Trade, harvest, and conservation of caterpillar fungus (Ophiocordyceps sinensis) in the Himalayas

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Abstract

Unsustainable trade in wildlife is regarded as a major driver of biodiversity loss and ecosystem degradation. Unregulated wildlife trade propels over-exploitation of species, resulting in population declines, and often in combination with other factors may ultimately extirpate species from their natural habitats. Concern about the impacts of trade on biodiversity has largely focused on flagship animal species. Here, we report on the impact of trade on natural populations of the world’s most expensive biological resource, a unique caterpillar fungus (Ophiocordyceps sinensis). Based on interviews with 203 harvesters and 28 traders, and focus group discussions in Dolpa, Nepal, we quantify the amount of harvest and trade. After legalization of trade in Nepal in 2001, trade volume increased persistently, reaching a peak of 2442.4 kg in 2009 and subsequently declining to 1170.8 kg in 2011. The local market price has increased by up to 2300% over the last 10 years. However, mean annual harvest declined from 260.66 ± 212.21 pieces per person in 2006 to 125.82 ± 96.84 pieces per person in 2010. Our analysis of harvesters’ perceptions of resource abundance and sustainability shows that virtually all harvesters (95.1%) believe the availability of the caterpillar fungus in the pastures to be declining, and 67% consider current harvesting practices to be unsustainable.

1. Introduction

Unsustainable wildlife trade is regarded as a major driver of biodiversity loss and ecosystem degradation (Broad et al., 2003). Because local harvests are often guided by demand and price in regional and global markets (Weckerle et al., 2010), rising prices can result in over-exploitation of many species leading to population declines in their habitats (Nijman, 2010). Studies on the impact of commercial trade on biodiversity are largely focused on flagship species of mammals (Corlett, 2007), amphibians and reptiles (Schliewen et al., 2005), and fishes (Sethi et al., 2010) that have been commercially traded for relatively long periods of time. Here, we report the impact of trade on natural populations of a comparatively new natural commodity on the international stage, the caterpillar fungus complex.

1.1. Species

The caterpillar fungus is celebrated for its extensive medicinal use, extraordinary life history, and high market value. The fungus is believed to strengthen lung and kidneys, increase energy and vitality, stop hemorrhage, and decrease phlegm (Holliday and Cleaver, 2008). A recent study seems to show anti-aging and anti-tumor effects (Wong et al., 2010). However, the caterpillar fungus is widely traded as an aphrodisiac and a powerful tonic (Holliday and Cleaver, 2008; Winkler, 2010a,b), and it has been hyped as a ‘Himalayan Viagra’ by popular media including The Wall Street Journal, The Economist, and CNN.

In Tibet, the caterpillar fungus is popularly called ‘Yartsa gunbu’, literally meaning ‘summer grass winter worm’ (Holliday and Cleaver, 2008); in Nepal it is ‘Yarsagumba’ and ‘Kira’ in Dolpa. However, it is neither a grass nor a worm, but a parasitic complex formed by the relationship of the fungus Ophiocordyceps sinensis (Berk.) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora with the larval stage of several species of moth (known as ‘ghost moth’) belonging to the genus Thitarodes (Winkler, 2010a). More than 50 species belonging to the family Hepialidae (Lepidoptera) are reported as the hosts of caterpillar fungus (Wang and Yao, 2011). Thitarodes spp. spend much of their life-cycle as winter-dormant larvae. After several years feeding on roots underground, the larvae pupate, reaching adult stage in early summer (Cannon et al., 2009). The fungal propagules are released from the stromata in late summer and infect the host caterpillar residing in the soil. Following the period of host dormancy, the fungus grows and spreads inside the host caterpillar, finally killing it by consuming the essential nutrients (Cannon et al., 2009). The fungus then enters a mycelial stage and infect the host caterpillar residing in the soil. Following the period of host dormancy, the fungus grows and spreads inside the host caterpillar, finally killing it by consuming the essential nutrients (Cannon et al., 2009).
Ophiocordyceps sinensis is restricted to high altitudes of the Himalayas and Tibet. It is found in alpine and sub-alpine pastures above tree line, having been recorded at elevations of 3540–5050 m in Nepal (Devkota, 2010), 4200–5200 m in Bhutan (Cannon et al., 2009), 3200–4200 m in India (Singh et al., 2010) and 3000–5000 m in Tibet (Winkler, 2010a).

Although the caterpillar fungus has presumably been used in traditional Tibetan and Chinese medicine as a tonic and aphrodisiac and as a relif medicine for lung, liver and kidney problems for centuries, it emerged as a significant market commodity only after economic liberalization in China in the 1980s (Winkler, 2010a). Global trade rapidly expanded after the 1993 World Athletic Championships in Stuttgart, Germany, when Chinese athletes–reportedly training on dietary supplements of Ophiocordyceps and turtle blood–set multiple records in distance running (Winkler, 2010b).

Today, it is the world’s highest-priced biological commodity (Stone, 2008), more expensive by weight than gold. Best quality fungus in China fetched up to US $100,000 kg$^{-1}$ (Yuan 650 g$^{-1}$) in March 2012 (Agile News, 2012), and in Singapore it reached US $130,000 kg$^{-1}$ (Leng, 2012) at a time when the price of gold was about US $68,000 kg$^{-1}$. On average, however, the retail price of the product ranges from US $45,000 to 90,000 kg$^{-1}$ (NPR, 2011; Agile News, 2012). Annual production in the Himalayas and Tibetan plateau is thought to be ~85–185 tons (Winkler, 2010a), yielding an astonishing total estimated current global market value of US $5–11 billion (Shrestha, 2012). From 1997 to 2008, the market price climbed by ~90% in Tibet (Winkler, 2010a), and from 2001 to 2011 by ~2300% in Nepal. Exploding market demand and the dramatic price increases of the last 10 years may pose a serious threat to the existence of this species in its native habitat. There is widespread concern about the sustainability of the current harvest rates of this species (Cannon et al., 2009), but the quantitative trends in harvest, trade, supply and demand are not well known. Here we: (a) quantify trends in harvest, trade, supply and demand over the last 5 years in Nepal Himalayas, a major supplier of caterpillar fungus in the global markets, and (b) document harvester perceptions of collection patterns, harvesting modes, resource abundance and sustainability, as well as trader perceptions of supply and demand. We show that the amount of caterpillar fungus collected in the field is sharply declining, and discuss the possible reasons for this decline.

2. Materials and methods

2.1. Study area

Field surveys to collect information on caterpillar fungus harvesting for this study were carried out in the remote alpine pastures of Majahal Village Development Committee (VDC) in Dolpa, western Nepal (Fig. 2), in the summer of 2011. Dolpa district is regarded as a major warehouse of caterpillar fungus, contributing ~40% of the total Nepalese supply in 2011. The caterpillar fungus of Dolpa is unusually large, has an attractive golden color, and, therefore, commands a higher price from traders (personal observation). The fungus is collected from 24 pastures in Dolpa district (DFO-Dolpa, 2010), among them five (Saikumari, Pokepani, Ruppatan, Chinarangsi, Batule) located in the Majahal VDC. This study addressed harvesters foraging caterpillar fungus in Saikumari, Chinarangsi, Ruppatan and Batule. Harvesters coming from different parts of Dolpa and adjoining districts set up camp for 2 months in three locations: Tarpore (28°53.15.7128’N, 82°46’56.8806’E, 4016masl), Opa (28°51’ 20.7102’N, 82°35’8.664’E, 3841masl) and Baghdanda (28°51’ 52.416’N, 82°47’2.313’E, 3743masl). Camp locations are permanently fixed and assigned by a local institution, Toridwari Jadibuti Sankalan Tatha Byabasthan Samitee (Toridwari Herbs Collection and Management Committee). A representative sample of harvesters from four districts, 18 VDCs and 50 villages were surveyed in these three camps. There were about 2600 collectors in three camps combined (A caravan of harvesters is shown in Fig. 3).

2.2. Data collection

Qualitative data were collected through key informant interviews, focus group discussions, informal communications, and personal field observations. The study proposal was approved prior to field research by the Institutional Review Board (IRB) of University of Massachusetts, Boston. Written consent was secured from all respondents before interviews and discussions by explaining the study objectives. Altogether we interviewed 203 harvesters (~10% of total and ~35% of the population of the three camps meeting the selection criteria—see below) with sets of structured and semi-structured questionnaires in harvester’s camp sites during May–June 2011.

We limited surveys to harvesters having at least 5 years experience of caterpillar fungus harvesting. We first collected and listed names of all harvesters in our pool with at least 5 years harvesting experience. Name slips were placed in a box and interviewees were randomly chosen through the lottery method and without replacement. A substitute was chosen if the randomly drawn respondent was unavailable or did not want to be interviewed. We asked about quantities harvested, number of days spent (effort) and sale price. We also documented harvesters’ perceptions of collection patterns, harvesting modes, resource abundance, and trends in success rate per unit effort. Furthermore, we conducted nine focus group discussions and several informal meetings with four local institution leaders, four school teachers, and five government officials. In the focus group discussions, we validated the information gathered from individuals. We also gathered trade information by interviewing 28 village and district level traders at the camps and in Dunai, the district headquarters of Dolpa and documented trader’s perception on trends of supply and demand. The data were analyzed using PASW 18. We used linear regression to observe harvest trends per capita.

3. Results

3.1. Trade in caterpillar fungus

Although trade in caterpillar fungus in Nepal started in 1987–1988 and may have started in Dolpa (unpublished data), it was only legalized in 2001, with the provision of revenue of 20,000 Nepalese rupees kg$^{-1}$ to the government. In 2006 the revenue amount was reduced to 10,000 Nepalese rupees kg$^{-1}$. Notable amounts of caterpillar fungus are traded without paying revenue, but revenue...
data are the only official source of information to quantify total amount of trade. According to revenue figures from the Government of Nepal, only 3.1 kg of caterpillar fungus was officially traded in 2002 from all of Nepal; trade volume reached a peak at 2442.4 kg in 2009 and then declined to 1170.8 kg in 2011 (Fig. 4A). From Dolpa district, 3.1 kg was marketed in 2002 (this was the only district of Nepal officially marketing the fungus in that year). Dolpa trade volume peaked at 872.4 kg in 2009 and then declined continuously to 473.8 kg in 2011. In that year, revenue on fungus trade was collected from five districts (Darchula, Dolpa, Jumla, Kathmandu and Myagdi), showing that trade has expanded spatially, despite falling total volumes characterizing the last few years.

3.2. Market price of caterpillar fungus

Along with the surging trade volume, the price of caterpillar fungus has also increased dramatically. Virtually no monetary value existed in 1987–1988; caterpillar fungus was traded for cigarettes, noodles, and other goods not easily available in the village (unpublished data). By 2001, Dolpa harvesters sold fungus for NRs 20–25 per piece, but they received NRs 200–600 per piece in 2011, representing an increase of ~900–2300% (Fig. 4B). Similarly, local traders sold one kg to wholesalers/exporters for NRs 80,000–130,000 in 2001, but received NRs 1,100,000–1,600,000/kg in 2011—an increase of ~1275–1131% (Fig. 4C). However, local market prices are erratic and large fluctuation is common, influenced by market demand, timing and location of trading.

3.3. Caterpillar fungus harvest

Caterpillar fungus is traditionally harvested by the poorest of the poor living in the high mountain regions of the Himalayas during May–July. The annual harvest per person ranged between 48 and 427 pieces (mean 260.66 ± 212.21, n = 167) in 2006; in 2010 it sank to between 28 and 123 pieces (mean 125.82 ± 96.84, n = 197). The average decline was thus 32.58 (SE = 3.70, P < 0.0001) pieces per harvester per year during the last 5 years (Table 1). Similarly, the average daily collection per person decreased by 3.14 (SE = 0.32, P < 0.0001) pieces per year during...
the same period. By contrast, the average number of collection days increased from 16.87 ± 10.89 (n = 167) in 2006 to 20.76 ± 10.34 (n = 197) in 2010 or a day (0.97) per person per year (SE = 0.25, P < 0.0001) (Table 1).

3.4. Local perceptions about trade and sustainability

Most traders believe that the demand for the caterpillar fungus has been increasing but the supply decreasing. Analysis showed that 64.3% of traders believe demand is increasing while 25.0% believe demand is decreasing (Fig. 5A). Regarding supply, 92.9% of traders believe supply is decreasing whereas 7.1% think there has been no change (Fig. 5B). This is reinforced by declines of ~28% in trade volume per trader during the last 5 years. The average amount of caterpillar fungus traded by a trader was 6.16 ± 5.45 kg (n = 28) in 2006, and 4.46 ± 3.84 kg (n = 28) in 2010. Furthermore, most of the harvesters (95.1%) believe that the availability of the caterpillar fungus in the pastures has decreased; only 1.0% believe that the amount of fungus has increased and 2.5% find no change (Fig. 5C). Therefore, most harvesters (70.9%) think it has become more difficult to find the fungus while only 3.9% think it has become easier (Fig. 5D). We asked harvesters if they expect to continue finding the fungus in future, assuming that current rate and mode of harvest continue. We

Table 1

<table>
<thead>
<tr>
<th>Year</th>
<th>Average total number of harvest per person (pieces)</th>
<th>Mean days of spending</th>
<th>Average per person per day harvest (pieces)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>260.66 (±212.21)</td>
<td>16.87 (±10.89)</td>
<td>19.63 (±17.98)</td>
</tr>
<tr>
<td>2007</td>
<td>222.12 (±189.86)</td>
<td>17.45 (±10.97)</td>
<td>16.73 (±17.51)</td>
</tr>
<tr>
<td>2008</td>
<td>186.60 (±152.23)</td>
<td>17.89 (±10.30)</td>
<td>13.31 (±14.69)</td>
</tr>
<tr>
<td>2009</td>
<td>164.04 (±124.26)</td>
<td>19.28 (±10.11)</td>
<td>10.12 (±8.54)</td>
</tr>
<tr>
<td>2010</td>
<td>125.82 (±96.84)</td>
<td>20.76 (±10.34)</td>
<td>7.25 (±6.63)</td>
</tr>
</tbody>
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found that many harvesters are concerned about conservation and sustainability of the resource: 67% consider current harvesting practices unsustainable while 29.6% believe it is sustainable (Fig. 5E).

4. Discussion and conclusion

Recently, Olsen and Larsen (2003) quantified trade in 11 species of medicinal plants in the Nepal Himalayas but excluded O. sinensis, perhaps because trade in this species was relatively insignificant at that time. This study documents trade volumes and provides the first quantitative analysis of trends in harvest for the caterpillar fungus in the Nepal Himalayas. Global production of caterpillar fungus is about 83.2 tons per year. China is the largest producer (80–175 tons), followed by Nepal (1.0–3.2 tons), India (1.7–2.8 tons) and Bhutan (0.5–1.5 tons) (Winkler, 2010a). However, the trade in caterpillar fungus is shrouded in secrecy. Thus uncertainty and margin of error associated with these figures might be high. Although Nepal’s share in the international trade of caterpillar fungus is nominal (up to 2%), Nepal is the second largest supplier of caterpillar fungus to the global market after Tibet, China. Therefore, the evidence provided here has significant implications for the overall scenario of trade, harvest and supply of caterpillar fungus. Our results showing recent explosive increases in caterpillar fungus trade and prices in Nepal are consistent with documented price increases in Tibet, the world’s major producer/supplier of caterpillar fungus (Winkler, 2010a).

Despite increases in price and demand, our results show that harvests at the local level are decreasing. Moreover, harvesters are experiencing declines in resource abundance. During our interviews with harvesters, Laxmi Karki (52) who has 20 years’ experience of collection and trading of caterpillar fungus recalled his old days as “15–20 years ago, people of Majpal VDC used to bring it in ‘Doko’ (a basket made locally by Bamboo) and wash it in ‘Dhara’ (tap water) and sell it in ‘Dharmi’ (local measurement unit, 1 Dharmi = 2.5 kg). Now, individuals are finding less than 100 pieces (30–40 g). Our pastures run out of ‘Kira’ (caterpillar fungus) in coming 10 years if current practices of harvesting continues.”

“A few people, who had connection with handful of traders, were involved in collection of caterpillar fungus 20–22 years ago. Now, you can see thousands of harvesters. The number of harvesters has increased a lot but amount of harvest has decreased in recent years,” said Bal Bahadur Lama (49), who claimed himself as a pioneer of caterpillar fungus trade in Dolpa. Our quantitative data also support the experiences of the veterans. The per capita harvest of caterpillar fungus has decreased significantly in the last 5 years (2006–2011). This trend could be attributed to increasing numbers of harvesters in recent years. Records of Toridwari Herbs Collection and Management Committee (the local institution managing pastures of the study area) based on the tax collected from individuals showed that the number of harvesters increased by at least 24% (~2100 harvesters in 2006 vs. ~2600 in 2010). But an overall decrease in total trade volumes, based on revenue data at the district and national levels, points to a sharp decline in the resource. Quoting local harvesters, the popular press has also reported a decline of the fungus in recent years (Taggart, 2012). District forest office of Dolpa estimates that about 50,000 people were involved in harvesting of caterpillar fungus during the 2010 season in Dolpa (DFO-Dolpa, 2010). Therefore, the intensity of the harvest and pressure on the resource due to this large number of collectors can be easily anticipated. Although it is not possible to attribute this decline to a single cause, over-harvesting and premature harvesting are likely to be important factors. We sampled 1257 individual caterpillars collected by 157 harvesters and observed by magnifying glass (20×) that 94.4% of the caterpillar fungi were reproductively immature—lacking spores in the stromata at the time of harvest. Therefore, current harvesting practice almost certainly impedes the timely release of spores into the soil, inhibiting reproduction. Most of the harvesters we interviewed are aware of these problems and consider current harvesting practice unsustainable.

Apart from over-harvesting and harvesting of immature individuals, other factors may be contributing to the decline of populations. These include (a) decrease in moth and larval populations due to loss or degradation of host plant resources for moths and larvae; (b) modification of the soil microhabitats congenial to fungal spores by the harvesters; (c) increased grazing intensity in high-altitude pastures as local harvesters take their cattle with them; and (d) climate changes. In Japan, along with market demand, loss of favorable habitat particularly mortality of host tree (Japanese Red Pine) has been implicated as the primary cause of decline of mycorrhizal mushroom—Matsutake (Tricholoma matsutake) (Saito and Mitsumat, 2008). In our case, the host populations of moths may have declined due to degradation of host food resources. Climate effects such as less snow, early melting of snow-pack, erratic rainfall, increased mean temperatures and increasing extremes in temperature and precipitation experienced by harvesters...
Decline in availability and calls for sustainable management have also come from Bhutan (Cannon et al., 2009), northern India (Negi et al., 2006), and Tibet (Stone, 2008) in recent years. Therefore, measures for the conservation of this species should be discussed and implemented at the regional scale throughout the Himalayas.

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References


