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ORIGINAL PAPER

People, money, and protected areas: the collection of the caterpillar mushroom *Ophiocordyceps sinensis* in the *Baima Xueshan* Nature Reserve, Southwest China

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Abstract The caterpillar mushroom *Ophiocordyceps sinensis* (syn. *Cordyceps sinensis*) is among the most valuable mushrooms in the world, and plays a major role for the local economies in its distribution area on the Tibetan Plateau and adjacent regions. Large proportions of its habitat fall into protected areas, and best practice of sustainable harvest is under discussion, considering both, *O. sinensis* as a valuable income source for rural poor and protection of its populations and habitat. This study aims for a detailed analysis of *O. sinensis* collection in a nature reserve in Southwest China. We found that harvesting is unevenly distributed among households and villages, with households who have access to the resource but lack adequate alternatives for income generation such as rewarding wage labor, fertile agricultural fields or harvest of other high value products being most involved. Although collection is de jure forbidden, authorities of the nature reserve apply adaptive management strategies for sustainable resource use. This includes the allocation of

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collection areas to communities based on their traditional land use strategies and the control of harvesters from outside, triggering self-policing of the resource by the local people. The strategies applied provide a promising model also for other protected areas where the caterpillar mushroom is collected.

Keywords Biodiversity conservation · China · Commons management · *Cordyceps sinensis* · Medicinal mushroom · Natural resources · Tibet · Yunnan

Introduction

Natural resources, livelihoods and conservation

Biodiversity rich areas tend to harbor a conspicuous cultural diversity, i.e. biodiversity hotspots are often inhabited by diverse ethnic groups with traditional livelihood strategies (Smith 2001). In all parts of the world, traditional livelihoods include the collection and use of wild natural resources in general and non-timber forest products (NTFPs) in particular. Conservation efforts thus not only have to address questions of the impact of harvest strategies on the environment but also on local livelihoods which depend on these resources. While the majority of the wild collected resources are directly used by the local people or are traded locally in small quantities (e.g. edible plants, medicinal plants, fuel wood or plants for religious use) some play a major role for local cash income and are traded on regional and international markets (for China e.g. Arora 2008; Weckerle et al. 2006; Winkler 2008). Commercial collection of natural resources is highly influenced by regional and global market conditions as well as fluctuations in demand and supply. When promoting NTFPs and other natural resources as means for livelihood improvement or conservation objectives, this complex network of interrelations between resource availability, local livelihood strategies, market demand, policies and environmental conditions has to be considered (Belcher and Schreckenberg 2007). The interrelation between natural resource utilization and conservation are thus multifarious and complex and various studies try to shed light on these networks of relations (see e.g. Cocks et al. 2008; Varghese and Ticktin 2008 and references therein).

Three main factors can be identified having a major impact on harvest pressures for commercially exploited natural resources, namely the biology of the collected species, access regime to the resource and the development of market prices. With increasing prices for a certain product, the number of harvesters tends to increase concurrently. This often takes place in areas with open access status without allocation of the resources and corresponding responsibilities to their sustainable management. Hardin's (1968) paper on open access resource management as the "tragedy of the commons" concluded that open access in combination with increasing demand inevitably leads to overexploitation of a given natural resource. However, sustainable management systems for natural resources do exist, and local communities may develop adaptive management practices to safeguard their livelihoods (see case studies by Basurto 2005; Berkes et al. 1989). Dietz et al. (2003) pointed out that the management of open access resources may be most sustainable when local communities understand the problems of commercial exploitation and can retain control over the management in close collaboration with all stakeholders. When protected areas are concerned, access to natural resources is discussed controversially, with

some scientists favoring a total exclusion of people and others supporting land use strategies sustaining local and often traditional livelihoods (Brechin et al. 1991; Galvin and Haller 2008; Holt 2005). In the latter case, clearly defined access regimes and harvest practices are needed, which allow for a sustainable use of the protected areas and resources.

The current paper analyses the network of interrelations between protected areas, livelihoods and market patterns in the case of *Ophiocordyceps sinensis* collection in Southwest China, a high value medicinal mushroom harvested from alpine grasslands in the Himalayas.

The caterpillar mushroom *Ophiocordyceps sinensis*

The caterpillar mushroom *Ophiocordyceps sinensis* (Berk.) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora (syn. *Cordyceps sinensis* (Berk.) Sacc.; Chinese: *Chongcao*; Tibetan: *Yartsa gunbu*), is among the most valuable mushrooms in the world, and plays a major role for cash income for local people in its distribution area on the Tibetan Plateau and adjacent regions (Winkler 2008). The fungus parasitizes the caterpillar of moth species belonging to the genus *Thitarodes* living in the soil of grass- and scrublands between an altitude of 3000 and 5000 m. The fungus grows in the body of the infected caterpillar, and before its death, the caterpillar moves close to the soil surface allowing the fruiting body of the fungus to develop above ground (for a detailed description of the ecology of the organism see Cannon et al. 2009). *Ophiocordyceps sinensis* is used since centuries in Tibetan and Chinese medicine. Recently, however, its use as a tonic and medicinal food increased dramatically mainly in Hong Kong, the wealthy coastal cities of China, and among the overseas Chinese communities (for an overview of its bioactive compounds and its pharmacology see Paterson 2008). While it is possible to cultivate the mycelium of the fungus on artificial substrate, attempts to cultivate the fungus on infected caterpillars, which are perceived as most valuable and effective, failed so far. Therefore, the increasing market demand has a direct impact on the wild harvest of the species on the Tibetan Plateau and adjacent regions. Winkler (2008) gives a comprehensive overview of the collection practices and the role of *O. sinensis* harvest on the Tibetan plateau. He states that the enormous price increase in recent years turned this fungus into the most important source of cash income in contemporary rural Tibet. However, little is known about the long term impact of its harvest on species population level. So far, conservation initiatives concentrate with various successes on minimizing the side effects of its harvest on the surrounding fragile alpine environment (e.g. fuelwood collection, hunting, garbage production, etc.; Cannon et al. 2009). Factors influencing *O. sinensis* collection at both the household and community level of the local people are largely unknown, and the discussion on best practice of sustainable harvest considering both, *O. sinensis* as a valuable income source for rural poor and protection of its habitat, is ongoing. The present paper aims to contribute to this discussion with a detailed analysis of the collection of the fungus in a nature reserve in Southwest China. It focuses on the household and community level and highlights the factors which influence the engagement of the local people with *O. sinensis* collection. The management measures of the nature reserve are analyzed from a community perspective and conclusions for sustainable harvest of high value natural resources in protected areas are drawn and discussed in the context of the literature available from other *O. sinensis* collection areas such as the Tibetan Plateau, Bhutan and Nepal.

Research area

The *Baima Xueshan* Nature Reserve

Baima Xueshan (literally: White Horse Snow Mountain) is one of over twenty 5000 m plus peaks in the area, and gives its name to the nature reserve in the very northwest of Yunnan Province. The *Baima Xueshan* (BX) Nature Reserve is located between 98°57′–99°25′ E and 27°24′–28°36′ N at altitudes between 2100 and 5500 m. With a total area of ~2820 km^2, which is divided into core, buffer, and experimental zones, it spans both Deqin county in the north and Weixi county in the south (Fig. 1). It is part of the 'Three Parallel Rivers of Yunnan Protected Area' and belongs to the Hengduan Mountains, one of the world's biodiversity hot spots recognized by Conservation International (Myers et al. 2000). The BX Nature Reserve was established in 1983 mainly to protect populations of the Yunnan snub-nosed monkeys [*Rhinopithecus bieti* (Milne-Edwards 1897)] and their habitats, and was promoted to a national level reserve in 1988. The upland temperate forests found here and elsewhere in Southwest China include a large number of endemic plant and animal species. Typical vegetation consists of pine forest, evergreen oak forests,

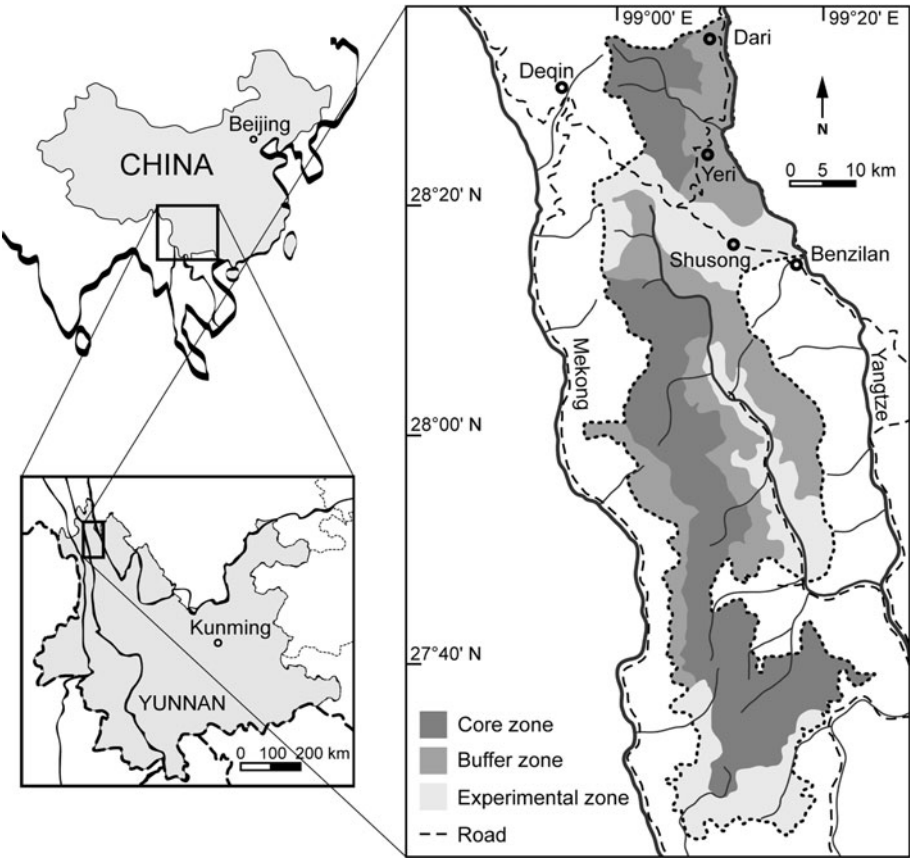

Fig. 1 Map of the *Baima Xueshan* Nature Reserve, northwest Yunnan, China

mixed coniferous and deciduous-broadleaf forest, and high-elevation fir forest. The climate is influenced by the southwest monsoon causing a warm and wet summer and cold and dry winter. The wet season lasts from May to September, followed by a dry season from October to April, with total annual rainfall of ca. 900 mm (for details on the ecology of the southern part of the nature reserve see Grüter 2009).

The BX Nature Reserve is populated by around 9600 people. More than two-third (78%) are Tibetans and live in the northern part of the nature reserve, while the inhabitants of the southern part comprise mainly Lisu, with additional Bai, Hui, Yi, Nu, Pumi and Naxi communities.

Following the implementation of the 'Natural Forest Protection Program' (NFPP; Chinese: *tianranlin baohu gongcheng*) in 1998, which bans all logging activities in the upper reaches of the Yangtze and Yellow River, incomes of local people have decreased significantly. Today, in the northern part of the nature reserve, it is around 1000 CNY per capita, according to the governmental statistics for 2007.

The people in the nature reserve rely on the collection of natural resources both for personal use, e.g. firewood, leaves and branches for fodder and manure and various plants for food, medicine and religious purposes, and for cash income, particularly with high value medicinal plants and mushrooms such as *Coptis teeta* Wall., *Fritillaria* spp., *Saussurea* spp., *Morchella esculenta* (L.) Pers., *Ophiocordyceps sinensis* and *Tricholoma matsutake* (S. Ito & S. Imai) Sing (*Baima Xueshan Guojiaji Ziranbaohuqu* 2003). The demand for these commercially collected products increased dramatically with the opening to the international markets in China since the late 1980 s. While *Ophiocordyceps sinensis* collection is one of the most important income sources for households in the northern part of the BX Nature Reserve, it plays only a minor role in the southern part due to lower altitudes and a climate less suitable for *O. sinensis*.

Materials and methods

The present study focuses on the northern part of the *Baima Xueshan* (BX) Nature Reserve which comprises three village committees, Shusong, Yeri and Dari, with totally 36 villages and ca. 620 households with 3900 people.

Fieldwork for the present study started in May 2007 with a visit of the two BX Nature Reserve camp sites in order to establish contact with *Ophiocordyceps sinensis* collectors and to develop an appropriate questionnaire, based also on interviews with traders at the *O. sinensis* market in Deqin as well as staff of the BX Nature Reserve. In May 2008, camp sites were revisited for participatory observation of collectors' daily routines such as search strategies and interactions with local buyers. Interviews with village heads on the socio-economic background and agricultural activities were conducted.

In November 2008, detailed interviews and household surveys were carried out in 54 households in five villages of the three village committees of Shusong, Yeri and Dari (for the number of interviewed households per village see Table 3). In two additional villages, interviews were conducted with the village heads only. The semi-structured interviews included questions about the *O. sinensis* collectors in the household, collecting strategies, prices for different *O. sinensis* qualities in 2007 and 2008, and total income from *O. sinensis* in the years 2007 and 2008, among others. Interviews were again conducted with traders, and officials of the BX Nature Reserve.

For statistical analysis, independent samples *t*-test, Pearson's correlation coefficient and Kendall's tau were performed where appropriate, by using PASW Statistics 17 for

Windows. For the calculation of the correlation of *O. sinensis* collection with other factors at village level (Kendall's tau) the different factors such as *Tricholoma matsutake* collection, crop productivity etc. were ranked for the 36 villages together with the village committee leaders as follows, none: 0; little: 1; medium: 2; much: 3; very much: 4. The ranking was crosschecked with staff from the nature reserve.

Results

Ophiocordyceps sinensis collection at village, household and individual level

Villages

Shusong comprises 13 villages of which six are highly involved in *Ophiocordyceps sinensis* collection (meaning that almost all households collect), four moderately and three only little. In Yeri, five out of 16 villages are highly involved, six moderately and five little and in Dari only one of totally seven villages is highly involved. Table 1 gives an overview of the interdependence of *O. sinensis* collection with other socioeconomic factors at village level. While the collection of *Tricholoma matsutake* strongly positively correlates with the collection of *O. sinensis*, no other significant correlation could be found.

Access to the high-elevation grasslands for *O. sinensis* collection is managed differently among these village committees. In Shusong, the rangelands belong to the experimental zone of the reserve. For grazing, a rotation system has been developed, i.e., every year each village rotates to a new grazing site. For *O. sinensis* collection, the whole area is open to all members of the community.

The collection sites of Yeri are located in the core zone of the nature reserve. The management of rangeland access in Yeri is more complicated than in Shusong. The grassland is divided in different parts on different slopes which are managed by the villages. Since the different areas do not have the same productivity of *O. sinensis*, villagers used to collect *O. sinensis* on the grassland of other villages as well. With the dramatically increase of the prices, however, one of the villages with very good *O. sinensis* sites did not allow

Table 1 Correlation of *Ophiocordyceps sinensis* collection with other factors at village level (Kendall's tau_b)

	O. sinensis collection		Villages
	Correlation coefficient	Sig. (2-tailed)	*N*
T. matsutake collection	.426**	.003	36
Crop productivity	−.265	.065	36
Walnuts	−.132	.349	36
Fruits	−.153	.279	36
Livestock	.049	.735	36
Low-wage work outside	−.087	.543	36
Highly qualified job outside	−.123	.391	36
Altitude	.169	.196	36

* Correlation is significant at the .05 level (2-tailed)

** Correlation is significant at the .01 level (2-tailed)

other villagers to collect on its site anymore, eventually leading to local conflicts. Negotiations by the local government resolved the issue recently.

In Dari, the harvesters traditionally go to the grasslands of Nanren, which is outside the nature reserve and belongs to Yangla township.

Households

In 2007 and 2008, ~50–60% of the households in the northern part of the BX Nature Reserve were involved in *Ophiocordyceps sinensis* collection. With an average number of 6.4 (±1.8) members per household, 1–3, rarely four persons, averaging 2.0 (±.9) collectors, pick *O. sinensis*. Table 2 shows the correlation of different factors at household level with the income generated from the caterpillar mushroom.

The collecting time of *O. sinensis*, and also *Tricholoma matsutake*, falls largely into lean periods of agricultural activity, i.e. between sowing and harvesting of the crops. The main exception is the harvest of barley and wheat in early June, when *O. sinensis* collection is still ongoing (Fig. 2). Households deal with this time conflict differently. While in some, particularly small families, the elderly stay at home taking care of children and harvesting wheat and barley, other families send one or two *O. sinensis* collectors back home for the crop harvest. Depending on the situation after harvest, they will go back for collecting until the end of the season.

Collectors and harvest practices

Extrapolations based on the household and village surveys show that ~600–700 collectors were involved for *Ophiocordyceps sinensis* collection in the northern part of the nature reserve in 2007 and 2008. Due to increasing prices, the number of collectors doubled within the last 5 years. Totally, 52.0% of the interviewed harvesters started to collect *O. sinensis* within the last 5 years, 91.2% started within the last 10 years ($n = 102$). Both women and men collect the fungus, with men making up ~2 out of 3 of total collectors. In 2007, the interviewed collectors aged between 17 and 54 years, with an average age of 28.5 (±8.5) years.

The collecting season starts at the end of April or beginning of May and ends in August. Questioned how they know that the season is over, 52.1% of collectors mentioned that they stop to collect when the fruiting bodies get long and soft, 33.3% stop when they cannot find a mushroom for several days, and 12.5% mentioned a combination of both. The collectors

Table 2 Income from *Ophiocordyceps sinensis* in 2008 and correlating factors at household level (Pearson)

	Income from *O. sinensis* in 2008		Households
	Correlation coefficient	Sig. (2-tailed)	*N*
Total annual income	.810**	.000	49
Number of harvesters/household	.608**	.000	49
Collection duration (days)	.498**	.000	48
Collecting experience (years)	.364*	.011	48
Area of farmland	.249	.084	49
Income *T. matsutake*	−.105	.476	48

* Correlation is significant at the .05 level (2-tailed)

** Correlation is significant at the .01 level (2-tailed)

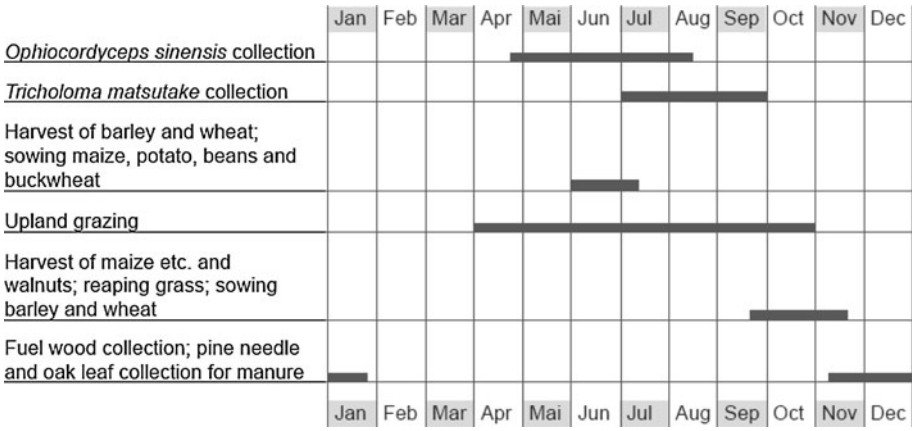

Fig. 2 Seasonal calendar of agricultural activities and NTFP collection in Shusong

spend between 9 and 82 days per season for *O. sinensis* harvesting, averaging 50.3 (±14.9) days. Collectors find between 0 and 20 *O. sinensis* individuals per day, depending on the season, their searching skills and luck. Table 2 shows a significant positive correlation between the experience of the harvesters and the income generated.

Harvesters mentioned fluctuations of the abundance of *O. sinensis* from year to year, due to climatic factors such as snow fall and temperature. They also perceived an increased competition between harvesters during the last years but explained that although the collected amount per person decreases, the generated total income still increases due to high market prices. Generally, they do not think that *O. sinensis* is overharvested or that populations are threatened.

Collectors mentioned that *O. sinensis* always occurs in pairs, i.e., if one picks one caterpillar mushroom another one must be around in the close vicinity. If the pair is not found that may indicate that the caterpillar is still alive. A living host caterpillar is regarded as an even more valuable and potent medicine than the fungus, and in the past, collectors used to start digging the area searching for the living caterpillar. In order to protect the grassland, this method has recently been banned in the nature reserve.

Prices of *Ophiocordyceps sinensis* and income generation

Table 3 gives an overview of the total income of households from five different villages and the share of *Ophiocordyceps sinensis*. Table 4 shows the prices of *O. sinensis* pairs for 2007 and 2008. For all three qualities, i.e. high, middle and low, the prices increased significantly from 2007 to 2008 ($P < .001$).

Management measures of the BX Nature Reserve

Although the regulations of the nature reserve de jure forbid the collection of *Ophiocordyceps sinensis*, authorities mentioned that in practice it is a vital income source for local communities, so they will not and cannot restrict its harvest. Instead, in all areas collectors are instructed to follow strict management measures, and in the core zone collection of resources is restricted to *O. sinensis* only.

Table 3 Total income of households and income from *Ophiocordyceps sinensis* in 2007 and 2008

Village (total households)	*N*	Average persons/ household	Average income/ household [CNY][a]	Income range [CNY]	Average income from *O. sinensis* in 2007 [CNY]	Average income from *O. sinensis* in 2008 [CNY]	Increase *O. sinensis* income 2007–8 [%]	Range [%]
Shusong								
Village 1 (27)	18	5.6 (±1.7)	9,972 (±4,174)	3,500–15,000	4,211 (±2,788)	4,694 (±2,916)	19.8 (±40.5)	100.0–(−40.0)
Village 2 (19)	17	6.6 (±1.7)	9,324 (±5,850)	3,500–20,000	3,194 (±1,976)	4,438 (±2,780)	30.9 (±47.9)	200.0–.0
Village 3 (7)	3	7	8,000 (±4,359)	3,000–11,000	nd	nd		
Village 4 (27)	4	7.5	18,500 (±27,743)	2,000–60,000	na[b]	na		
Yeri								
Village 5 (16)	12	7.2 (±1.9)	13,833 (±6,103)	4,000–22,000	6,308 (±3,339)	8,033 (±4,720)	29.4 (±35.0)	87.5–(−55.6)
Total	54	6.4 (±1.8)	11,148 (±8,703)	2,000–60,000			25.2 (±41.7)	200.0–(−55.6)

na, not applicable; *nd,* no data

[a] 1 CNY (Chinese Yuan) = 0,147 USD (August 2008)

[b] In village 4 virtually nobody is collecting *O. sinensis*

Table 4 Prices of *Ophiocordyceps sinensis* pairs[a]

Village	*N*	Prices for *O. sinensis* pairs in 2007 [CNY][b]			Prices for *O. sinensis* pairs in 2008 [CNY]		
		Quality					
		High	Middle	Low	High	Middle	Low
Shusong							
Village 1	18	66.1 (±11.7)	36.9 (±4.9)	22.0 (±5.4)	100.0 (±.0)	51.4 (±6.8)	29.2 (±2.6)
Village 2	17	65.2 (±6.1)	42.1 (±6.2)	24.6 (±5.0)	100.0 (±.0)	50.6 (±2.5)	30.3 (±2.9)
Yeri							
Village 5	12	60.8 (±9.3)	36.3 (±6.1)	20.8 (±5.6)	89.6 (±10.1)	57.5 (±10.6)	30.4 (±7.5)
Total	47	64.8 (±9.6)	38.3 (±6.7)	22.4 (±5.7)	97.2 (±6.8)	52.3 (±8.0)	29.7 (±4.5)

[a] Collectors sell it in pairs

[b] 1 CNY (Chinese Yuan) = 0,147 USD (August 2008)

In 2003, authorities of the BX Nature Reserve together with the Shusong village leaders decided that all collectors in the Shusong area have to camp at two designated sites: one big camp established next to the main road leading to Deqin and a smaller one, more remote but still accessible by car. From ~100 collectors in the main camp in 2003 the number tripled to over 300 in 2007. Since the mountain ranges of Shusong, Yeri and Shengping (outside the nature reserve) are connected, collectors used to pick *O. sinensis* in this whole area. However, in 2006 and 2007, collectors from Shusong were not allowed to enter the rangelands of Yeri and Shengping anymore. As response, they also closed their area for non-local collectors which finally resulted in a reduction of the number of collectors at the main camp side of about one-third to ~200 in 2008. The harvesters now spend around 20 CNY per person and season to hire guards to control the boundaries of the collection area. Towards the end of the season when money gets scarce, guards are organized by the villages on a rotational basis. Former residents who married and live outside Shusong keep the right to collect *O. sinensis*, but have to pay additional five CNY per person. However, since they often bring their relatives along, this regulation is still under discussion.

In 2006, the staff of the BX Nature Reserve and the Shusong village committee with the support of the Shusong Matsutake Management Committee formulated a series of management measures for the camps. It was decided to prohibit tree-cutting for fuel wood and the digging out of living caterpillars, to use standardized digging tools and to close up the digging holes, to urge the collectors to keep the camp sites clean and to collect the garbage and burn it. However, the main Shusong camp site visited after the collecting season in 2007 was nevertheless covered with garbage. Finally, only trade with locally collected *O. sinensis* is allowed at the camp sites and it is planned that the staff of the nature reserve inform the collectors about market prices and tourist buses passing near the camp sides.

Discussion

Collection and trade of *Ophiocordyceps sinensis* in the BX Nature Reserve and the factors which influence the collection at village and household level

Commercial collection of *Ophiocordyceps sinensis* is a very important source of cash income among communities living in the northern part of the BX Nature Reserve.

However, harvesting of *O. sinensis* is unevenly distributed among households and villages. Also, according to our interviews, cash income between households varies considerably. High incomes are usually found among households who either trade with natural products such as *O. sinensis* or *Tricholoma matsutake* or who have family members with a regular employment. This was especially the case in one village of Shusong (village 4, cf. Table 3), where a large percentage of people have a high education background and almost each family has at least one member with a good position outside the village. Not surprisingly, this village is not engaged in *O. sinensis* collection, which is perceived as a very laborious activity. Our data show that households try to diversify their income sources. Several factors seem to play a role that some villages are heavily engaged in *O. sinensis* collection and others are not. Although there is no significant correlation between the altitude of a given village and involvement in *O. sinensis* collection, the location of a village does play a role. Some of the villages close to valley bottoms do not participate. Also villages with good agricultural land are usually less involved, as they meet their subsistence needs more easily than others and at the same time have surpluses for cash income generation. Primarily villages above a certain altitude engage themselves in *O. sinensis* harvest. They are usually involved in yak herding, have relatively poor agricultural fields and low cash income from other sources. In these villages, the collection of other high value natural products such as *T. matsutake* may also play a role, which is apparent in the significant positive correlation of *O. sinensis* and *T. matsutake* collection at village level. Again, villages with very good *T. matsutake* collection sites are not engaged in *O. sinensis* collection as it is perceived to be more laborious.

At household level, income from *O. sinensis* depends on the number of collectors, their experience and the time they can spend on harvesting. Prices increased significantly between 2007 and 2008, and averagely, the income at household level increased between 20 and 30%. The harvest of barley and wheat and sowing of corn and buckwheat falls into the collection season of *O. sinensis*. So far, our observation and interviews revealed that the communities do not neglect agricultural activities due to *O. sinensis* harvest timing. It seems that the continuation of agriculture as a foundation of local livelihoods plays an important part in the diversification of subsistence and cash income sources.

Analysis of the management measures of the BX Nature Reserve

The exploitation of open access resources often represents the only opportunity for generating cash income for people with limited access to land, education, capital and other resources (Belcher and Schreckenberg 2007). However, open access resources are prone to overexploitation, as no responsibilities and incentives for sustainable harvest are fostered among the collectors. Either control mechanisms need to be defined on a policy level and applied by administrative authorities or resources need to be allocated to local communities or households. Measures for sustainable resource management are most successful if local communities are formally or informally integrated into policy making and control mechanisms (Dietz et al. 2003; Robbins et al. 2009). We found that the collection of *Ophiocordyceps sinensis* in the BX Nature Reserve is a good example for an integrated management of high value natural resources. The needs of local residents are respected, i.e. collection by local residents even within the core zone is tolerated, management measures are developed in coordination with the local population and activities of outsiders are strictly controlled. The resource management further has clearly adaptive characteristics, as for example the nature reserve authorities are changing villages from the buffer zone

status to the experimental zone, allowing the communities for improved economic development. By controlling outsider collectors, the rates of change in resources, resource-user populations, technology and economic and social conditions are moderate, which according to Dietz et al. (2003) facilitates establishing an effective management of open access resources.

Unlike many medicinal plants, it seems that moderate collection has no negative effect on *O. sinensis* populations in the BX Nature Reserve so far. Local people do not perceive a reduced abundance over the last years but do explain fluctuations mainly with climatic factors. Also, a majority mentioned that they stop harvesting as soon as the fruiting bodies get longer and soft which indicates, that a certain number of mushrooms can mature and produce spores. These findings correspond with other studies showing that mushrooms are more resistant against over collection compared with many medicinal plants (Arora 2008 and references therein). However, *O. sinensis* is a parasitic fungus with a complex biology and therefore more detailed studies on its population dynamics are needed to determine sustainable harvest levels (Cannon et al. 2009). In any case, the fragile alpine ecosystem is threatened by accompanying activities such as fuel wood collection and littering at the camp sites as well as effects on the vegetation and soil layer through intensive trampling and digging during the collection period. However, with the new management measures, these issues are addressed.

Even though the life history and biology of *O. sinensis* is complex and difficult to understand, local collectors do have a concept of its sustainable harvest. It was suggested by different collectors to end the collecting season earlier so that *chongcao* "seeds" (i.e. spores) remain and guarantee for the same amount in the next year. This proposal also would solve the time conflict with the wheat and barley harvest, which overlaps with the ending of *O. sinensis* collection. As this concerns all local collectors, we suggest to negotiate an additional contract on an early ending of the collection season.

High value natural resource collection and protected areas: Other *Ophiocordyceps sinensis* collection areas

Regarding *Ophiocordyceps sinensis*, a trend can be observed that with the increase of the value the need to regulate access and harvest increases concurrently. Winkler (2008) states that the tremendous increase of the price for *O. sinensis* in recent years turned this fungus into the most important cash income source in contemporary rural Tibet, making up 50–80% of total household income in the areas where *O. sinensis* occurs. We found similar numbers for the households which are involved in *O. sinensis* harvesting in the BX Nature Reserve. As with the price also the number of harvesters and thus harvest pressure increases, initiatives were launched in 2006 in both places for a regulation of the collection and protection of *O. sinensis* (Winkler 2008).

In Nepal, particularly the District of Dolpo is known for its *O. sinensis* abundance, where large proportions of its habitat fall into protected areas. Collection was forbidden from 1996 until 2001 and later under strict control of the Maoists until 2006 (Parajuli 2006). In recent years, however, the number of harvesters increased tremendously with tens of thousands searching for the caterpillar mushroom each year, arriving from distant places. At the moment, the government tries to control the harvest via taxes, but severe side effects of the massive collection threaten the alpine ecosystems (Parajuli 2006). In Bhutan, similar to Nepal, large areas of *O. sinensis* occurrence fall into nature reserves. Collection and trade of *O. sinensis* was officially not allowed before 2004, fostering not only illegal

trade with Tibet, but also harvesters illegally entering from Tibet (Cannon et al. 2009). In the meantime, collection has been allowed for herders, who traditionally graze their yaks in areas where the fungus occurs. Cannon et al. (2009, p. 2271) state that "In view of the likely level of unauthorized harvest, the consultancy report recommended a partial lifting of the collection ban [of *O. sinensis*] in an attempt to achieve self-policing of the crop by the local villagers, who would then have a greater incentive to discourage external poaching." This is very much in accordance with our results from the BX Nature Reserve, which show that instead of a collecting ban, which would hardly be enforceable, the integration of the local people in the development of sustainable harvest measures is a most promising approach for protected areas.

Conclusions

Ophiocordyceps sinensis collection is a strategy for income generation in the BX Nature Reserve, which, however, is unevenly distributed among households and villages. It is perceived as a very laborious activity but at the same time constitutes an important cash income source for households who have access to the resource but lack adequate alternatives such as rewarding wage labor, fertile agricultural fields or harvest of other high value products. De jure, the collection of *O. sinensis* is not allowed within the BX nature reserve, but a collecting ban for high value natural resources is not enforceable in an area where income is low and local livelihoods depend on non-timber forest product collection. Rather, adaptive management strategies are applied by the nature reserve staff, which involve the local population in the development of sustainable resource management measures. Also, allocation of collection areas to communities based on their traditional land use strategies and control of harvesters from outside is supported, triggering self-policing of the resource by the local people. This management allows for a successful implementation and finally benefits both, the local people as well as conservation goals. Since many collection areas of *O. sinensis* lie in protected areas, the strategies applied in the BX Nature Reserve may provide a promising model also for other regions where the caterpillar mushroom is collected.

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