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Yartsa gunbu – *Cordyceps sinensis*: economy, ecology & ethno-mycology of a fungus endemic to the Tibetan plateau

Abstract – *Cordyceps sinensis* is a fungus parasitizing the larvae of a moth of the genus *Thitarodes* (*Hepialus*), which lives in alpine grasslands of the Tibetan Plateau. Collection and trade of the caterpillar fungus is one of the most important sources of income for pastoral Tibetan communities. Tibetans know the fungus as "yartsa gunbu", “summer grass-winter worm”, and often derive over 50% of their annual cash income from its collection in spring and summer. Written records in Tibet date back at least 500 years, but the market is driven by Chinese consumers, who know it as chongcao (dongchong xiacao), a highly valued tonic in Traditional Chinese Medicine. A field study in Lithang County and other sites in Ganzi Tibetan Autonomous Prefecture, Sichuan (China), analyzed the local market, and the quantity and value of the harvest. Results are contrasted to Chengdu and Lhasa market prices, which peaked at 40,000 Renminbi/kg in 2003/4. Such information as is available regarding *Cordyceps* collection in other plateau regions, such as Golok TAP and Tibet Autonomous Region as well as the Himalayas, is integrated. In addition, the mycology (esp. reproduction, taxonomy and recognition of new species), ethno-mycology, distribution and geo-ecology of *Cordyceps* are presented, based on western, Tibetan, and Chinese sources to lay a foundation for further research on the issue of the sustainability of current harvesting rates.

Riassunto – Yartsa gunbu – *Cordyceps sinensis*: economia, ecologia & etno-micologia di un fungo endemico dell'altopiano tibetano.

Cordyceps sinensis, fungo parassita che vive nelle praterie alpine dell'altopiano tibetano, attacca le larve di una falena appartenente al genere *Thitarodes* (*Hepialus*). La raccolta ed il commercio del "fungo-bruco" è una delle fonti di guadagno più importanti per le comunità di pastori Tibetani. I tibetani designano il fungo "yartsa gunbu", "estate erba-inverno verme", e dalla sua raccolta in primavera ed estate ricavano sovente più del 50% del guadagno in denaro contante. Le fonti scritte tibetane risalgono ad almeno 500 anni fa, ma il mercato è nelle mani dei consumatori cinesi, che lo chiamano chongcao (dongchong xiacao), un tonico molto rinomato in medicina tradizionale cinese. Una ricerca di campo nella Contea di Lithang e in altre zone della Prefettura Autonoma Tibetana di Ganzi, Sichuan (Cina), ha analizzato il mercato locale, la quantità ed il prezzo del prodotto raccolto. I risultati sono stati confrontati con il prezzo di Lhasa e Chengdu, che ha raggiunto 40.000 Renminbi/kg nel 2003/4. Sono anche riportate le informazioni disponibili sulla raccolta di *Cordyceps* in altre regioni dell'altopiano, per esempio nella Prefettura Autonoma Tibetana di Golok, nella Regione Autonoma Tibetana e nelle regioni himalayane. Sono inoltre descritte la micologia, (in particolare la riproduzione, tassonomia e l'identificazione di nuove specie), l'etnomicologia, la distribuzione e la geoecologia di *Cordyceps*, basandosi su fonti occidentali, tibetane e cinesi. Questi dati possono costituire un punto di riferimento per ricerche future sul tema della sostenibilità dell'attuale tasso di raccolta.

INTRODUCTION

The importance of *Cordyceps sinensis* for rural populations, especially nomads in the Tibetan areas, cannot be overstated. In past centuries it was an important bartering good to obtain tea from China, a mainstay in the Tibetan diet. Nowadays, it provides a cash income to households, which are still carrying out most of their pastoral and, where possible, agricultural activities on a traditional subsistence basis. It enables otherwise impoverished households to purchase goods, and to pay school fees, hospital bills or taxes. Collection of medicinal plants has a long-standing history in Tibetan culture, be it for personal use or for trade. With the continuous advance of a cash economy onto the Tibetan Plateau, collection of tradable plants and fungi, as medicine, as food or aroma source, has gained increasing importance, especially for rural populations who are otherwise participating only marginally in the new cash economy.

ETHNO-MYCOLOGICAL SUMMARY

The Tibetan name yartsa gunbu (*dbyar rtswa dgun 'bu*) means “summer grass-winter worm”. “Grass” (*rtswa*) is also used to denote other mushrooms such as *Ganoderma lutescens*, which is also collected as a medicinal mushroom for the Chinese market in some Tibetan areas. Boesi (2003) notes that this term describes the life stages of *Cordyceps*; Tibetans “believe that during winter the yartsa gunbu lives as a worm and that, after a metamorphosis occurring at the beginning of spring, it transforms into a kind of grass. Tibetans recognise two distinct phases in the transformation process. At first, from the head of the larvae the “grass” starts growing. At this stage the worm, whitish in colour, is still alive and it is possible to see it moving over the ground with a short horn protruding from its head. Subsequently, as the season progresses, the horn continues to grow until the worm dies. When the metamorphosis is completed, the worm, [now] brownish-yellow in colour, is transformed into the root of a kind of grass”.

The first mentioning of yartsa gunbu in Tibetan Medicine can be traced to the 15th Century[1], according to Yonten Gyatso's ongoing research (pers. com., 2004). Yonten points out that Yartsa Gunbu is mentioned in Zurkhar Nyamnyi Dorje's (*Zur mkhar mnyam nyid rdo rje* [1439-1475], 1993) text: *Man ngag bye ba ring bsrel* (*Oral instructions on a myriad of medicines*). Thus, Tibetan medicinal use of *Cordyceps sinensis* is clearly documented for over 500 years, predating the first references in Chinese Medicinal texts by three centuries (see below). In Gawä Dorje's (1995) contemporary compendium on Tibetan *materia medica* yartsa is placed in the category of "medicinal essences" (*rtsi sman*), which includes several tonics. It is used for general strengthening, boosting the immune system, virility, and is prescribed for kidney and heart problems. It is also used for treatment of Hepatitis B. In Tibetan Medicine yartsa is mostly prescribed in composite remedies, which contain a variety of ingredients to balance each other, thus optimizing their efficiency and minimizing side effects.

It is interesting to note that yartsa is collected by a majority of Tibetans who base their subsistence on traditional land use techniques, although there used to be a traditional taboo placed on digging yartsa and other medicinal plant roots. Namkhai Norbu (1997), who grew up in Derge (Ganzi TAP), reports that "Rigya [*ri rgya*], the general laws that govern relations with the environment", forbid the digging of certain tubers and yartsa gunbu. Nomads of Dzachukha and Sertar regard yartsa as a treasure of "the earth spirits". Digging yartsa gunbu provokes these earth spirits who will strike the offender, his family and clan with sickness and punish his livestock with ill health[2]. This Tibetan belief probably predates Buddhist thought. However, in Lithang Boesi (2003) did not encounter such beliefs. He speculates that "this may be related either to the loss of that belief in the area or to a different local tradition". It is very plausible that the taboo has been lost in Lithang. It can be speculated that throughout the centuries Tibetans observed Chinese collectors digging in Lithang without suffering too many ill effects. Also pointing in this direction is the fact that in Golok yartsa gunbu was not really exploited by Tibetans in the past, but large-scale exploitation was ushered in after PRC took control in the 1950s. Before that Golokpas were famous for keeping all outsiders, Chinese or Western, out of their territory, thus

[1] Some Tibetan scholars recognize *Da byid* as another name for Yartsa Gunbu (pers. com. Mingkyi Tsomo, 2004). This recognition is based on Gawä Dorje's (*dGa' ba'i rdo rje*, 1995) recent work, who mentions *rtswa da byid* as another name for yartsa gunbu. This identification is controversial. However, *da byid* is already mentioned in the ancient Gyu Zhi (*rGyud bzhi*), the "Four Tantras" (*g.Yu thog yon tan mgon po*, 2002), which were composed between the 8th and 11th Century, laying the theoretical basis for Tibetan medicine. If this controversial identification can be substantiated, the first *Cordyceps* reference could be over a thousand years old.

[2] Similar beliefs prevented Tibetans from mining gold in the past. Since most Tibetans would not mine gold, this encouraged lowland Chinese to come and exploit these resources. However, this situation has changed recently and Tibetans are getting involved in mining if not priced out by extremely costly mining licenses issued by County governments.

very successfully protecting their traditions, while Lithang was much earlier impacted by Chinese imperial policy[3].

CHONGCAO IN TRADITIONAL CHINESE MEDICINE

In traditional Chinese medicine (TCM) *Cordyceps sinensis* is known as *dōngchóng xiàcǎo*, "winter worm-summer grass", clearly the literal translation of the Tibetan name. Commonly it is just referred to as *chóngcǎo*, "worm-grass". In TCM it was first recorded in Wu Yiluo's "Ben cao cong xin" ["New compilation of materia medica"] in 1757 (Zhu, Halpern & Jones, 1998)[4]. However, Chinese doctors had learned about the healing power of *Cordyceps sinensis* earlier. Already in 1736 the Jesuit Du Halde describes how the Emperor's physician at the Court in China treated him successfully with "Hia Tsao Tong Tchong". Du Halde mentions the fact that it is hard to "procure" and that its value is four times its weight in silver. It can be taken as a food ingredient, traditionally as a stuffing of duck, chicken or pork, as a soup ingredient, or ground up. *Cordyceps* tastes agreeable and I would describe it as primarily fungal without much difference in taste between the fruiting body and the former body of the larva. The recommended daily dosage is 3-9 g (Yao & Zhang, 1996), which would cost about 75-350 RMB [$9-$43] in 2003 retail prices, making it an extremely costly treatment. In general chongcao is used as a tonic in TCM to strengthen the system and regain energy, somewhat similar to the tonic functions of ginseng (*Panax* spp.). Liu (1994) summarizes chongcao's healing capacity as a tonic to enhance vitality. Its main TCM applications are for treating exhaustion, TB, asthma, back pain and reproductive issues (i.e. premature ejaculation). Its use as an aphrodisiac seems to be the driving force with male consumers in China, a fact Tibetan informants liked to comment on, pointing out that they have no need to take *Cordyceps*. The development of new drugs addressing erectile dysfunction might reduce the demand for *Cordyceps*[5].

MYCOLOGY - *CORDYCEPS* AND ITS HOSTS

[3] Lithang had a small Chinese garrison since 1720, but direct Chinese control was not imposed until 1906, when General Zhao Erfeng's armies quelled the 1905 rebellion in Kham against Chinese rule (Adshead, 1984).

[4] There is a recent claim (Halpern, 1999) that *Cordyceps sinensis* was already mentioned in TCM texts from the Tang Dynasty (8th Century). However, this claim could not be substantiated.

[5] Luckily these new drugs also might ease the pressure on the dwindling wild populations of tiger and rhinos commonly used for virility issues in Chinese communities.

Cordyceps is an entomophagous (feeding on insect) flask fungus (Pyrenomycetes, Ascomycotina) in the family Clavicipitaceae[6]. There are 300 to 400 species of *Cordyceps* (Sung, 2004), of which 68 species have been recorded in China (Wang, 1999); 33 species have been recognized in the Tibetan Plateau and Himalayan region (Zang & Kinjo, 1998). *Cordyceps* species parasitize insects, spiders, and sometimes deer truffles (*Elaphomyces,* a hypogeous ascomycetous fungus). Only a few are collected for their medicinal properties. Most commonly used among these is *Cordyceps sinensis*. Several other species are also referred to as chongcao in TCM, such as *Cordyceps militaris*, which is widely distributed in North America and Eurasia (Arora, 1986), as well as *Cordyceps ophioglossoides*, *C. sobolifera*, C. *liangshanensis* and *C. cicadicola* (UNW, 1996). However, no other species is considered as powerful as *Cordyceps sinensis,* or is as costly (Chen *et al*., 2002). Zang & Kinjo (1998) have described several distinct species so far clustered under *C. sinensis*: *C. gansuensis*, *C. kangdingensis* and *C. nepalensis*. In this article *C. sinensis* will be used *sensu lato*. There will be no further differentiation of *C. sinensis* from the apparently very similar newly recognized alpine species.

Cordyceps sinensis (Berk.) Sacc. parasitizes a range of grass root-boring caterpillars, which would hatch as whitish ghost moths, when not attacked by *Cordyceps*. The normal reproductive cycle for *Thitarodes* (*Hepialus*) takes up to five years; most of the life cycle is lived as a caterpillar, the moth itself living for only a short time, 2-5 days in the case of *H. biruensis* (Chen *et al*., 2002). As many other ghost moths, the adult *Thitarodes* moth is not able to eat. So far, the host for *C. sinensis* most commonly reported is *Thitarodes armoricanus* (Oberthür) Ueda, Hepialidae, Lepidoptera. Other host larvae have been identified, such as *Hepialus oblifurcus* Chu & Wang (Gao *et al*., 1992), *H. baimaensis* Liang and *H. biruensis* Fu Huang & Chen (Chen *et al*., 2002). All in all, nearly 40 species of *Thitarodes* (*Hepialus*) moths are recognized in the Tibetan Plateau region and, according to Chen *et al*., 30 species can be infected by *Cordyceps sinensis*. Chinese entomologists are still using the generic name *Hepialus*, although it has been restricted to a single European species – *Hepialus humuli* – for some thirty years. The genus *Thitarodes* was erected in 1968 to accommodate *Hepialus armoricanus* and other related species placed originally in *Hepialus* (Nielsen *et al*., 2000), many of them the host for *Cordyceps sinensis*.

[6] Clavicipitaceae also contain *Claviceps purpurea* – wheat ergot, from which lysergic acid is derived (Arora, 1986). It is interesting to note that *Cordyceps ophioglossoides* is used by indigenous healers as a neurotropic in Mexico (Guzman *et al*., 1998).

Kendrick (1992) reports that *Cordyceps* fungi have developed a special adaptation to improve their chances of reproductive success. Since reproduction is dependent on a very specific host, each spore fragments into 100 or more part-spores so that each fungal fructification produces 32 million propagules, thus increasing the odds of landing on a larva. Li *et al*. (1998) report that *Cordyceps sinensis* produces 30-60 propagules, and that usually 15 days pass between spore dispersion, their breaking up into propagules and larval infection. The propagules usually attach themselves to the larval state of the insect, but they also can attach themselves to mature moths as well. Apparently the larvae is forced by the fungus to move into its final position before being immobilized, since the fungus needs proximity to the surface to grow its fruiting body (stroma) above ground. Not infected larvae will not hibernate close to the surface. The mycelium – a cotton-like mesh composed of white threads (hyphae) – develops inside the body of the insect, first feeding on less vital parts, until it has taken over the complete organism filling the caterpillar with its hyphae. After the insect is completely mummified and emptied of nutrients, leaving behind the larval exoskeleton filled with the *Cordyceps* mycelium, the fungus will develop a fruiting body out of the head above the eyes, where the larvae has a horn-like protuberance in early spring. The 5-10 cm long, brown, club-shaped fruiting body grows above ground to have its propagules dispersed by the wind in order to find a new host insect. The stroma is nearly twice as long as the caterpillar when fresh (Fig. 2 and 3). It takes several weeks for the spores to mature. As the insect is the sole source of food for the fungus, the size of its stroma is dependent on the size of the host caterpillar (Arora, 1986). Fruiting of *Cordyceps sinensis*, according to collectors in Lithang, is enhanced by high precipitation – plateau winters are arid and frigid – and by mild temperatures in spring. However, as Boesi (2003) reports, if too much snow accumulates during the harvest season the stromata will rot and much of the harvest is lost. While most other commonly collected mushrooms, many of them living in ectomycorrhizal symbioses with trees, fruit in clusters, *Cordyceps* does not fruit in groups, but is highly dispersed, since each individual fungus is feeding on a different larva. However, specific site conditions might contribute to a concentration of larvae and thus of fruiting bodies.

Figure 1

Figure 2

Figure 3

DISTRIBUTION AND ECOLOGY

Cordyceps sinensis is endemic to the Tibetan Plateau including the adjoining high altitude areas of the Central and East Himalayas (Nepal, Bhutan and India's Uttaranchal, Sikkim, Himachal and Arunachal Pradesh). In addition, Zang & Kinjo (1998) also report *C. sinensis* from the Tian Shan and Altai Shan in Xinjiang, NW China. However, there is also abundant misleading information available regarding the distribution of *Cordyceps sinensis*, which is explained by the fact that TCM's chongcao includes a range of other *Cordyceps* species. Countless webpages list Guizhou, Hubei, Zhejiang and some other Chinese provinces; this might be quoted from "Icones of Medicinal Fungi from China" (Ying *et al*., 1987), which also misreports *Cordyceps sinensis* growing in marshlands. *Cordyceps sinensis* is common in grasslands and shrublands of the Tibetan Plateau including West Sichuan, North Yunnan and vast areas of Tibet AR, Qinghai and West Gansu (see Fig. 1). Its distribution is limited to areas with an average annual precipitation above 350-400 mm. In general, *Cordyceps* is not found in areas where precipitation is below 300 mm/a, such as the Changtang and other arid areas of the northwestern Plateau.

The grasslands providing habitat for *Thitarodes (Hepialus)* moths and thus for *Cordyceps sinensis* consist predominantly of *Kobresia* sedges. *Kobresia* can cover up 80-90% of the subalpine grasslands (Wu, 1997a). According to Miehe *et al*. (2004), *Kobresia* pastures of the Tibetan plateau are the world's largest alpine ecosystem covering 450,000 km^2 with an altitudinal range from 3,000 m to nearly 6,000 m gradually rising from the southeast to the northwest of the Plateau. In general *Kobresia* pastures are dominated by these *Kobresia* species: *K. capillifolia, K. humilis, K. pygmaea*, and *K. schoenoides*. The dominance of *Kobresia* in plateau grasslands seems to be a result of intensive grazing (ibid.). Aside from *Kobresia* sedges, a range of grasses and a great variety of forbs are common. For dominant species in Lithang see Table 1. Zang & Kinjo (1998) report that alpine *Cordyceps* species associate with *Polygonum affine*, *P. viviparum*, *P. macrophyllum*, *P. glaciale*, *Astragalus balfourianus* and *A. craibianus*. Chen *et al*. (2000) state that *Thitarodes (Hepialus)* prefers to feed on young roots of plant species of the families of Polygonaceae, Fabaceae, Cyperaceae, Poaceae and Liliaceae. Its favorite fodder species in Nagchu are *Polygonum viviparum*, *Rheum pumilum*, *Astragalus yunnanensis* and *Salix lindleyana*. Here in good habitat an average density of 0.42 specimen per m^2 is reported, but it can reach 4 specimens per m^2.

Table 1 - Typical species in subalpine grasslands (3,800-4,800 m, ≈800 mm precipitation/a) including shrubs in Western Sichuan (Sichuan Zhibei, 1990; Wu, 1997b).

Sedges and Grasses	**Forbs**	**Shrubs**
Kobresia setchwanensis, Kobresia pygmaea, Kobresia kansuensis, Poa elanata, Poa gracilior, Ptilagrostis dichotoma, Festuca rubra, Festuca ovina, Deyeuxia scrabescens	*Potentilla anserina, Anemone rivularis, Astragalus* spp.*, Primula sikkimensis, P. prattii, P. secundiflora, Aconitum rockii, Gentiana veitchiorum, Polygonum viviparum, Rheum alexandrae, Nardostachys chinensis, Ligularia* spp.*, Pedicularis* spp.*, Cremanthodium campanulatum, Leontopodium franchettii, Aster batangensis, Saussurea stella, Anaphalis flavescens, Meconopsis horridula, M. integrifolia, Lancea tibetica, Saxifraga montana, Rhodiola dumulosa, Fritillaria cirrhosa, F. przewalskii, Allium beesianum*	*Spiraea schneideriana, Spiraea myrtilloides, Spiraea alpina, Ribes glaciale, Potentilla fruticosa, Caragana jubata, Lonicera hispida, Lonicera thibetica, Berberis approximata, Rhododendron litangense, Rh.* spp.

Caterpillar fungus thrives in subalpine and alpine grasslands or meadows as well as open dwarf scrublands around the potential treeline. Based on the potential treeline, a relatively well-researched geo-ecological indicator (i.e. Li, 1994; Miehe, 2004) assessment can be made regarding the altitudinal distribution range of *C. sinensis*. It is distributed within a range of 400-500 m of altitude to the potential treeline. Basing the distribution on the potential treeline is helpful, since the current actual treeline has been strongly influenced by human activities. Wide areas of the Tibetan Plateau forests have been replaced by pastures through the millennia, see Winkler (1998, 2000).

Table 2 - Altitudinal Distribution of *Cordyceps sinensis* in correlation to the potential treeline on the Tibetan Plateau.

Area	**Distribution of *Cordyceps sinensis***			**Potential Treeline**
	Lower Limit	**Upper Limit**	**Source**	
Ganzi TAP (Sichuan)	3.500 m	4,700 m	Liu, 1994	3,800 - 4,400 m
Lithang, Ganzi TAP (Sichuan)	3,800 m	4,800 m	Winkler	4,200 - 4,400 m
Qamdo Prefecture (Tibet AR)	4,300 m	5,000 m	*dGa' ba'i rdo rje*, 1995	4,400 - 4,600 m
Naqu Prefecture (Tibet AR)	4,100 m	5,000 m	Chen, Yin *et al*., 2000	4,400 - 4,600 m
Bhutan	4,070 m	4,800 m	Namgyel, 2003	3,800 - 4,000 m
Kumaon Hills, Uttaranchal, India	3,300 m	4,300 m	Arif & Kumar, 2003	3,600 - 3,800 m

In Lithang, caterpillar fungus is mostly found on north-facing slopes according to Boesi (2003). Pastures on north-facing slopes – all grasslands are grazed at some point through the year – usually retain more moisture through the arid winter months, since snow will not melt and/or evaporate as quickly as on south-facing slopes. In Machen (Maqen) County (Golok/Goluo Prefecture) and other Counties of South Qinghai Province and NW Aba TQAP, *Cordyceps*

proliferates on well-drained sunny slopes with lush grass vegetation (pers. com. Toni Huber, 2004). In Nagchu Prefecture (Tibet AR) *Cordyceps* is confined to rich pastures and absent from marginal areas. Also, sites which are too wet or waterlogged, such as bogs and tussock grass areas, do not have *Cordyceps* populations.

YARTSA GUNBU HARVEST

Each year, when spring arrives in the grasslands, Tibetan nomads, farmers and also some city dwellers, venture on foot or on horseback out into the grasslands to look for "bu", as Khampas and other Tibetans call it for short. At lower elevations the season can start as early as mid April, but in many places not before the beginning of May. In colder high altitude areas, such as in Bachen or Biru County, Nagchu Prefecture, it lasts into July. The collection peak phase should not last longer than 6 weeks in a given area. The present decentralized grassroots gathering (no pun intended) is very efficient. Some people are concerned it might be too efficient and there are concerns regarding its sustainability (see below). The harvest procedure itself is simple; collectors usually carry a small hoe or use their knife to lift the caterpillar fungus out of the fertile topsoil. This needs to be done carefully, since the *Kobresia* turfs are very dense and breaking off the stroma from the head of the larva reduces the value.

The actual gathering of yartsa requires an intensive but extensive search. The grasslands and shrublands are vast and the visible part of the fungus is very small, often not longer than 2-5 cm. It can be spotted only at close range[7] and individual yartsa are dispersed, not like many other fungi whose mycelia may produce several fruiting bodies close together. A daily harvest in Lithang's grasslands is anywhere from a few specimens to several dozen specimens, sometimes up to 100 specimens per collector. In high season a common average seems to be around 20 to 40 specimens per collector per day.

During yartsa season Tibetans focus on gathering, and keep other activities to a minimum, since the income generated is very important. Consequently, during peak season, it is difficult to carry out labor-intensive projects. Community or government infrastructure projects, such as

[7] In April 2004, when looking for yartsa gunbu in Kangding County near Gye La at 4,100 m, one phrase came to my mind again and again 'looking for a needle in a haystack'. Actually, the odds of finding the tiny brown stromata, which grow around aromatic small purple-flowered Rhododendrons of the Lapponica subsection, seemed stacked against us. In 3 hours, two experienced Tibetan friends and I found 3 "bu" (worms). This site was apparently not a prime collection area.

local road construction, come to a halt. Finding local workers for reforestation can become difficult. To attract workers wages need to exceed the potential income from gathering, often a multiple of common wages. However, since the mushroom hunt also includes the risk of finding very few specimens, some people prefer a guaranteed income, as I was told by locals working in reforestation in Lithang. In some areas schools give vacations, so that students can join in collecting. For example, in adjoining Nyarong County (Pinyin: Xinlong, Kandze/Ganzi TAP) most schools close for 20 days in late May (pers. com. Pam Logan, 2002) and also in Beizha, Nangchen County (Nangqian, Yushu TAP, Qinghai), the Gar Monastery school scheduled their month-long vacation period to coincide with the yartsa gathering season (pers. com. R. Harris, 2004). Even attendance at traditional festivals, such as Cham dances in Songpan (Aba, TAP), suffers from people collecting "bu" in the grasslands instead of joining the celebration (pers. com. Mona Schrempf, 2004).

In Lithang's Junba District communities live and farm in deep, forested valleys (Tibetan: *rong*), but graze their livestock above treeline on the grasslands (*thang*) in summer. In spring often most members of a household camp out in the grasslands (Fig. 4 and 5) without livestock, turning the hunt into a joyful event. Also, some people set up tents around collectors' camps to serve as shops or bars, thus taking their share from the freshly made *Cordyceps* money. In Chungba (Junba) I was told that collectors are confined in collecting to their legal grazing grounds. Collectors from outside reported that they had to pay a flat fee of 25 RMB ($3) per collector to the administration for the 2001 season in Chungba District. However, in Lithang, grasslands are in general perceived as openly accessible for collection of plants and fungi. Local herders do not own their pastures according to Chinese law, but have usage rights. Exploitation of resources on common property often causes disputes. Although in Lithang and Sershul (Serxu/Shiqu) many collectors complained that there are too many people collecting nowadays, no informant reported violent conflicts during yartsa collection. Also Boesi (2003), who carried out a detailed study of the yartsa harvest in Lithang, reports that "cropping activities are not controlled by any particular local rules or traditions, there is no competition between the gatherers of the produce (*'bu rko ba*), either they are recurrent or occasional labourers or they come from different villages to exploit the produce. Nobody claims the right to pluck over a certain area".

Figure 4

Figure 5

HISTORY OF TRADE

Many early western explorers of Eastern Tibet (Rockhill, 1891; Pratt, 1892; Bacot, 1912; Wilson, 1913) reported on the collection and the trade of caterpillar fungus from Tibet to China often in exchange for tea or luxury goods like silk, confirming its economic importance. Bailey (1945) brought to the west the first photo of yartsa collection taken in Lithang in 1911. Shelton (1921), a missionary who spent 17 years in Batang wrote: "Wonderful and awe-inspiring concoctions of Chinese medicine contribute much to the industries of the Tibetans. [..] In the spring and summer months Tibetans also dig plants and collect fungi and other articles of supposed medicinal value for export to the Chinese market. One of the ingredients is the grass worm. [..] This seeming combination of animal and vegetable life is not only used as a medicine, but is also eaten as a delicacy". Coales (1919) reported on trade in "Tachienlu" (Pinyin: Kangding, Tibetan: Dardsendo) "the medicines exported are mainly rhubarb and other vegetable drugs for the Chinese market. The most interesting is the curious Chungtsao or insect grass, a dried caterpillar about 2 inches long, which has been killed by a fungus of about the same length growing out of one of its segments. It is supposed to be an excellent restorative to weak constitutions". Yartsa traditionally and still today functions as currency in many areas. It is a favorite trading good, since it is small and light-weight (<1 g), it does not readily deteriorate, and is very valuable.

Historically 60% of China's chongcao supply came from the Tibetan areas of Sichuan (Liu, 1994). Already during the late Qing dynasty (1796-1874) 10 t of yartsa gunbu were exported annually from the Kham[8] region when trade between China and Tibet blossomed (Wang, 2000). Statistics for Sikang (Pinyin: Xikang), a former province (1920s - 1961) comprising most of the Tibetan cultural area of Kham list chongcao production at 15 t in 1939; at that time 1 kg was worth 8 Yuan. In 1953/4 in Kandze/Ganzi Prefecture alone, there was an output of 10 t. According to the Ganzi Mushroom Institute in Kangding the highest annual production in Ganzi TAP[9] was 20 t. During the Cultural Revolution and the Commune phase the chongcao market cooled off, but it resumed with the economic liberalization in the early 1980s. In 1982 prices

[8] More or less today's Sichuan's Ganzi TAP, Tibet AR's Qamdo Prefecture, NW Yunnan's Deqen TAP and Qinghai's Yushu / Jyekundo TAP.

[9] In Ganzi TAP there are four main 'production' areas: Sershul (Serxu, Shiqu), Lithang, Kandze (Garze/Ganzi) and Sertar (Serta, Seda) (Liu, 1994). These are all Counties with vast grasslands.

were still very low: one specimen cost 0.1 RMB or 200 to 250 RMB per pound in Lithang. In Chengdu 1 jin (500g) was traded for 400 to 500 RMB. The overall production of *Cordyceps sinensis* is estimated at nearly 100 t per year in all of China according to an unpublished Chinese industry report.

THE PRESENT *CORDYCEPS* MARKET

Since economic liberalization in the early 1980s, caterpillar fungus has developed into one of the most important "cash crops" on the southeastern Tibetan Plateau. Since caterpillar fungus is consumed dried and not fresh, there is no need for rapid marketing as with culinary mushrooms. Its small size, its easy preservation, and its high value make transport very easy. Furthermore, dried specimens often fetch much higher prices in winter. Lack of cash and fluctuating prices deter most people from holding back their harvest and speculating on profits to be made by selling in winter. However, yartsa is also used as a way of keeping savings at home.

Cordyceps is traded in several categories; the main criteria are water content (fresh, dried), state of processing (uncleaned, cleaned) as well as size, the main retail price factor. The fungus becomes more valuable with increased cleanness and dryness. Freshly harvested caterpillar is encased in a black topsoil layer. The coating is first opened by hand or commonly with a toothbrush. Careful brushing exposes the caterpillar's body; the stroma itself is not encased in soil. It is important not to break off the stroma during cleaning. Broken specimens lose value; sometime a piece of match is used to reconnect the broken-off stroma. After cleaning, specimens are dried again, often on paved sidewalks or side streets in Lithang (Fig. 6). Also of importance is the origination of the *Cordyceps*. Dealers in Chengdu's Hehuazi market distinguish between origin from Tibet AR, Qinghai and West-Sichuan. However, the differences seem to be based mostly on size, not medicinal qualities per se. Tibet AR, especially Biru and Tengchen, is known for growing the biggest specimens. Those from Qinghai and West-Sichuan fungi are both smaller and regarded as being similar in quality.

Figure 6

After collection most caterpillar fungus is usually first marketed in the local administrative center or directly in the County seats or other important market towns. In remote areas in

Lithang, prices are 5% to 10% lower than in the County seat. For example, in 1999 in Chungba (Junba) town 1 jin (= 1 metric pound = 500g) was sold for 1,300 RMB. In Lithang town, 6 hours away by jeep, the same bunch would fetch 1,400 RMB. Asked about selling their harvest in Kangding or Chengdu informants from Lithang said that the prices are fluctuating and the extra input of time does not justify taking the risk.

Some collectors clean their mushrooms themselves; others sell their uncleaned fungi to local dealers, who will hire locals for cleaning before reselling. Prices nearly double for the same amount of specimen after cleaning due to the weight loss incurred during cleaning. Cleaned fungi are bought up by middlemen, whose average acquisition from collectors is 250 g to 1 kg at around 1,500 RMB per jin. Local dealers often do 10 to 20 such transactions per day, which would require a capital of 3,000 to 30,000 RMB. Many of these dealers also trade other medicinal plants or matsutake mushrooms in the summer. All of these transactions take place on Lithang's main streets. The whole area is buzzing from the fungi deals (Fig. 6). Regular shopkeepers are not involved in the trade. Sellers from the most remote areas in Lithang and adjacent Counties are in town to sell off their fresh harvest, be it from a couple of days hunting or from 6 weeks of work. Dealers with scales, which signal their interest, walk up and down the streets to attract the next deal or they simply hang out on a chosen spot waiting for sellers to come by. Prices are being discussed constantly, but are relatively stable. However, prices usually change through the season on the basis of supply and demand. Sellers, flush with cash, use their visit to town to buy staples or luxury goods and enjoy their windfall in fancy restaurants.

The daily quota of the middlemen, mostly Tibetans and also Hui[10], was estimated by informants at 1 to 5 kg, is later bought up by big dealers, many of them lowland Chinese or Tibetans, for South Chinese phytopharma companies. These transactions do not take place on the street. Several middlemen estimated that there are about 100 dealers buying up small quantities from local collectors. This information allows a rough estimate of a daily transaction of 100 kg to 500 kg in Lithang Town. For a 6-week caterpillar fungus season this would indicate that 4.5 t - 22.5 t of *Cordyceps sinensis* is traded annually in Lithang. However, the higher end seems clearly too high a guesstimate. Dealers and officials interviewed estimated the annual harvest at between 5 t and 10 t (value: 7.5-15 million RMB), however one yartsa dealer was convinced that Lithang annually produces only about 1t, but local trades included another 1-2 t collected in neighboring Counties. All in all, these figures compare well with official figures from Kandze TAP's Derge

[10] Huis – Chinese Muslims – travel all over the Tibetan areas of Qinghai and Sichuan buying up *Cordyceps*, medicinal plants, gold and yak hides, the latter a trade supposedly completely controlled by Hui dealers. Also many shops are owned by Huis in Kham and Amdo.

County, which reports an annual production of *Cordyceps* of 3 t (Derge County statistics, 1997). Tengchen County (Denqen / Dingchen, NE Qamdo Prefecture, Tibet AR) is reported to annually trade up to 7,5 t, which provides 60% of Denqen's GDP (CTI, 2003). Chen *et al*. (2000) report from Naqu Prefecture (Tibet AR) that the annual yield of *Cordyceps sinensis* is 7 t. There, yartsa mostly grows in the relatively warmer and moister southern Counties, such as Diru (Biru), Drachen (Bachen/Baqin), Sok (Suo), Lari (Jiali), Nyanrong (Nierong), and Nagchu (Naqu) of Nagchu/Naqu Prefecture.

MARKET PRICES

During our two-week stay in Lithang in May and June 1999, prices were relatively stable. Individual specimens were traded for 1 to 5 RMB depending on size, the bigger the fungus, the higher the price. The price of the biggest specimens increased from 4 RMB to 5 RMB through this season. 1 jin (500 g) unsorted wet & cleaned yartsa was sold for 1,400 to 1,500 RMB, which indicates about 800 to 1,000 specimens per kg. Prices in 1999 were substantially higher than in 1998, when 1 jin wet & cleaned yartsa sold for only 900 RMB. In 1997, the price was much higher at 2,000 RMB/jin for cleaned fungi.

Table 3 - Fresh Caterpillar fungi prices in Lithang Town between 1997 and 2004.

Year	1997	1998	1999	2000	2001	2002	2003	2004[11]
RMB/jin	1,800-2,000	800-1,000	1,400-1,800	1,700-2,000	4,500-7,000	8,000-12,000	8,000-20,000	9,000-15,000

The degree of dryness of yartsa is an important factor when basing the price on weight. Dealers assess the moisture content by the flexibility of the fungus; the less pliable the fungus, the dryer it is. At Chengdu's Hehuazi market, China's biggest medicinal plant market, informed dealers stated that 3.5 jin of fresh wet fungi will weigh 1 jin when completely dry. This would indicate a weight reduction of 71.5%[12]. Using this formula, if 1 jin of fresh, wet and clean chongcao costs 1,500 RMB in Lithang, 1 jin of dried chongcao would elsewhere cost 5,250 RMB plus transportation cost and profit margins. However, even relatively fresh fungi will have lost

[11] These prices are from late April 2004, the very onset of harvesting season.

[12] Fungi usually lose 75-85% of their weight when dried.

some moisture when coming onto the market, especially when collectors sell off the harvest of a month's search. Figures in Table 4 support the trend of this formula. Dealers at Chengdu's TCM market add about 1,000 RMB to each jin. Overall, what seems like a steep increase in prices from Lithang's 1,300-1,500 RMB/jin to Chengdu at 7,000-8,500 RMB/jin mostly evaporates once moisture content is taken into account.

In Hong Kong in October 1999, 37.5 g of packed bigger specimen cost 528 HK$, small ones sold for 480 HK$. This indicates a retail price of 7,125 to 7,750 RMB/jin. A former chongcao dealer reported that in 1992 1 jin of dried & cleaned fungus cost 1,800 RMB in Kandze Prefecture. In Guangdong, the same jin was worth 2,250 RMB, which is an increase of value of 25%.

Table 4 - Caterpillar fungi prices in Lithang Town and at Chengdu' s Hehuazi Market in May and June 1999.

Market Location	**Type of Cordyceps sinensis**	**Acquisition per jin in RMB**	**Selling per jin in RMB**	**Specimen per jin**
Lithang Main street	wet, uncleaned, unsorted	700 - 800	800 - 900	200 - 300
	wet, cleaned, unsorted	1,300 - 1,400	1,400 - 1,500	400 - 500
Chengdu Yaocai Market	dry & small	6,000 - 8,000	7,000 - 8,500	1,400 - 1,800
	dry & biggest	7,000 - 10,000	12,000 - 13,000	1,000 - 1,200

Prices clearly fluctuate through the years, especially depending on the annual harvest. Seasonally, the prices are at their lowest in harvest season in spring and peak in winter, since there is much less product available, but this is also partly caused by the much lower water content of *Cordyceps* so long after harvest season. Thus, winter prices are better compared to the markets in the lowlands, which trade mostly in completely dried fungi. In the winter of 1997/98 the price was at 6,000 RMB/jin for fully dried caterpillar fungus. In Chengdu 1 jin of big chongcao can cost up to 18,000 RMB, small ones to over 10,000 RMB/jin. Here seasonal price changes have a range of 30% to 40%, the price of bigger specimens being more susceptible to fluctuation. Dealers would like to buy several hundred pounds in Chengdu, but going to the production areas is too risky. The fluctuation of prices makes it too uncertain. Some dealers go to Kangding to purchase fungi, but there are not enough fungi available. One has to go further, to the Counties of origin. Overall, the inflation of the price of *Cordyceps sinensis* is very impressive. While one jin (500 g) of average yartsa was available for 200-250 RMB in Lithang in 1982, twenty-one years later one jin fetched from 8,000-20,000 RMB, which is a price increase of 40 to 100 times. Recent dramatic price increases are reported by some as a result of the SARS

epidemic in China in 2002, since people apparently believed that *Cordyceps* would help prevent infection with SARS.

ECONOMIC IMPORTANCE

The income derived from yartsa gunbu is very important for Lithang[13] and all the other areas of Tibet where *Cordyceps* occurs. Resource control, be it usage rights or ownership, is crucial factor in accessing and developing economic plant and fungus resources. Unlike many other natural resources in the region, such as timber, gold and also increasingly hydroelectricity, where the profits are captured by the state sector, fungal income (and other income from wild collected plants) goes directly to rural households. There are three main factors that enable rural households to participate successfully in accessing this resource; open access of the grasslands, availability of harvesting knowledge, and no capital required for participation. Thus, resource access is assured to the people, who are otherwise marginalized by government control of local resources such as timber, by lack of formal education, lack of access to credit, etc. Thus, almost all rural households, who base their survival on traditional subsistence herding and agriculture, participate in yartsa gunbu collection (see also Winkler, 2003). Table 5 shows the *per capita* value derived from yartsa Gunbu harvest in Lithang.

Table 5 - Annual *Cordyceps sinensis* harvest and income generated in Lithang in 1999[14].

Estimated harvest	Fungus specimen	Total value in RMB	RMB per household	Harvest per capita	Specimens per capita	Specimens per ha grassland
1 t	900,000	2,700,000	325	20 g	23	1.5
5 t	4,500,000	13,500,000	1,626	102 g	113	7.6

These figures are impressive. For comparison, in 1993 the gross value of industrial and agricultural output in Lithang County is reported at 67 million RMB, including an agricultural output of 47 million RMB. Checking these figures back, by extrapolating Lithang's Chungba (Junba) District figures from 1998, where *Cordyceps sinensis* and the booming Matsutake mushroom (*Tricholoma matsutake*) collection contributed 60% to the District income of 959

[1313] Research between 1999 and 2002 was carried out during consulting work for The Bridge Fund, San Francisco. Special thanks to my co-workers Huadan Zhaxi and Mick Rigdrol.

[14] Figures in this table are based on a total of 44,336 inhabitants (1995) with 5.35 persons per household (Ganzi TAP average for Tibetan Households in 1990), 595,000 ha grasslands, at 450 *Cordyceps* specimen per 500g/1jin.

RMB per capita in 1998 (com. District leader, 2000), in Lithang County this would figure to around 40 million RMB while the official GDP figured at 107.4 million Yuan in Lithang in 1998[15]. However, much of the income derived from the mushroom industry apparently is not accounted for in official statistics. Underreporting of earnings reduces tax burdens and secures provincial and/or central subsidies and thus is a widespread phenomenon in rural China.

The importance of yartsa for rural households has been confirmed in many other locations. In connection with rural development project development, I have also interviewed local people in several Counties in Kandze TAP, such as Nyarong (Xinlong), Sertar's Golok (Seda) area, Sershul (Shiqu) and Derge (Dege). Unless people have access to precious non-timber forest products such as matsutake and morels, caterpillar fungus typically contributes 50% to 80% of the annual household cash income.

FUTURE MARKETING

The marketing mechanisms seem very evolved for a trade in such a remote region. The fact that the price between remote villages and Lithang's County seat differs by only about 8%, without deducting minimal transport cost, indicates an established marketing network. However, the network is informal with fluctuating prices, thus adding some uncertainty, which deters many dealers from getting involved in long distance trading. Only a few people occupy this niche, since trading in bigger quantities requires large amounts of capital. Even local dealers, buying a daily quota of 20 jin require a capital of 30,000 RMB, which exceeds 5 years' salary for an average government worker. The fungal trade, especially caterpillar fungus and matsutake, has helped to generate local capital that allowed some local dealers to finance jeeps and other vehicles. The informality of the sector is further illustrated by the fact that there is no real taxation, as one informant put it, "you need to get caught with a truck load at a check point", and that governmental statistics seem to not fully include the caterpillar fungus trade in their statistics.

Furthermore, Lithang and many other Tibetan localities need to establish their own brands of chongcao and raise its profile as a distinct geographic origin of medicinal fungi. Preparing a product ready for marketing would surely increase local profit margins and create job opportunities. In Lithang, there is already a distillery that produces liquor (qingke jiu) from

[15] The average *per capita* income was 2,333 Yuan in Lithang in 1998. However, the *per capita* income of rural households was only 905 Yuan per person in Lithang, while the average per capita income of County employees was 8,094 Yuan.

regionally grown barley with a few caterpillar fungi or fritillary bulbs (*Fritillaria* spp., beimu) floating in the bottle. Having processing and packaging companies in Lithang will be an important step in securing sustainability, since reduction in local output would be felt directly by the companies. In addition, higher profit margins are captured locally and employment opportunities created. Moreover, once this process is initiated and gains momentum it can be applied for many other precious medicinal resources.

ARTIFICIAL AND SEMI-ARTIFICIAL *CORDYCEPS* CULTIVATION

Chinese laboratories pioneered artificial cultivation of *C. sinensis* derived organisms in the early 1980s. The resulting asexual organisms are distinct from *C. sinensis* and since the fungus is not parasitizing *Thitarodes* caterpillars, but feeding on other substrates, the organism develops differently, and thus is regarded as a different species. There are many new species, known as agamotypes, i.e. *Paecilomyces hepiali*, *Hirsutella sinensis*, and *Cephalosporium donchongxiacae* (Wang *et al*., 1998). In China, liquid culture or fermentation is widespread. Tanks containing a liquid medium formulated to optimize mycelial growth are inoculated with a *Cordyceps* derived agamotype. Sterilized silkworm residue is commonly used as base for this medium. In America and Japan unconverted grain substrates are frequently used in solid culture (Holliday *et al*., 2004).

Cultivators like to advertise their product derived from the asexual propagation as “superior”, since it is asexually reproduced under controlled laboratory conditions and thus its potency is supposed to be guaranteed. Also, medical research is carried out on the efficiency of these lab strains. A consistent product might be guaranteed, but this does not assure that these products contain the same range of active ingredients as the natural product. Many cultivated products do not even contain Cordycepin, a key active ingredient of *Cordyceps sinensis* (Holliday *et al*., 2004). Thus, these widespread products need quality control. In addition, Asian consumers do value the fact that medicines are gathered from the wild. The plateau origin adds to the lure of the caterpillar fungus besides the curiosity of this “symbiosis” of insect and fungal world.

Wild fungi, as long as they are available, will probably not be replaced by laboratory produced fungal strains, but prices might be negatively affected. Artificially grown *Cordyceps sinensis* mycelium so far has not impacted the market of wild *Cordyceps* in Asia at all, as clearly

documented in recent price increases. Western consumers prefer artificially grown products to the real organism, since Western culture lacks a tradition of appreciating edible insects.

There are also experimental semi-artificial *Cordyceps sinensis* growing programs under way in Tibet AR (Lhasa), Qinghai and West Sichuan's Kangding. In Kangding (administrative centre of Kandze TAP), for example, the *Thitarodes (Hepialus)* host larvae are bred, building on China's rich knowledge of silkworm breeding. About 100 larvae each are placed into shoe carton-sized plastic containers with lids, which are filled with grassland soil containing the tubers and roots of their favorite natural foods collected from the wild, as well as some other roots from cultivation. After two years spores of *Cordyceps sinensis* are inoculated and about 10% of the larvae are actually taken over by the fungus and grow stromata, reducing the natural growing cycle from 5 to 2 years. In April 2004, longish stromata were observable in many boxes. This was the first large scale fruiting, I was told, the culmination of 25 years of research[16]. In another experiment, in a field station near Kangding, bred larvae were released to their subalpine grassland habitat, but there no *C. sinensis* fruiting has yet taken place.

Artificially and semi-artificially grown fungal substance and fungus might prove to be extremely helpful to reduce future pressure on the natural resource, which surely will increase steadily with the growing availability of disposable income in China and ongoing discovery of *Cordyceps sinensis* by Western consumers and continued medical research with promising results.

CORDYCEPS IN GOLOK TAP

Although I have not researched *Cordyceps* in Golok TAP myself (I only looked into the issue in Golok areas in the north of Sertar County, Kandze TAP), I have collected information from researchers and informants. Golok TAP, South Qinghai Province, is an important production area for *Cordyceps*. In general, these reports portray a similar situation regarding collection, marketing and the economic importance for local communities, but contain one striking difference: the fact that thousands of non-local migrating Hui and Han would come into pastoral areas for digging. To give an idea of the number of outsiders involved in the collection,

[16] Research on the ecology, reproduction and artificial cultivation of *Cordyceps sinensis* was included in PRC's 9th five-year plan [item 10-5] as a key science and technology development project. Thus central funds have been made available for *Cordyceps* research and these cultivation programs. In the case of the Kangding facility, private and central government funding enabled cooperation with experts from Chongqing University.

Goldstein (1996) reports from Sangrima (Xueshan) Township, Dari County, that 3,000 outsiders would come in to dig fungus for a fee of 700 RMB per person, while the local population numbered 1,031. In this case the fees were used by local authorities for pastoral development projects, which considerably improved the local pastoral economy according to Goldstein. Horleman (2002) reports: "it seems that [*Cordyceps*] resources are presently mainly exploited by Han seasonal migrants and not by the Golok pastoralists. The collectors have to buy a permit from the local authorities, which grants exclusive collection rights for certain sites. However, the pastoralists [..] receive only a small fraction of the collection fees, although they are the ones who suffer most from the grassland degradation caused by extensive digging. Most of the profit from the permits goes to the local authorities, that is, to the townships and to the villages and herders' associations." Horleman was told by officials that the permits can cost up to 10,000 RMB per season and that over 100,000 migrants are coming to Golok TAP, a number comparable to the overall population. How much a traditional taboo placed on digging yartsa (see above) had contributed to the fact that outsiders were encouraged by the administration to exploit these resources needs further research.

Informants and reports also have bitterly complained about the licensing approach, which not only deprived local herders of one of their most lucrative resources, but also left them stuck with degrading holes in their pastures. Outsiders often dig much bigger hoes and thus damage the turf more seriously. Not surprisingly, there are many reports of conflicts between local collectors and outside collectors in Golok. An informant from Jigdril County (Jiuzhi Xian), who financed his high school education with *Cordyceps* collection, reported frequently scaring away Han and Hui collectors, who had come up to this remote County for chongcao collection. Showing his long Tibetan knife, he cut the encounters short and for that day secured his resource without further discussion.

Overall, many Golokpas were not content with the licensing system and wished to exclude outsiders from collecting. Horleman was told that the outside exploitation of medicinal "plant" resources was banned in 2000, but actual enforcement took several years. Costello (2003) reports that administrations finally halted license sale to outsiders in 2003. However, many outsiders are still coming for the season (pers. com. Mick Rigdrol, 2004). The popular demand for preventing outsiders from collecting is understandable taking Costello's (2003) observation into account: "most pastoral families especially the poorer ones make most of their cash income not from selling livestock products, but from digging yartsa. The number of yartsa an individual can find each season varies greatly by individual, but averages between 600 and 1,000. The

price for an average yartsa varies both yearly and through the year, varying between 2-4 Yuan each[17]. For those who dig with even average success, the income from yartsa, supplemented with dairy products provides enough for a basic living". In addition, yartsa also provides income to local dealers. Costello observed that yartsa changes hands 5 times before leaving town. This might explain a common complaint that local collectors do not receive fair prices and that too much profit is made by middlemen.

CORDYCEPS IN THE TIBET AR

In Tibet AR *Cordyceps sinensis* in general is distributed in areas with more than 350 mm annual precipitation[18]. In the southern Counties of Nagchu Prefecture, such as Diru (Biru) and Bachen, where some of the best fieldwork so far published on *Cordyceps sinensis* and its host insects (Chen *et al*., 2000, 2002) has been carried out. South Nagchu is known for its large yartsa specimens. In Biru County yartsa collection has heavily impacted the local economy according to Ben Jiao (pers. com., 2004); now many locals earn enough money through yartsa collection that they can afford to hire Tibetans from poor areas in Shigatse Prefecture to carry out their agricultural work. During collection season tent cities develop in the grasslands complete with bars, brothels and shops. The County government tries to keep outside pickers away by charging high collection fees; also, there is a tax on trade of *Cordyceps sinensis* in Biru. Yartsa riches have been spent on new houses and trucks. Also Nyingchi County (Pinyin: Linzhi, Nyingchi Prefecture) blocked access for outsiders in 2003 and started to sell licenses only to locals. However, some locals figured out that selling their licenses to outsiders for good money is easier than collecting themselves. Licenses were partially introduced, since the previous harvest was much lower than previous years. This was attributed to over-collection according to Luorong Zhandui (com., 2004).

CORDYCEPS IN THE HIMALAYAS

[17] In May 2004 the prize for the biggest specimen peaked at ¥10 (pers. com. A. M. Fischer).

[18] The Atlas of Tibet AR (1996) reports *Cordyceps sinensis* in 47 of TAR's 75 Counties. Only 2 Counties with less than 300 mm/a are reported to have *Cordyceps*, while in 8 Counties with precipitation over 310 mm/a *Cordyceps* is not listed as a source of income.

In recent years the *Cordyceps* collection – Zang & Kinjo (1998) recognize the caterpillar fungus from Nepal as a distinct species, *C. nepalensis* – has increased dramatically in the Himalayan region. Most of the product is destined for export to Tibet AR. While Shresta *et al*. (1998) reported from Dolpo, Nepal, that locals receive below 15% of the price on the Chinese market, prices now have sharply risen in Nepal and also in India and Bhutan in the last years. In Bhutan, 1collection of *Cordyceps* is illegal in order to give them full protection. However, Turkelboom *et al*. (2001) rightly remark that outlawing harvesting of very valuable species without proper monitoring leads to poaching and all sustainability issues will be disregarded.

Similarly, in Nepal Yarsagumba is under legal protection and has been banned from export without a government permit since 1996. In 2001 it was opened for trading with the royalty of NR 500 (US$ 6.60) per piece, an irrational fee, which surely will encourage smuggling (Das, 2001). It is interesting to note that in connection with the insurgency in Nepal, where government control has ceased in many alpine areas, the insurgents have established a more realistic and thus more profitable taxation. Marietta Kind (pers. com., 2004) reports that the insurgents "control all the Yarsagumba business in Dolpo now." They collect "revolution tax" on each kilogram (5,000 NR) traded, combined with a tax per picker (500 NR) and a tax per trader (20,000 NR). They also encourage collectors from other regions of Nepal to join the picking to optimize their "tax base". So in 2003 the area with its formerly hidden valleys was crowded with thousands of pickers digging holes everywhere, using up scarce firewood and leaving behind piles of garbage.

Overall*, Cordyceps* harvest has increased dramatically in Nepal and other Himalayan areas. In addition Yarsagumba is also being collected in India's Arunachal Pradesh and Uttaranchal[19], where it has only recently come to the attention of researchers (Garbyal, 2001; Arif & Kumar, 2003), while its occurrence in the high altitude areas of Sikkim has been known for long time.

SUSTAINABILITY

It is known that yartsa has been collected for centuries; some sources indicate harvest rates totaling at least 100 million specimens per year since the 1950s. As reported, collectors in Lithang and other production areas did not mention reduced fruiting, but acknowledged the fact that there are more and more collectors each year. Dealers did not report a reduction in harvest quantities

[19] Uttaranchal is the Himalayan region to the west of Nepal and the east of Himachal Pradesh. It used to be administrated as part of Uttar Pradesh and became its own state in 2000.

either. In short, no widespread disappearance of *Cordyceps sinensis* has been reported from the Tibetan Plateau. However, it was reported to have historically disappeared from Xishan near Kunming (CAC, 1990: 185), but this could have been caused by a variety of reasons, such as local climate change or any other cause impacting the host moths or the fungus; in addition Xishan is a relatively small disjunct mountain area.

Still, in recent years the issue of the sustainability of current harvest rates has been raised frequently (i.e. He & Sheng, 1995; Bhattarai, 1995; Shei *et al.*, 2001; Zhang *et al*., 2001). An assessment regarding sustainability of current harvesting levels of *Cordyceps sinensis* is not possible based on the research currently available in the West. Accurate baseline data is missing (as with most mushrooms collected from the wild). In addition, annual fluctuations are very common as with all mushroom fruiting, thus further complicating the interpretation of available data. However, a clear trend toward increased harvesting pressure is recognizable over its entire distribution, which is further accelerating with increasing prices[20].

Pastoralists in many areas of the plateau complain about the destruction of their grasslands by diggers of *Cordyceps* (and other medicinal plants), who make unnecessarily big holes in the turf by using relatively big hoes and by not closing the hole after removal of the fungus. Such careless extraction, often attributed to outsiders poaching Yartsa Gunbu, not only impacts pasture quality, but also disturbs the habitat of the *Thitarodes* (*Hepialus*) moths, thus potentially undermining sustainability. In this context, the hotly debated issue of overgrazing and grassland degradation also needs to be considered. Although there is no data available on the impact of grassland degradation through overgrazing or desiccation and the abundance of *Thitarodes* (*Hepialus*), it can be speculated that a healthy grassland environment is favorable to larval development. Also, no informant reported on more abundant fruiting of the fungus in degraded areas[21].

The long-term impact of intensive collection on caterpillar fungus and its reproduction is still unknown. Although there are a variety of entomophagous fungi[22], *Cordyceps sinensis* being economically by far the most important, not much research was carried out on these organisms and to my knowledge no research on the long-term impact of recent intense harvesting has yet been published. From a mycological point of view, it can be speculated that, if the fungus is collected after it had time to release enough of its spores, there might be no negative impact at all.

[20] In Kangding in April 2004 specimens were offered for 10 RMB per piece. This was also reported from Zhiduo and Jyekundo / Yushu Town, Yushu TAP, Qinghai (pers. com. Harris, June 2004). A.M. Fisher observed big specimens being offered for 15 RMB in Golok in May 2004.

[21] Such a connection might seem far-fetched, however pika (*Ochotona* spp.), a grassland rodent, tends to benefit from overgrazing and is more abundant in degraded grasslands.

[22] Fungi specialized in digesting insects.

To the contrary, handling the fungus might even result in wider "spore" dispersal. As described above *Cordyceps* has developed the rare capacity to divide each spore into 50-100 propagules producing 32 million part-spores to increase its chances of finding its host organism. However, this astounding capacity is of no help if the fungus is removed before "spores" are released. This is the case with *Cordyceps* gathered early in the season. In late April 2004, at the onset of the collection season, none of the specimen offered for sale in Kangding showed signs of maturity of the asci, the spore producing organs (see Fig. 3). Collection of these specimens will negatively impact reproduction. Also Boesi (2003) observed in Lithang, that most of the fungi were collected "before its spores have been abundantly spread by the wind". It is evident that more research is crucial to assess the question of sufficient "spore" dispersal in order to secure sustainability. Also Boesi points out that a reduction of *Cordyceps* might seriously impact the ecological balance of the grasslands, since *Thitarodes (Hepialus)* larvae feed on roots of the forage species.

Outreach programs and public education campaigns need to be initiated to ensure that fungi are harvested only after sufficient spore dispersal has occurred. A simple measure facilitating post-collection spore dispersal could be the introduction of collection containers that allow spores to disperse, such as baskets or netted bags. Hopefully the question of sustainability will be answered in time before *Cordyceps sinensis* populations actually dwindle, an assumption that is not far fetched looking at the track record of *Homo sapiens* unwisely exploiting natural resources. Everything possible needs to be done to ensure that a healthy environment is sustained and sustainable harvesting carried out, so that medicinal fungi and plants will be able to provide a basic income to rural households and healing for generations to come.

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Figures

Figure 1 - Map of the Tibetan Plateau region and the distribution area of *Cordyceps sinensis sensu lato*. The distribution area is based on multiple sources including CAC 1990 and Atlas of Tibet AR 1996.

Figure 2 - *Cordyceps sinensis* freshly dug and partially cleaned laying on *Arenaria*. Note the caterpillar base and the well-developed asci at the top of the stroma. Photo: D. Winkler, June 26, 1997, Bachen County, 4,400 m, Tibet AR.

Figure 3 - *Cordyceps sinensis* freshly exposed *in situ*. Note the asci have not developed at the top of the stroma and thus this specimen is being harvested before it can produce propagules (=spores). Photo: D. Winkler, April 24, 2004, near Gye La, 4,000 m, Kangding County, Kandze TAP, West Sichuan.

Figure 4 - A family camping out in the grasslands to collect yartsa gunbu. Light snow fall is not uncommon during the season. Photo: D. Winkler, May 2, 2000, Lithang County, 4,450m, Kandze TAP, West Sichuan.

Figure 5 - Yartsa gunbu hunter camp at Chungba (Junba) La in Lithang County. Photo: D. Winkler, May 1, 2000, Lithang County, 4,200 m, Kandze TAP, West Sichuan.

Figure 6 - Yartsa gunbu dealers sitting around a small pile of drying *Cordyceps* in Lithang town. Photo: D. Winkler, June 5, 1999, Lithang County, 4,010 m, Kandze TAP, West Sichuan.