Chasing Chinese Caterpillar Fungus (Ophiocordyceps sinensis) Harvesters in the Himalayas: Harvesting Practice and Its Conservation Implications in Western Nepal

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Chasing Chinese Caterpillar Fungus (Ophiocordyceps sinensis) Harvesters in the Himalayas: Harvesting Practice and Its Conservation Implications in Western Nepal

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The Chinese caterpillar fungus is famous for its high market value, unusual life history, and significant medicinal uses. It is harvested by very poor communities and sold for an extraordinarily high price. Most of the studies on this species are focused on therapeutic uses, chemical analyses, ecology, and trade. However, harvesting techniques and intensity of the harvests remain undocumented. We document harvesting techniques, trends of harvest, and perceptions of the Chinese caterpillar fungus harvesters in Dolpa, Nepal, based on surveys, focus-group discussions, and direct observations. Along with increasing market value, intensity of the harvest has been increasing. The Chinese caterpillar fungus harvest has now become the second most important livelihood strategy for the local communities, after agriculture. Reported per-capita harvest based on the first day of collection has declined over the last 4 years, apparently because of the decline in the stock and the increasing number of harvesters.

Keywords biodiversity conservation, harvesting, medicinal fungus, Nepal

Collection and trade of nontimber forest products (NTFPs) including medicinal plants and fungi make significant contributions to household income in the hills and high mountains of the Nepal Himalaya (Olsen and Larsen 2003). It also

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contributed US$ 422,000 to the total revenue collected by the Nepalese government from the forestry sector in 2011. Among more than 150 species of NTFPs traded in Nepal, the most expensive and unique item is Chinese caterpillar fungus or caterpillar fungus \[\text{Ophiocordyceps sinensis} \text{ (Berk.) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora}\], an endemic fungal species found in the Himalayas and Tibetan plateau. It is popularly called \textit{Yartsa gunbu} (dbyar rtswa dgun 'bu) in Tibet, meaning “summer grass winter worm” (Winkler 2009), and in Nepal it is called \textit{Yarsagumba} or \textit{Yarsagunbu} (Shrestha et al. 2010). Although its literal meaning is closer to the life cycle, it is neither a grass nor a worm, but a parasitic complex formed by a parasitic relationship between the fungus \textit{Ophiocordyceps sinensis} with caterpillar of the “ghost” moth species belonging to genus \textit{Thitarodes} (Winkler 2009). The fungus spores are released from stroma and infect the host caterpillar inhabiting the soil. Following the period of host dormancy, the fungus grows and spreads inside the host caterpillar, killing it by consuming the essential nutrients (Cannon et al. 2009). The fungus finally forms one or more stroma from the head of the buried caterpillar (Winkler 2009). The fungal stroma grows to 2–6 cm or more above the soil surface in spring, when the stroma are harvested combined with the buried mummified caterpillar (Figures 1F and 1G).

The Chinese caterpillar fungus is found in high-elevation (3,500–5,000 m.a.s.l.) grasslands in China, Nepal, India, and Bhutan (Cannon et al. 2009; Devkota 2010; Singh et al. 2010; Li et al. 2011; Shrestha and Bawa 2013). It has been used
in Traditional Chinese Medicine (TCM) for at least 2,000 years (Shrestha et al. 2010) and documented in Tibetan medicine for more than 500 years (Winkler 2009). Therapeutically, it is used to strengthen lung and kidneys, increase energy and vitality, stop hemorrhage, and decrease phlegm (Holliday and Cleaver 2008). A recent study showed that it is effective as an anti-aging and antitumor agent (Wong et al. 2010). Nevertheless, the major trade of Chinese caterpillar fungus occurs with the popular name “Himalayan Viagra” for use as an aphrodisiac and tonic (Holliday and Cleaver 2008; Winkler 2009). It has traditionally been used as a tonic to enhance sexual power, and also to treat diarrhea and rheumatism in Dolpa, Nepal (Devkota 2006). It is administered in various ways: it is consumed with milk or with homemade liquor in Dolpa, Nepal, or it is taken by boiling the whole organism in water or soup in Tibet (Pegler et al. 1994); in Bhutan it is consumed in a hot soup composed of homemade liquor (Cannon et al. 2009).

Chinese caterpillar fungus is one of the most expensive natural medical resources in the world (Stone 2008; Shrestha 2012). In September 2012, the highest price of Chinese caterpillar fungus in China—the major trade destination—was $140,000/kg, three times more expensive than gold (Xuan 2012). Although the market price is remarkably high, the Chinese caterpillar fungus is harvested by the most impoverished communities of the Himalayas and Tibetan plateau. In Nepal, after the ban was lifted on harvesting and trade in 2001, Chinese caterpillar fungus harvesting became a major source of cash income for indigenous communities who had limited livelihood options due to the remoteness and harsh environmental conditions of their areas, which are also the areas where Chinese caterpillar fungus habitat exists. Chinese caterpillar fungus is reported to be collected from at least 27 northern mountainous districts of Nepal (Devkota 2010). Harvesting of Chinese caterpillar fungus provides lucrative income to the local communities in these areas. Local media reported that harvesters of Mugu district in Nepal sold 400 million Nepalese rupees ($4,700,000) of Chinese caterpillar fungus in 2012 (Shahi 2012). Chinese caterpillar fungus contributes about 40.5% to total NTFPs revenue collected by the Department of Forests, Government of Nepal, from 62 species of NTFPs in 2011 (Government of Nepal [GoN] 2011).

Because of the high market price, the income from Chinese caterpillar fungus harvesting has improved local food security, provided a much-needed safety net, and generated employment opportunity for the people in this region. The lucrative income from Chinese caterpillar fungus harvesting is a large incentive to increase the number of harvesters and the intensity of the harvest in recent years. Conservative estimates suggest that roughly 50,000–69,000 people are involved in Chinese caterpillar fungus harvesting every year in Dolpa district, Nepal (Devkota 2010; District Forest Office [DFO]-Dolpa 2010), and the number is growing continuously. Therefore, sustainable management of this resource has been a pressing socioeconomic as well as environmental issue in the region. There is a widespread concern about the sustainability of the current harvest rates of this species (Cannon et al. 2009; Zhang et al. 2012; Shrestha and Bawa 2013), but the harvesting practice and its impact on the sustainability of the species are largely undocumented. This study aims (1) to document harvesting techniques and patterns of harvesting of Chinese caterpillar fungus; (2) to quantify trends of daily harvest; and (3) to examine the perceptions of the harvesters regarding their harvesting practices and their implications for sustainability.
Study Area

This study was carried out in the remote alpine pastures of Majphal Village Development Committee (VDC) area in Dolpa District, Nepal (Figure 2), in May–July 2011 and 2012. Dolpa District is regarded as a major warehouse of Chinese caterpillar fungus in Nepal, contributing 40% of the Nepalese supply in 2011. It is the largest district out of 75 districts of Nepal with an area 7,932 km², but is sparsely inhabited with population density 5 person/km² (Central Bureau of Statistics [CBS] 2011). Dolpa District is located within the trans-Himalayan zone with elevations of between 1,275 and 7,625 m.a.s.l.; approximately 31.48% of the area of Dolpa is covered by grassland, which makes it a suitable habitat for Chinese caterpillar fungus.

According to harvesters and traders, the Chinese caterpillar fungus collected from Dolpa is large, has an attractive golden color, and is therefore paid for at a higher price; it is preferred by traders. It is collected from 24 pastures in Dolpa district (DFO-Dolpa 2010); among these, five (Saikumari, Pokepani, Ruppatan, Chinarangsi, and Batule) are located in the Majphal VDC area. This study covered the harvesters collecting Chinese caterpillar fungus in Saikumari, Chinarangsi, Ruppatan, and Batule. Harvesters coming from different parts of Dolpa District (local) and adjoining districts (nonlocal) set up camps in three localities: Tarpare (28°53′15.7128″ N, 82°46′56.8806″ E, 4,016 m.a.s.l.), Opa (28°51′20.7102″ N, 82°35′8.664″ E, 3,841 m.a.s.l.), and Baghdanda (28°51′52.416″ N, 82°47′2.313″ E, 3,743 m.a.s.l.). The camp locations are permanently fixed and assigned by a local institution, the Toridwari Jadibuti Sankalan Tatha Byabasthapan Sameetee (Toridwari Herbs Collection and Management Committee). A representative sample of the harvesters from 4 districts, 18 VDCs, and 50 villages was surveyed in 3 camp sites. According to the revenue record of Toridwari Herbs Collection and Management Committee, there were about 2,600 collectors in three camps combined in the third week of May 2011. This committee was formed by local residents in three villages (Durgaun, Tali, and Thargaun) of Majphal VDC in 2005 to regulate Chinese caterpillar fungus harvesting, to prevent poaching, and to collect fees from the harvesters.

Figure 2. Map of the study area.
Method

Data were collected through key informant interviews, focus-group discussions, formal and informal communications, and direct field observations. Qualitative information on harvesting techniques was gathered through focus-group discussions, direct observations, and informal interviews, whereas the quantitative information was gathered by a survey. Written consent from the respondents was secured before the interviews and discussions by explaining the study objectives. All interviews were conducted in Nepali, the common language of communication in the region.

The sampling protocol involved the following. We limited the survey to harvesters with a minimum of 5 years of experience in collecting Chinese caterpillar fungus. We developed a list of all harvesters and put each of their names on a slip of paper that was placed in a box, and the interviewees were randomly chosen. A substitute was used if the randomly drawn respondent was not available or declined to be interviewed.

Interviews were conducted during May–June 2011 in the evening when harvesters returned to their camps from the pasture after harvesting. We interviewed a total of 203 harvesters (~10% of total and ~35% of the population who met the selection criteria of minimum 5 years of harvesting experience). We administered a questionnaire involving both structured and semistructured questions. Normally, Chinese caterpillar fungus harvesting begins the second week of May and lasts until the end of July, depending upon the locality. We were also able to develop a record of daily harvest of 150 harvesters for 1 month during May–June 2012 (i.e., they kept track of the number of pieces collected each day). However, we used data of only 91 harvesters for 29 days for further analysis, excluding 59 incomplete records. In addition, we used recall to quantify the number of Chinese caterpillar fungus collected on the first day of collecting seasons each year from 2009 to 2012 by 126 harvesters we encountered in the collection area during different dates of the survey period.

We also documented harvesters’ perceptions on collection patterns, harvesting modes, resource abundance, and sustainability. Furthermore, we conducted nine focus-group discussions and several informal meetings with four local committee leaders, four school teachers, and five government officials. We used the focus-group discussions to compare the information we gathered from individuals. We also gathered trade information by interviewing 28 village- and district-level traders at collection camps and in Dunai, the district headquarters of Dolpa. The data were analyzed using PASW (Predictive Analytics Software) Statistics 18.

Results

The Harvesters

In recent years, Chinese caterpillar fungus harvesting has become an important activity in the mountain regions of Nepal where they are found. Although local communities have been collecting and personally using Chinese caterpillar fungus for decades, the trade and commercial harvesting began around 1987–1988 in Nepal. People of various ethnic groups, ages, professions, and educational levels are involved in Chinese caterpillar fungus harvesting during the harvesting season (Table 1 and Figure 1E). With poorly developed physical infrastructure coupled with
geographic remoteness, harvesters must walk for up to 5–6 days to reach the Chinese caterpillar fungus collection areas.

Both men and women were actively involved in Chinese caterpillar fungus harvesting. Among harvesters, on average 48.2 ± 24.2% of the family members engaged in Chinese caterpillar fungus harvesting; only old people and toddlers remained in the villages, and hence villages surrounding the collection areas are literally empty during the harvesting season. Average age of the harvesters we interviewed was 31 ± 11 years but direct observation suggests their ages range from less than 10 to more than 65 years.

Approximately 38.4% of those interviewed brought children and 28% were students, studying in high school to graduate school. Harvesters completed an average of 7.10 ± 4.32 years of education, but 21.2% of the harvesters were illiterate. All educational institutions in this region were closed for 4–5 weeks during the collection season to permit students and teachers collect the fungus. The income from collecting this fungus is a much-needed boon for students because they can buy educational materials, pay tuition, and obtain spending money, and even buy expensive mobile phones. There are several reasons why collectors reported taking children to the cold and harsh collection areas (Table 2). About 32.1% of the respondents did so because they thought a greater number of family members can collect more fungus. About 29% of the harvesters said that children have sharp vision and thus can collect more, whereas 30% of parents brought children because schools were closed and there was nobody at home to take care of them. Based on informal interview with children and parents, we observed that most of the children were very willing to participate.

Due to the minimal areas suitable for agriculture in this region and low productivity of the land, Dolpa is regarded as a food-insecure district in Nepal. Only 31% of the Chinese caterpillar fungus harvesters in the study area have sufficient agriculture crops to feed their families; 69% have insufficient food from their agricultural activities for the year. On average they had sufficient food for 6.2 ± 1.9 months. For the remaining months they rely on food supplied by the government or other aid agencies, or seasonal labor. Selling fungus has become the second most important livelihood for the local communities next to agriculture; 79.8% ranked agriculture as the most important livelihood strategy, compared to 63.5% who answered with Chinese caterpillar fungus collection.

Table 1. Summary of the harvesters’ characteristics from surveys

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of respondents</td>
<td>203 (170 male, 33 female)</td>
</tr>
<tr>
<td>Number of respondents from outside Dolpa (outsiders)</td>
<td>76</td>
</tr>
<tr>
<td>Number of respondents from Dolpa (native)</td>
<td>127</td>
</tr>
<tr>
<td>Average family size</td>
<td>5.94 ± 2.40</td>
</tr>
<tr>
<td>Average percentage of family members involved in harvesting</td>
<td>48.2 ± 24.2%</td>
</tr>
<tr>
<td>Average age of respondents (years)</td>
<td>31 ± 11</td>
</tr>
<tr>
<td>Number of food sufficient months</td>
<td>6.2 ± 1.9</td>
</tr>
<tr>
<td>Average education years of respondents</td>
<td>7.10 ± 4.32</td>
</tr>
<tr>
<td>Average years of harvesting experience</td>
<td>7.7 ± 3.89</td>
</tr>
<tr>
<td>Average days of walking from their home to harvesting localities</td>
<td>2.17 ± 1.65</td>
</tr>
</tbody>
</table>

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The collected Chinese caterpillar fungus are typically sold to either middlemen who come to the camp or in the village after the collectors return. In the majority of cases, harvesters were paid in advance by middlemen and hence they sold the fungus before returning home. Middlemen lend cash to the harvesters during the time of cash shortage with the promise that harvesters will sell their collected fungus only to them. Middlemen are often local people who work on commission either with district-level traders or with traders from Kathmandu. The traders of district headquarter either supply to the bigger traders of Kathmandu or export Chinese caterpillar fungus directly to China (Tibet), Hong Kong, and Singapore.

**Camping**

Harvesters set up camps (Figure 1A) 3–4 days before the harvesting formally begins. Camps involve either a single family or multiple families, depending upon the size of the camp. We found 2–21 harvesters occupying a single camp. Previously, camps were located within the habitat of Chinese caterpillar fungus, but from 2008 the local committee prohibited this practice and designated fixed camping sites 3–5 km away from the collection area. We observed a total of 495 camps in three localities of the

<table>
<thead>
<tr>
<th>Table 2. Harvester’s reasoning about informed harvesting, termination of harvesting, bringing children in pasture, and rotational harvesting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvesters’ response</td>
</tr>
<tr>
<td><strong>How do you know about harvesting for the first time?</strong></td>
</tr>
<tr>
<td>Villagers</td>
</tr>
<tr>
<td>Traders</td>
</tr>
<tr>
<td>Early childhood</td>
</tr>
<tr>
<td>Media</td>
</tr>
<tr>
<td><strong>What are the reasons for ending the harvest?</strong></td>
</tr>
<tr>
<td>Don’t find continuously for 3–5 days</td>
</tr>
<tr>
<td>Household tasks back in home (e.g., agriculture)</td>
</tr>
<tr>
<td>Start finding “date expired” ones (with dark color and shrunken caterpillar part)</td>
</tr>
<tr>
<td>Start greening of the pasture and can’t see anymore</td>
</tr>
<tr>
<td>Poor health condition</td>
</tr>
<tr>
<td>Food finished and can’t afford more</td>
</tr>
<tr>
<td><strong>Why do you bring children in the pasture?</strong></td>
</tr>
<tr>
<td>Children have sharp vision</td>
</tr>
<tr>
<td>More people can collect more</td>
</tr>
<tr>
<td>Schools are closed</td>
</tr>
<tr>
<td>Nobody is at home to take care of children</td>
</tr>
<tr>
<td><strong>Do you change the collection locality?</strong></td>
</tr>
<tr>
<td>Collect in same locality every year</td>
</tr>
<tr>
<td>Change localities every year</td>
</tr>
<tr>
<td>Change localities in every 2 years</td>
</tr>
<tr>
<td>Collect wherever possible</td>
</tr>
</tbody>
</table>
study area during the first week of the collection season; by the end of the fourth week the number of camps was reduced by 32% in Opa, 31% in Bagdanda, and 39% in Tarpare. Fuel wood was the only energy source for cooking and heating. Camps were normally made by setting up plastic tents involving tree branches, and had poor sanitation and heating. There was no provision for solid waste management.

**Beginning and Ending of the Harvest**

Harvesting formally starts on May 23 (Jestha 10 in local calendar) every year in all collecting areas in Dolpa with few exceptions. The opening date has become a tradition and was fixed by a meeting between local organizations (which are responsible for managing the collection pastures and issuing collection permit), the district forest office (which issues trade permits), the security agency (provides security to the harvesters), and other stakeholders (representatives of political parties and the district development committee). The opening date was broadcasted on local FM radios once fixed.

When formal harvesting begins, the harvesters must walk 3–4 hours each way daily from the campsites to the Chinese caterpillar fungus habitat for day-long foraging. Although opening date of harvest was normally fixed, dates for leaving the pasture (end of collection) vary depending upon the harvest, food availability, personal health, and urgency of other tasks back at home. In general, harvesters stop harvesting when they decide the harvest rate has become uneconomic; about 67% of harvesters returned home if they didn’t find any Chinese caterpillar fungus continuously for 3–5 days, about 14% harvesters returned home after they started finding lesser quality fungus (i.e., with dark colored and shrunken caterpillar parts), and 9% returned home due to agricultural demands such as weeding maize and harvesting of wheat at home (Table 2). Most collectors had left the area after about two months.

**Harvesting Techniques**

A photographic display of harvesting, cleaning, and drying techniques is provided (Figure 1B, 1C, and 1D). Harvesters hunted fungal stroma of the Chinese caterpillar fungus that emerges ~2–6 cm above ground in the pasture with their naked eye. The fungus was uprooted with the help of small hoe, knife, or stick. Most of the harvesters removed the top part of the fungal stroma immediately after uprooting it, with a belief that keeping the stroma would cause the host caterpillar to become empty and reduce the value of Chinese caterpillar fungus. Daily harvested Chinese caterpillar fungi were cleaned with a toothbrush to remove soil and humus, and dried by placing them in a soft cloth bag.

Besides quantity, harvesters were looking for quality harvest. The size and color of the caterpillar were the most desired characteristics. Cleanliness, dryness, and to a lesser extent aroma were also characteristics preferred by the traders. We found that 53% traders ranked the size (of caterpillar part) as first preference and 47% ranked color as second. As noted earlier, fungi that were larger, compact, and of golden color were purchased for more than the smaller, baggy, and darker ones. Harvesters perceived that fully grown stroma with spores had exhausted the caterpillar inside the soil, and they referred to them as “date expired ones”; these are purchased for
less (about half of the price) by traders. By preferring large sizes of caterpillars, harvesters apparently were seeking the Chinese caterpillar fungus with smaller fungal parts and preferred to collect Chinese caterpillar fungus before sporulation. We observed 1,257 specimens collected by the harvesters on different dates and found that only 5.6% specimens had a spore on them.

Temporal and Spatial Patterns of Harvest

The Chinese caterpillar fungus is collected from open access pastures. However, local communities claim a customary right based on the traditional usage of the pastures. Local communities have formed formal and informal institutions (village committee) to manage this resource. The starting day of harvest was very important as the collection pastures were safeguarded from intruders that come from outside villages and unauthorized collection was prohibited prior to the beginning of harvest. The local village committee deployed armed volunteers with locally made rifles 20 days before the harvest began, to stop poaching. Conflicts between local volunteers and poachers are common and these sometimes turn violent and even cause death. Local volunteers take an oath of honesty and integrity to report intruders, an oath taken in a religious shrine by dipping their hands in the blood of sacrificed animals. This is because the likelihood of collecting more fungus on the opening day was very high. The average first day collection in 2012 was 16 (\( n = 91 \)) pieces/person and the number declined significantly in subsequent days. Minor peaks were observed in a week interval but there was no clear pattern in the daily harvest (Figure 3A). Harvesters collected every specimen of Chinese caterpillar fungus wherever and whenever they encountered them for the two-month period recurrently, suggesting that harvesting runs until Chinese caterpillar fungus is not available. By the end of the season, not a single inch of the land was left unsearched. Our data showed that the reported number harvested in the first day has been declining for last four years, from an average 59 (\( SD = 63, n = 125 \)) pieces in 2009 to 17 (\( SD = 15, n = 125 \)) pieces in 2012, a significant decline of 15 pieces per person per year (\( SE = 1.79, p < .0001 \)) (Figure 3B).

We documented the spatial pattern of harvesting locations: Most of the local harvesters collected Chinese caterpillar fungus from the same pastures every year; however, nonlocal collectors selected pastures based on abundance and quality of Chinese caterpillar fungus, security, easy access, and water source. About 65% of the harvesters—most of them were local—collected Chinese caterpillar fungus at the same location every year, whereas 21% of harvesters collected wherever possible and 11% changed the locations every year (Table 2). As noted earlier, searching for Chinese caterpillar fungus is very intensive; harvesters search an entire pasture without leaving an inch unexamined. As snow melts, it opens up the newer areas. Searching and finding might overlap with the regeneration of Chinese caterpillar fungus.

Perceptions about Abundance and Sustainability

Most harvesters (71%) thought that it has become more difficult to find Chinese caterpillar fungus, whereas 3.9% thought it had become easier (Figure 3C). We asked harvesters if they thought they could continue to find Chinese caterpillar fungus in the future based on the current trend and mode of harvests. We found that harvesters were concerned about conservation and sustainability of the resource:
67% harvesters considered that the current harvesting practice of collecting entire specimens without leaving them for regeneration was unsustainable, while 30% believed that it was sustainable (Figure 3D).

Discussion and Conclusion

Trade and collection of nontimber forest products including medicinal plants have a long history in the Himalayas (Olsen 2005), but harvesting of Chinese caterpillar fungus has become extremely popular in recent years, surpassing all other species in terms of revenue. It has become an undeniably important part of local livelihoods in Dolpa and similar mountains areas of Nepal. During the collection season (May–July), entire villages were emptied, which is similar to the situation in China; about 80% of families in the major production areas of China are involved in Chinese caterpillar fungus harvesting, and cash income from sales of this resource accounts for 50% to 80% of their total income (Weckerle et al. 2010; Ma 2010). Likewise, in Bhutan, contribution of Chinese caterpillar fungus to local livelihood ranges from 60% to 100% (Shrivastava 2010). This provides sufficient evidence that a significant portion of the population in mountain communities in this region is involved in harvesting fungus. Therefore, sustainable management of this species is crucial to
sustaining the livelihood of impoverished mountain communities with limited livelihood options.

Ma (2010) conservatively reported that about 300,000 Chinese citizens are involved in harvesting of this resource in China; a similar estimate in Nepal suggests that 50,000–69,000 people are involved in Dolpa alone (Devkota 2010; DFO-Dolpa 2010). With these figures, given the smaller land areas suitable for the Chinese caterpillar fungus habitat in Nepal compared to China, per-capita pressure and intensity of harvest are much higher in Nepal than in China. China accounts for 90% of production areas of Chinese caterpillar fungus and shares 90% to 95% of annual production of Chinese caterpillar fungus globally, compared to 1% to 3% share of Nepal (Winkler 2009). Furthermore, the harvesting practice in Nepal is relatively newer than it is in China; therefore, formation of governance institutions, development of sustainable harvesting guidelines, and regulation of collections to conserve this species are relatively rare in Nepal.

Our data suggests declines are occurring on the first day of collection. This finding is similar to the trends reported by Shrestha and Bawa (2013), who showed that the harvest has decreased significantly from $261 \pm 212$ in 2006 to $126 \pm 97$ pieces/person in 2010, suggesting overexploitation of the species (Shrestha and Bawa 2013). Yield decline by 70% from 1978 to 2001 is reported in China (Tsim and Shao 2005). In Bhutan, 70% of harvesters viewed overexploitation and habitat destruction of Chinese caterpillar fungus as major factors for the decline (Shrivastava 2010).

Along with various anthropogenic and ecological causes including increasing number of harvesters, the harvesting technique and harvesters’ preferences can also have a detrimental impact on the natural population of Chinese caterpillar fungus. Most of the harvesters are motivated by an “if not taken by me another will” attitude, which leads them to search the entire habitat and harvest all the specimens they find. It is the leftover specimens that are able to disseminate spores for regeneration, and these are only the ones not seen and hence not collected by harvesters. With huge number of harvesters, the number of specimens left is obviously few. Furthermore, the tendency to harvest non-spore-producing specimens precludes sporulation and thus impedes regeneration. The practice of harvesting non-spore-producing Chinese caterpillar fungus, although undermines spore distribution, could paradoxically serve as a means to sustain the population of the host moth since it would be less of a sacrifice to leave it in the ground (Stewart 2009; cf. Winkler 2009). However, there is no evidence of such impact; nonetheless, the harvesting data showed continuous declining trends. Furthermore, the ecological impact of a large number of harvesters on the host species and food plant species of the host is unknown.

Government data revealed that trade volume in Dolpa has continuously increased from 2002 to 2009 and decreased thereafter (Shrestha and Bawa 2013). Since the life cycle of the host larvae completes in 2–3 years or more and the living larvae can be alive for 2–3 years (Zhang et al. 2012), the current population might have been sustained by the caterpillars infected 3–4 years ago, with the population starting to dwindle now. However, the empirical evidence for the impact of such extensive harvest on regeneration is lacking in China, Nepal, and Bhutan. Similarly, the impact of harvesting on larvae and moth population is largely unknown (Winkler 2009). In addition to collection of Chinese caterpillar fungus, damage to the caterpillar by harvesters and livestock grazing might also be responsible for the decline of this resource. We observed that any living caterpillar of this species encountered by the harvesters was either brought home or swallowed or killed by the harvesters.
on the spot. The magnitude of harvesting is likely to be a significant factor in the reduction of host caterpillars and subsequently on trade volume.

The impact of fuel wood, open defecation, and amassing solid waste in the landscape can be easily observed, although the impact of these activities on the local ecosystems has not been closely studied or measured quantitatively. In Nyingchi district of Tibet, 100,000 m² of grasslands is disturbed each year by Chinese caterpillar fungus harvesters (Zhou et al. 2009; cf. Zhang et al. 2012). Soil compaction was visible as a result of excessive movement of harvesters. Older harvesters recalled that 15–20 years ago they did not require a hoe but used their fingers to uproot the fungus, but now a hoe is compulsory because of the compacted soil. Local harvesters also bring cattle with them and these are now grazing in areas that were not grazed before. Furthermore, cattle are now being brought to highland pastures earlier in the season and kept for a longer period in the collection pastures than before; this may contribute to overgrazing and higher soil compaction, with subsequent degradation of the pasture. It is necessary to measure the environmental costs of harvesters’ broad range of activities to identify sustainable management of this resource.

Efforts toward conservation and sustainable management have been initiated in this region but have been slow. The State Council of the People’s Republic of China listed Chinese caterpillar fungus as an endangered species in 1999 (Zhang et al. 2012). Three relevant laws, Qinghai Ophiocordyceps Collection Management Regulations, Tibet Ophiocordyceps Collection Management Regulations, and Ganzi Tibetan Autonomous Prefecture Ophiocordyceps Collection Management Regulations, are operational in China to regulate the collection of Chinese caterpillar fungus (Guo et al. 2012). Regulatory mechanisms including antipoaching measures were developed in Bhutan (Cannon et al. 2009). This species has been listed in Schedule 1 of the Forest and Natural Conservation Act of Bhutan (Government of Bhutan [GoB] 2002; cf. Cannon et al. 2009). Strict regulation of central government of Nepal (ban on collection, trade, distribution, carriage, and export) based on Forest Act 1993 (His Majesty’s Government of Nepal [HMGN] 1993) and Forest Regulation 1995 (HMGN 1995) has become unsuccessful in Nepal due to the remoteness of the habitat and inadequate government presence in those areas to prevent unauthorized harvest; therefore, it was lifted in 2001 in Nepal. A similar situation of failure of a strict ban occurred in Bhutan and the ban was lifted in 2004. Instituting a ban on harvesting would have a detrimental impact on people’s livelihood.

Belcher and Schreckenberg (2007) suggest that intensification through management and cultivation when populations are low and demand and competition are high would help to sustain species. However, the complex biology of this species becomes a major hurdle for artificial cultivation (Zhang et al. 2012). Although artificial culture of the fungal part of Chinese caterpillar fungus was claimed and patented (Cleaver et al. 2011), successful production of Chinese caterpillar fungus with caterpillar has not as yet been reported. Providing higher economic incentives to the local harvesters who comply with harvesting guidelines might motivate sustainable harvest (Varghese and Ticktin 2008). However, existing institutions cannot offer sufficient economic incentives to the harvesters because of the high market value. In Bhutan, Chinese caterpillar fungus is marketed in auctions administered by the central government, which gives harvesters more bargaining power (Cannon et al. 2009).

In an open-access situation, a necessary first step for sustainable management of natural resource will be the creation of institutions governing resource access and use
(Belcher and Schreckenberg 2007). Such institutions have begun to be formed in various parts of Dolpa and other parts of Nepal by local communities for management and conservation of Chinese caterpillar fungus. Some regulations such as a ban on cutting green trees, recycling of solid wastes, taxing systems, fixed opening date for the harvest, and in some areas rotational harvesting have been practiced by such nascent institutions. However, the management capacity and governance structure of such local institutions are poor. We also observed that local people are unaware of the ecology and natural history of Chinese caterpillar fungus. Guidelines for the sustainable governance of common resources exist and could inform this situation. These include those suggested by Ostrom (2007) as well as others: Strong local institutions, local participation, equitable distribution of economic benefits, and secure rights are key factors necessary for sustainable management of resources (Brooks et al. 2012). Furthermore, the cooperation between national, regional, and local institutions is very important for sustainable management of the resource (Ostrom 1999).

In conclusion, sustainable use of a resource demands consideration of many interlinked dimensions of ecology, biology, social, culture, and economy (Ghimire et al. 2005). Therefore, those creating interventions in Nepal to develop government policy related to the sustainable management of Chinese caterpillar fungus (e.g., Forest Act 1993 and Forest Regulation 1995 of Government of Nepal) would be advised to pay greater attention to building strong governance institutions, including raising the capacity of local communities, to strengthening fair regulatory mechanisms, to investing in science generating knowledge on ecology and biology of the species, and to increasing awareness and incentives among harvesters to adhere to evolving best management practices.

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