tbody>
</table>

The total density of the shrub layer was recorded between 3200 (no/ha) to 5440 (no/ha) in the study area. Maximum shrub density was observed at site II (power house site). This site was dominated by *Eupatorium adenophorum*, which showed a density of 1240 plant/ha. The density of other shrub species was reported in the order: *Berberis aristata* (760 plants/ha) > *Colebrookia oppositifolia* (340 plants/ha) > *Woodfordia fruticosa* (320 plants/ha) > *Adhatoda vasaica* (300 plants/ha) > *Urtica dioica* (280 plants/ha) and *Desmodium elegans* (260 plants/ha). *Woodfordia fruticosa* (IVI=75.79), *Rubus ellipticus* (IVI=68.08), *Desmodium elegans* (IVI=60.0), *Eupatorium adenophorum* (IVI=56.63), *Berberis aristata* (IVI=52.40) were observed dominant species in shrub layer in all the study sites (Table 3).

**Table 3:** Phytosociological attributes (density, abundance, frequency, total basal area and importance value index) of shrub species in the studied six sites of Vishnugad-Pipalkoti area.

<table>
<thead>
<tr>
<th>Species name</th>
<th>A</th>
<th>F(%)</th>
<th>D ha⁻¹</th>
<th>TBC (m²/ha)</th>
<th>IVI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site I</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Woodfordia fruticosa</em></td>
<td>2.67</td>
<td>90</td>
<td>960</td>
<td>2.3</td>
<td>75.79</td>
</tr>
<tr>
<td><em>Eupatorium adenophorum</em></td>
<td>2.86</td>
<td>70</td>
<td>800</td>
<td>1.44</td>
<td>56.63</td>
</tr>
<tr>
<td><em>Berberis aristata</em></td>
<td>2</td>
<td>40</td>
<td>320</td>
<td>0.96</td>
<td>30.07</td>
</tr>
<tr>
<td><em>Adhatoda vasaica</em></td>
<td>2.33</td>
<td>30</td>
<td>280</td>
<td>0.56</td>
<td>21.93</td>
</tr>
</tbody>
</table>

**Online version available at:** www.crdeepjournal.org/jilj
A well-developed herb layer recorded in the present study is a characteristic feature of the Western Himalayan forest. Total density of herbaceous flora ranged from (126250 plants/ha to 196500 plants/ha) in the study area. Maximum no of herb species (25) was recorded at site IV. In herb layer, Artemisia vulgaris showed highest density (19250 no/ha) followed by Chrysopogon fulvus(19000 plants/ha), Anaphalis contortata(16000 plants/ha), Parthenium hysterophorus (15000 plants/ha), Cynodon dactylon(15000 plants/ha), Rumex hastatus(14750 plants/ha), Achyranthes bidentata(14500 plants/ha) (Table 4).
Table 4: Phytosociological attributes (density, abundance, frequency, total basal area and importance value index) of herb species in the studied six sites of Vishnugad-Pipalkoti area.

<table>
<thead>
<tr>
<th>Species name</th>
<th>A</th>
<th>F(%)</th>
<th>D ha$^{-1}$</th>
<th>TBC (cm$^2$ m$^{-2}$)</th>
<th>IVI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site I</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anaphalis contorta</td>
<td>1.94</td>
<td>80</td>
<td>15500</td>
<td>0.07</td>
<td>28.00</td>
</tr>
<tr>
<td>Achyranthes bidentata</td>
<td>2.32</td>
<td>62.5</td>
<td>14500</td>
<td>1.33</td>
<td>46.53</td>
</tr>
<tr>
<td>Eriophorum comosum</td>
<td>2.70</td>
<td>50</td>
<td>13500</td>
<td>0.72</td>
<td>32.47</td>
</tr>
<tr>
<td>Rumex hastatus</td>
<td>2.56</td>
<td>40</td>
<td>10250</td>
<td>0.76</td>
<td>28.85</td>
</tr>
<tr>
<td>Lindenbergia grandiflora</td>
<td>2.38</td>
<td>40</td>
<td>9500</td>
<td>0.76</td>
<td>28.28</td>
</tr>
<tr>
<td>Chrysopogon fulvus</td>
<td>2.71</td>
<td>35</td>
<td>9500</td>
<td>0.08</td>
<td>15.28</td>
</tr>
<tr>
<td>Artemisia vulgaris</td>
<td>3.60</td>
<td>25</td>
<td>9000</td>
<td>0.08</td>
<td>13.00</td>
</tr>
<tr>
<td>Urtica dioica</td>
<td>2.57</td>
<td>35</td>
<td>9000</td>
<td>0.02</td>
<td>13.90</td>
</tr>
<tr>
<td>Other species</td>
<td>18.27</td>
<td>185</td>
<td>35500</td>
<td>1.81</td>
<td>93.68</td>
</tr>
<tr>
<td><strong>Site II</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artemisia vulgaris</td>
<td>3.21</td>
<td>60</td>
<td>19250</td>
<td>1.08</td>
<td>48.90</td>
</tr>
<tr>
<td>Chrysopogon fulvus</td>
<td>3.45</td>
<td>55</td>
<td>19000</td>
<td>0.17</td>
<td>26.59</td>
</tr>
<tr>
<td>Nepeta ciliaris</td>
<td>2.6</td>
<td>50</td>
<td>13000</td>
<td>0.04</td>
<td>18.29</td>
</tr>
<tr>
<td>Anaphalis contorta</td>
<td>2.42</td>
<td>47.5</td>
<td>11500</td>
<td>0.85</td>
<td>35.98</td>
</tr>
<tr>
<td>Ainsliaea aperta</td>
<td>2.5</td>
<td>45</td>
<td>11250</td>
<td>0.54</td>
<td>28.06</td>
</tr>
<tr>
<td>Eriophorum comosum</td>
<td>2.38</td>
<td>40</td>
<td>9500</td>
<td>0.08</td>
<td>15.13</td>
</tr>
<tr>
<td>Oxalis corniculata</td>
<td>1.64</td>
<td>55</td>
<td>9000</td>
<td>0.08</td>
<td>17.10</td>
</tr>
<tr>
<td>Apluda mutica</td>
<td>1.88</td>
<td>42.5</td>
<td>8000</td>
<td>0.02</td>
<td>13.09</td>
</tr>
<tr>
<td>Other species</td>
<td>14.13</td>
<td>225</td>
<td>39250</td>
<td>1.37</td>
<td>96.85</td>
</tr>
<tr>
<td><strong>Site III</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rumex hastatus</td>
<td>2.27</td>
<td>65</td>
<td>14750</td>
<td>1.27</td>
<td>43.08</td>
</tr>
<tr>
<td>Anaphalis contorta</td>
<td>2.04</td>
<td>67.5</td>
<td>13750</td>
<td>0.13</td>
<td>18.41</td>
</tr>
<tr>
<td>Chrysopogon fulvus</td>
<td>1.82</td>
<td>70</td>
<td>12750</td>
<td>0.04</td>
<td>16.18</td>
</tr>
<tr>
<td>Eriophorum comosum</td>
<td>1.88</td>
<td>65</td>
<td>12250</td>
<td>0.91</td>
<td>33.83</td>
</tr>
<tr>
<td>Oxalis corniculata</td>
<td>2.09</td>
<td>55</td>
<td>11500</td>
<td>0.06</td>
<td>14.16</td>
</tr>
<tr>
<td>Apluda mutica</td>
<td>2.14</td>
<td>52.5</td>
<td>11250</td>
<td>0.09</td>
<td>14.58</td>
</tr>
<tr>
<td>Lindenbergia grandiflora</td>
<td>1.38</td>
<td>65</td>
<td>9000</td>
<td>0.08</td>
<td>14.13</td>
</tr>
<tr>
<td>Pteridium aquilinum</td>
<td>1.64</td>
<td>55</td>
<td>9000</td>
<td>0.01</td>
<td>11.59</td>
</tr>
<tr>
<td>Other species</td>
<td>21.29</td>
<td>437.5</td>
<td>68000</td>
<td>2.12</td>
<td>134.06</td>
</tr>
<tr>
<td><strong>Site IV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chrysopogon fulvus</td>
<td>2.38</td>
<td>65</td>
<td>15500</td>
<td>1.27</td>
<td>50.61</td>
</tr>
<tr>
<td>Parthenium hysterophorus</td>
<td>2.5</td>
<td>60</td>
<td>15000</td>
<td>1.01</td>
<td>42.86</td>
</tr>
<tr>
<td>Cynoglossum glochidiatum</td>
<td>2.8</td>
<td>50</td>
<td>14000</td>
<td>0.56</td>
<td>29.58</td>
</tr>
<tr>
<td>Artemisia vulgaris</td>
<td>2.36</td>
<td>55</td>
<td>13000</td>
<td>0.12</td>
<td>18.27</td>
</tr>
<tr>
<td>Rumex hastatus</td>
<td>2.08</td>
<td>60</td>
<td>12500</td>
<td>0.11</td>
<td>18.14</td>
</tr>
<tr>
<td>Oxalis corniculata</td>
<td>1.38</td>
<td>65</td>
<td>9000</td>
<td>0.05</td>
<td>15.14</td>
</tr>
<tr>
<td>Themeda triandra</td>
<td>1.21</td>
<td>70</td>
<td>8500</td>
<td>0.34</td>
<td>22.75</td>
</tr>
<tr>
<td>Anaphalis contorta</td>
<td>2.06</td>
<td>40</td>
<td>8250</td>
<td>0.05</td>
<td>11.41</td>
</tr>
<tr>
<td>Other species</td>
<td>17.17</td>
<td>362.5</td>
<td>56750</td>
<td>0.4</td>
<td>91.24</td>
</tr>
<tr>
<td><strong>Site V</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artemisia vulgaris</td>
<td>1.76</td>
<td>42.5</td>
<td>7500</td>
<td>0.91</td>
<td>33.21</td>
</tr>
<tr>
<td>Solanum nigrum</td>
<td>2.12</td>
<td>42.5</td>
<td>9000</td>
<td>0.85</td>
<td>32.28</td>
</tr>
<tr>
<td>Urtica dioica</td>
<td>1.44</td>
<td>62.5</td>
<td>9000</td>
<td>0.44</td>
<td>23.15</td>
</tr>
<tr>
<td>Heteropogon contortus</td>
<td>2.58</td>
<td>30</td>
<td>7750</td>
<td>0.38</td>
<td>17.37</td>
</tr>
<tr>
<td>Aster peduncularis</td>
<td>1.84</td>
<td>62.5</td>
<td>11500</td>
<td>0.07</td>
<td>14.06</td>
</tr>
<tr>
<td>Cassia tora</td>
<td>1.85</td>
<td>65</td>
<td>12000</td>
<td>0.05</td>
<td>14.05</td>
</tr>
<tr>
<td>Potentilla fulgens</td>
<td>2.15</td>
<td>65</td>
<td>14000</td>
<td>0.01</td>
<td>13.93</td>
</tr>
<tr>
<td>Nepeta elliptica</td>
<td>1.90</td>
<td>52.5</td>
<td>10000</td>
<td>0.1</td>
<td>13.08</td>
</tr>
<tr>
<td>Other species</td>
<td>35.08</td>
<td>555</td>
<td>115750</td>
<td>0.85</td>
<td>138.9</td>
</tr>
</tbody>
</table>
Diversity

The species diversity, concentration of dominance, species richness and evenness index of different vegetation layers of the forests were also measured and given in Table 5. Highest total number of species were recorded at site III (53 spp.) and lowest number of total species were observed at site I (36 spp.). Among all vegetation layer of study sites, the maximum number of species was encountered for the herb layer of site V (24) and the minimum (5) for the tree layer in the site I. Diversity Index (H') ranged from 1.33 to 2.34 for tree layer, from 2.20 to 2.68 for shrub layer and for herb layer between 2.64 to 3.11. Shannon diversity (H') was recorded highest for the herb layer of site V (3.11) and minimum for tree layer of the site I (1.33). The Simpson diversity was ranging between 0.05 to 0.31 in all life forms. Species Richness of trees ranged from 1.01-2.96; shrubs from 2.31-3.39, herbs from 2.37-3.45. Richness index showed maximum value for the herb layer in the site V (3.45) and minimum for tree layer in the site I (1.01). Evenness index values were recorded between 0.82 to 0.98 in all vegetation layers. ANOVA analysis revealed significant differences in Shannon-wiener diversity index (F= 16.88, p=0.01) and Simpson diversity index (F= 9.42, p=0.01) for all vegetation layers in the study sites. It is also evident from the comparative account of the forests in the study area that the site III has a rich diversity of species and abundance of all the plant species compared to the forests of the other study sites.

Table 5: Diversity indices of tree, shrub and herb layer in the studied six sites of Vishnugad-Pipalkoti area.

<table>
<thead>
<tr>
<th>Study Site</th>
<th>Vegetation type</th>
<th>Shannon-Wiener Diversity Index (H')</th>
<th>Concentration of dominance (Cd)</th>
<th>Evenness Index (E)</th>
<th>Richness Index (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site I</td>
<td>Tree</td>
<td>1.33</td>
<td>0.31</td>
<td>0.82</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
<td>Shrub</td>
<td>2.20</td>
<td>0.14</td>
<td>0.86</td>
<td>2.31</td>
</tr>
<tr>
<td></td>
<td>Herb</td>
<td>2.64</td>
<td>0.08</td>
<td>0.91</td>
<td>2.73</td>
</tr>
<tr>
<td>Site II</td>
<td>Tree</td>
<td>2.18</td>
<td>0.14</td>
<td>0.88</td>
<td>2.61</td>
</tr>
<tr>
<td></td>
<td>Shrub</td>
<td>2.65</td>
<td>0.10</td>
<td>0.89</td>
<td>3.39</td>
</tr>
<tr>
<td></td>
<td>Herb</td>
<td>2.62</td>
<td>0.08</td>
<td>0.94</td>
<td>2.37</td>
</tr>
<tr>
<td>Site III</td>
<td>Tree</td>
<td>2.34</td>
<td>0.12</td>
<td>0.89</td>
<td>2.96</td>
</tr>
<tr>
<td></td>
<td>Shrub</td>
<td>2.68</td>
<td>0.08</td>
<td>0.93</td>
<td>3.14</td>
</tr>
<tr>
<td></td>
<td>Herb</td>
<td>2.93</td>
<td>0.06</td>
<td>0.96</td>
<td>3.09</td>
</tr>
<tr>
<td>Site IV</td>
<td>Tree</td>
<td>2.19</td>
<td>0.12</td>
<td>0.91</td>
<td>2.35</td>
</tr>
<tr>
<td></td>
<td>Shrub</td>
<td>2.64</td>
<td>0.08</td>
<td>0.93</td>
<td>2.92</td>
</tr>
<tr>
<td></td>
<td>Herb</td>
<td>2.82</td>
<td>0.06</td>
<td>0.96</td>
<td>2.81</td>
</tr>
<tr>
<td>Site V</td>
<td>Tree</td>
<td>1.99</td>
<td>0.15</td>
<td>0.91</td>
<td>1.90</td>
</tr>
<tr>
<td></td>
<td>Shrub</td>
<td>2.51</td>
<td>0.11</td>
<td>0.88</td>
<td>3.10</td>
</tr>
<tr>
<td></td>
<td>Herb</td>
<td>3.11</td>
<td>0.05</td>
<td>0.98</td>
<td>3.45</td>
</tr>
<tr>
<td>Site VI</td>
<td>Tree</td>
<td>1.66</td>
<td>0.20</td>
<td>0.92</td>
<td>1.32</td>
</tr>
<tr>
<td></td>
<td>Shrub</td>
<td>2.55</td>
<td>0.09</td>
<td>0.94</td>
<td>2.76</td>
</tr>
<tr>
<td></td>
<td>Herb</td>
<td>2.84</td>
<td>0.06</td>
<td>0.95</td>
<td>2.95</td>
</tr>
</tbody>
</table>

Discussion

Forest loss and fragmentation in association with creation of dams and reservoirs can alter the ecosystem characteristics and negatively affect species diversity (Terborgh et al. 2001, Laurance et al. 2002). Floral diversity of a region is directly affected of while developing a hydro-project as damming of a river will have immense effects both downstream and upstream stretches (Panwar et al. 2010). The rich floral diversity of the Alaknanda valley may be attributed to the presence of different physiognomic conditions and altitudinal range, microclimatic variation and ecological factors. Several other studies carried out in the Alaknanda valley also proved the rich wealth of the valley (Hajra and Balodi 1995, Upeti and Negi 1995, Samant 1993). The structure and composition of vegetation in Vishnugad-Pipalkoti area changed with the change environmental and physiographic conditions. In study area, Chir-pine was most dominant species in lower altitudes near power house site, dam site and downstream of dam site of project, whereas the higher altitude regions (influence area and catchment area) were dominated by Quercus leucotrichophora and Cedrus deodara species. Singh and Singh (1987) had also suggested that environmental conditions are favourable in the central Himalaya up to 2500 m or so for tree growth. The
phytosociological values obtained for tree, shrub and herb species in the present study were comparable with the earlier reported values from different parts of the Western Himalayan region (Saxena and Singh 1982, Rawal & Pangtey 1994, Dhar et al. 1997, Kumar and Ram, 2005). The poor composition of vegetation at lower elevation i.e. site I, Site II was mainly due to anthropogenic impacts on these sites. Total basal area values in the study sites showed a decreasing pattern with the increase in altitude. This may be due to sudden changes in the environmental conditions. Singh and Singh (1987) have also observed similar situations in response to a sudden decline in rainfall, severe cold and windy conditions. Tree height, stratification, diversity and canopy density is reduced drastically due to microclimatic factors. Tree species diversity varied greatly from place to place mainly due to variation in biogeography, habitat and disturbance (Sagar et al. 2003), which have also been considered as the important factors for structuring the forest communities (Burslem and Whitmore, 1999).

Shrub layer was presented on all the study sites. Site III (maina nadi adit site) showed maximum shrub density i.e. 5440 plants/ha. The most frequent shrub species were Eupatorium adenophorum, Pyracantha crenulata, Colebrookia oppositifolia, Berberis asiatica, Rubus ellipticus and Woodfordia fruticosa etc. A well-developed herb layer as recorded in the present study is a characteristic feature of the Western Himalayan forest. Composition of herbaceous layer showed variation during different season. Rumex hastatus, Ageratum houstonianum, Bidens pilosa, Cynodon dactylon, Oxalis corniculata, Themeda triandra, Solanum nigrum,Eriophorum comosus, and Parthenium hysterophorus were some common herbaceous species of the study sites. Shrub and herb layer density values were comparable with earlier reported values of Himalayan forest by different workers. (Dhar et al., 1997; Rawalad Pangtey, 1994; Pant and Samant, 2006; Ram et al., 2004; Gairola et al., 2008).

In the present study Diversity Index (H') ranged from 1.33 to 2.34 for tree layer. For the shrub layer the values of Diversity Index ranged from 2.20 to 2.68. Monk (1967), Risser and Rice (1971) reported the value of diversity between 2.00 to 3.00 for temperate forests. Upeti et al. (1985) reported the value of diversity for oak forest at Nainital as 1.04 for tree layer and 2.33 for shrub layer. The value of concentration of dominance (Cd) ranged between 0.12-0.31 and 0.09 to 0.14 for tree and shrub layer, respectively. Published values of Cd for temperate vegetation ranged from 0.10-0.99 (Whittaker 1975, Risser and Rice1971). For Central Himalayan forests, it was reported between 0.22-1.00 (Tewari and Singh 1985). The values of diversity and concentration of dominance of present study were comparable with those reported from Western Himalayan forest.

An area faced habitat fragmentation due to the establishment of any developmental projects. In Vishnugad- Pipalkoti area vegetation of study sites I, II, III and IV may face more disturbance due to various construction activities. The pine mixed forest that was occurred in the main project construction sites viz. dam site, power house site and adits was also well represented in the catchment area of project. The impacts of Vishnugad- Pipalkoti HEP development can be visualized in terms of direct losses (primary impacts) due to diversion of forest land for construction of dam, power house, roads, colonies and other project structure and indirect losses (secondary impacts) on nearby forest area due to the alteration in landuse/landcover of project area. The direct impact of construction activity of any water resource project in a mountainous terrain similar to that of proposed project is generally limited in the vicinity of the construction sites only. The local communities of study area depend on forest for fuelwood, fodder, timber, grazing of animal etc. Acquisition of forest land will create extra pressure of nearby forest areas of Alaknanda valley. It is anticipated that during construction stage of project plants species of the project area would be directly affected due to change of landuse pattern, diversion of land (forest as well as non-forest land ) for construction of dam, powerhouse, approach roads, muck disposal, adits, tailrace channels, migration of labour force, generation of dust during construction period etc. Submergence of forest land and diversion of forest/grazing land and relocation of the human population would create some extra pressure on residual forest areas of the Alaknanda valley. Due to acquisition of forest land for various construction activities following species will be affected- tree species; Pinus roxburghii, Alnus nepalensis,Mallotus philippensis, Melia azedarach, Albizia lebbeck, Cupressus torulosa, Toona ciliata and Ficus semicordata etc. Shrub species-Woodfordia fruticosa, Eupatorium adenophorum, Berberis aristata,Adhatoda vasica, Pyracantha crenulata, Agave americana, Prinsepia utilis, Callicarpa macrophylla, Coriaria nepalensis, Debregeasia salicifoliaetc. Herb Species- Ageratum houstonianum, Rumex hastatus, Anaphalis contorta, Chrysopogon fulvis, Nepeta ciliaris, Eriophorum comosus, Lindenhergia grandiflora, Achyranthes bidentata, Commelina benghalensis, Artemisia vulgaris, Apluda muticaetc. Although, these species are well distributed in the catchment area of Alaknanda valley. Nearby forest patches and plant species of catchment area may face further anthropogenic pressure for the fuel, fodder, timber, medicinal plants etc. requirement of dependent communities. VPHEP project would create disturbed habitat during construction of the project, therefore, expansion of invasive species such as Eupatorium adenophorum, Lantana camara and Parthenium hysterophorus could occur, which ultimately affect the native vegetation of the area.

A relatively young and ecologically fragile mountain range like the Himalaya needs much more attention for any infrastructure construction activity. In other words, the conservation of ecology and economic development has to go together, which is necessary for the progress and overall development of the Himalayan region (Samant et. al, 2007). For conservation of floral diversity of the region conservation measures likely germplam conservation in botanical garden/arboretum, habitat improvement programme (viz. afforestation, green belt development around project area, pasture land development), catchment area treatment plan, control of fire and grazing in forest areas, energy conservation measures by adopting LPG cylinders and community kitchen facilities, encouragement for community participation in floral diversity conservation, organization of capacity building and biodiversity conservation awareness programme for community etc. could be implemented with the help of forest department, universities, research institution,
project affected communities, civil societies and other stakeholders in the project area. Effective and regular monitoring is an important part of the floral diversity conservation and management. All the conservation and management activities/programmes needs to be closely and regularly monitored during construction and operation phase of the projects. A floral biodiversity post impact assessment study may also be carried out to assess the impact of project on vegetation status of the project area in future.

Conclusion
Indian Himalayan Region is rich repository of biological diversity and also encompasses with various forest types. It is also known as the water tower on the earth. Keeping in view the vast water resources of IHR, the Government of India is planning to harness the hydropower potential of region to increase the electricity requirement for socio-economic development, minimize electricity shortage and to reduce the GHGs emission from coal based projects in the country. The present study assess that the vegetation of the Vishnugad-pipalkoti area play important role in day to day life of local communities. In Vishnugad-Pipalkoti Hydro Electric Project area, Chir-pine was most dominant species of lower altitudes near power house site, dam site and downstream of dam site, however in higher altitude in catchment area sites Quercusleuco trichophora and Cedrus deodara were dominant species. Species diversity was observed higher at sites situated far from human habitation and lower at sites situated near villages due anthropogenic disturbances. It has been assessed that development of Vishnugad-Pipalkoti may directly affect the vegetation of construction sites due to diversion of forest land for construction of dam, power house, roads, colony etc. and indirectly create some extra pressure on catchment area forest and vegetation due to the change in landuse/landcover of project area. Therefore, sound implementation of vegetation and forest management measures are urgently needed for the conservation of floral wealth of the region. It is also very essential to establish a plant biodiversity monitoring programme to assess the nature of the changes as they occur and to take appropriate step to mitigate any future adverse effects of hydropower projects on plant biodiversity in the area.

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