An Appraisal of Human Impact on Vegetation in High Altitudes (Khumbu Region) of Nepal

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Abstract
Impact of anthropogenic disturbances on vegetation through growing trekking in the Khumbu region encompassing Sagarmatha National Park in north-eastern Nepal Himalaya is reported. Five major sites at an interval of 500 m covering the altitudes from 3000 m (near Lukla) - 5000 m (near Lobuche) were examined where species richness decreased with increasing altitude. Littering was found in every 27.6 human steps (ca. 14 m) and the tree wounds were rampant on the major trek route. Effects of growing tourism on the alpine vegetation of the region was vividly noticeable. Development of confined trail for the visitors to close superfluous paths and monitoring change in resources are suggested.

Keywords: Floristic patterns, Littering, Sagarmatha National Park, Species richness, Trampling

Introduction
Tourism has grown considerably in the Khumbu region (Sagarmatha National Park) since 1964 when only 20 tourists visited the region. Between July 1996 and July 1997, 17412 tourists entered the Park (SPCC 1997). The first lodges were built in 1970s which grew from 7 to 81 between 1973 and 1991 (Lachapelle 1995). Bjonness (1983) feared that tourism has caused extensive deforestation. At higher altitudes, juniper scrub, which requires 60 or more years to mature to the size of 35 cm above the ground, are cut and their roots extracted. At lower altitudes, booming trade in firewood has resulted in tree felling and cutting with little regard to species, age or site (Jefferies 1982). Some have concluded that the Khumbu's watershed has been nearly destroyed by tourists-induced deforestation (Hinrichsen et al. 1983).

Despite the work of previous researches and reports of damage to the resource-base through tourism related pressures (such as over grazing and the disposal of expedition waste), no detailed work has been published to specify the extent of any damage or threat to the continuity of plant species in the Park. This study presents (1) anthropogenic disturbances such as littering and damage to the vegetation along Lukla-Lobuche, a major trek route, and (2) an appraisal of human impact on vegetation patterns such as plant species richness and floristic composition.

Methodology
Study Site
The study was carried out in the Khumbu region, north-eastern Nepal (Fig. 1). The upper Khumbu region was designated as a National Park by the Nepal Government in 1976 and as a World Heritage Site by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 1979. The Park is 1,113 sq. km in size made up of three vegetation zones; lower zones comprising forests of oak, pine, birch and rhododendron, alpine mid zones where dwarf rhododendrons and juniper scrub dominate and upper alpine zone made up of moss and lichens (Lachapelle 1995).

The climate is cool with wet summers and cold-dry winters. Average precipitation in the region is 1078 mm, 845 mm most of which falls in the monsoon that lasts from June to September. Average mean minimum and maximum temperature at Tengboche in the coldest month of January is -9°C and 3°C and in the warmest month of July is 4°C and 14°C. Some snow falls during the winter months, November to February, during which time day-time temperature remains close to 0°C (SNP Visitor Center Data 1998).

Sampling
The study, conducted in September 1998, included five major sites representing different altitudes viz. 3000 m (near Lukla), 3500 m (near Namche),
Figure 1. Map of Nepal showing Sagarmatha National Park, inset major glaciers and the trail from Lukla to Lobuche

Table 1. Littering and damaged tree in trekking route from Lukla to Lobuche, Sagarmatha National Park, Nepal

<table>
<thead>
<tr>
<th>Route</th>
<th>Distance (km)</th>
<th>Littering*</th>
<th>Damaged tree (no.)</th>
<th>No of lodges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lukula-Phakdin</td>
<td>7.0</td>
<td>18.7</td>
<td>6</td>
<td>29</td>
</tr>
<tr>
<td>Phakdin-Monju</td>
<td>4.0</td>
<td>17.3</td>
<td>58</td>
<td>14</td>
</tr>
<tr>
<td>Monju-Namche</td>
<td>4.0</td>
<td>18.5</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Namche-Tengboche</td>
<td>7.0</td>
<td>46.1</td>
<td>53</td>
<td>36</td>
</tr>
<tr>
<td>Tengboche-Periche</td>
<td>7.5</td>
<td>20.5</td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>Periche-Lobuche</td>
<td>5.0</td>
<td>44.7</td>
<td>No tree</td>
<td>16</td>
</tr>
</tbody>
</table>

* Normal human step (ca 50 cm)

4000 m (near Tengboche), 4500 m (near Periche) and 5000 m (near Lobuche) in the Khumbu region, East Nepal (Figure 1). Littering of all types viz. discarded bottles, cans, plastic bags/wrappers etc. were recorded in the sectors between major rest-sites which included Lukula-Phakdin, Phakdin-Monju, Monju-Namche, Namche-Tengboche, Tengboche-Periche, and Periche-Lobuche. The recordings were made while walking in normal pace and totaling about two km (over 30% of the total distance) for each sector in the route. Similarly, wounded trees along the path were counted in the routes to estimate the damage by cutting.

At each site, ten quadrates (size: 1 m x 1 m) were laid nearby the trail and the coverage and number of the vascular plant species were measured. Species richness was calculated as an average of the total number of species counted in those ten quadrates. Height and frequency of occurrence of Juniperus recurva were measured in degraded and protected sites in Namche, the most densely populated village in the route.

**Results and discussion**

Littering and tree damage

Table 1 presents the littering and damage of the trees in various routes from Lukla to Lobuche (ca. 34 Km). In average, in every 27.6 human steps (ca. 14 m) there was a litter. Except in the routes between Namche-Tengboche and Periche-Lobuche, the litter-
ing occurred in less than 20 human steps, i.e. 10 m. In the former routes, the littering interval was above 40 human steps. The litters were primarily non-degradable plastic wrappers of instant noodles, biscuits, chewing gums and others left by the trekkers. Glass bottles and metal cans were few. Glass bottles are banned by the Park.

During the fiscal year 1996-97, the Sagarmatha Pollution Control Committee (SPCC), a local non-government organization, disposed a total of 24,309 kg of garbage from Khumbu region of which 28% included non-disposable items (SPCC 1998). A majority of such garbage was generated from Namche and Lukla with 60% and 18.65% of the total respectively. Both Namche and Lukla are based with the highest concentration of the lodges (Table 1) indicating a link between garbage generation and number of visitors in the region.

A lot of lopped/wounded trees were also noted on the way (Table 1). The number of such trees were high (above 50) in the routes of Phakdin-Monju and Namche-Tengboche. The former is outside the Park while the latter is inside. The wounds were mostly by the Khukri, a typical knife carried by the porters and fuel-wood collectors. In the routes of Lukla-Phakdin, Monju-Namche, and Tengboche-Periche, only a few trees (less than six) were found wounded. Whilst the Monju-Lukla was at the entrance of the national park, the forest in Lukla-Phakdin was mainly a secondary growth and it was a naturally sparse type in Tengboche-Periche route. The tree line ended at near Periche. It was reported that the passers-by specially the less paid porters cuts the tree-stems that would finally collapse or kill the tree to give them fuel wood (personal communication M. N. Sherpa, SPCC 1998).

Species Richness

The species richness (per square meter) in the Khumbu region was seven in average, of which 85% was herbaceous species (Figure 2). In general, the species number tended to decline with the increase of the altitude which can be attributed to the severe environment such as cold and short-growing season. The species richness was recorded highest in Namche (nine species) and the lowest in Lobuche (below five species). At Lobuche, woody species were absent. Namche (human pop. 1328, livestock pop. 1828; source: SPCC 1999) was found to be the most disturbed site of the all.

The increase in the species richness in relatively more disturbed site (Namche) is in consistent with the model of species density under several levels of environmental stress (Connell 1978, Grime 1979).

Similarly, species richness increased at the intermediate level of trampling disturbance in an urban forest in Central Japan (Bhuju & Ohsawa, in press).

Floristic Patterns

In the present study, major trail species recorded from the sites included Plantago sp., Trisetum spicata, Agrostis piosa, Poa sp., Danthonia sp., Helictotrichon virens, Calamagrostis sp. (Table 2). Plantago is a common trail perennial of rosette growth form (Mucina et al. 1991, Ikeda & Okutomi 1990) which can thrive well in the wear sites. The Plantago was recorded throughout the trek route till Periche (4500 m) which could be the limiting altitude for the species. Agrostis is an ectozoochrous species, the seeds of which are disseminated by attaching the hairy skin of the cattle and trousers of the passers-by. They are also easily transported by the wind.

Garden flowers such as Cosmos sp. was found up to Periche, while vegetable such as lettuce (Lactica sativa) was found grown still at higher elevation of 4620 m (Tukla), the tongue of the Khumbu glacier.
Table 2. Major species in five different sites/altitudes nearby the trails en-route from Lukla to Periche, Sagarmatha National Park, Nepal

<table>
<thead>
<tr>
<th>Near Site</th>
<th>Alt. (m)</th>
<th>Major trail/herb species nearby the trail</th>
<th>Major tree/woody spp. in nearby forest</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lukla</td>
<td>3000</td>
<td><em>Plantago</em> sp., <em>Aster</em> sp., <em>Anaphalis contorta</em></td>
<td><em>Rhododendron arborium</em>, <em>Eurya</em> sp., <em>Quercus semicarpfolia</em>, <em>Berberis angulasa</em>, <em>Gaultheria fragransissima</em></td>
<td>Secondary growth of <em>Rhododendron</em> forest Maximum tree height 2.5m</td>
</tr>
<tr>
<td>Namche</td>
<td>3500</td>
<td><em>Plantago</em> sp., <em>Helicotrichon virescens</em>, <em>Poa</em> sp., <em>Calamagrostis</em> sp., <em>A. contorta</em>, <em>Sedum</em> sp., <em>S combusta</em></td>
<td><em>Abies spectabilis</em>, <em>Pinus wallichiana</em>, <em>Juniperus recurva</em>, <em>B. angulasa</em>, <em>Cotoneaster microphyllous</em></td>
<td>Highly disturbed</td>
</tr>
<tr>
<td>Tengboche</td>
<td>4000</td>
<td><em>Plantago</em> sp., <em>Poa</em> sp., <em>Trisetum spicatum</em>, <em>Agrostis</em> sp., <em>Gentiana prolata</em>, <em>Persicaria polystachya</em>, <em>Potentilla sp.</em></td>
<td><em>Betula utilis</em>, <em>A. spectabilis</em>, <em>R. arborium</em>, <em>R. campanulatum</em>, <em>B. angulasa</em></td>
<td>Intact forest Low light on ground</td>
</tr>
<tr>
<td>Periche</td>
<td>4500</td>
<td><em>Plantago</em> sp. <em>T. spicatum</em>, <em>A. pilosula</em>, <em>Poa</em> sp., <em>Danthonia</em> sp., <em>G. prolata</em>, <em>Leontopodium sp.</em>, <em>Ephedra himalensis</em></td>
<td><em>J. recurva</em>, <em>Rhododendron lepidotum</em>, <em>R. setosum</em></td>
<td>Lettuce cultivation</td>
</tr>
<tr>
<td>Lobuche</td>
<td>5000</td>
<td><em>Potentilla</em> sp., <em>Juncus</em> sp., <em>Phlomis rotata</em></td>
<td>No woody species</td>
<td>No tree</td>
</tr>
</tbody>
</table>

Several natural forest patches of *Rhododendron arboareum*, *Abies spectabilis* and *Betula utilis* in Namche and Tengboche specifically on the sunny slopes were found replaced/colonized by *Pinus wallichiana*. Sherpa (1983) reported that the blue pine seeds germinated faster than any other species in the Park.

In degraded lands near villages the original bushes of *Juniperus recurva* were short and scanty which were replaced by semi-natural vegetation of *Euphorbia prolifera*, *Thermopsis inflata*, *Cotoneaster microphyllus* and *Berberis angulasa*. *Euphorbia* is a non-edible poisonous shrub while *Cotoneaster* and *Berberis* are thorny shrubs. In Namche, the frequency of occurrence of *J. recurva* in degraded habitats was only 20% with compared to 100% in protected sites. Similarly, the plants were short (< 30 cm) in the disturbed sites with compared to average 4 m in the protected ones (Fig. 3).

In a study conducted in Khumbu region, Buffa et al. (1998) reported that the over grazed areas are colonized by unpalatable low plants like *Cotoneaster* and *Berberis*. A relationship has been worked out between the degradation of natural forests/grass lands and increased livestock specially the yaks (Rogers 1997, Buffa et al. 1998) and this increase in the yak population stems from the demand for cheese and meat by flocking number of tourists (Yonzon & Hunter 1991).

**Conclusions**

Reports have shown that the alpine vegetation is very sensitive to trampling (Bell & Bliss 1973) and the probability of vegetation damage is greater in high altitudes. Bare ground and trail will proliferate with increased use by the flocking trekkers and high altitude climbers in the Khumbu region. Human trampling may contribute in species richness and diversity but it also affects the succession through soil hardness (de Gouvenain 1996, Bhuju & Ohsawa 1998). Development of asphalt or other types of trails that may confine walking will be effective in closing the superfluous paths and thereby diminishing trampling hazards (Willard & Marr 1971). Monitoring the change in resource and use characteristics should be carried out to assess and manage the effects of increasing trekking in the region.

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References