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Authors: Pradhan, Bharat Kumar, Sharma, Ghanashyam, Subba, Bindhya, Chettri, Santosh, Chettri, Arun, et al.

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Distribution, Harvesting, and Trade of *Yartsa Gunbu* (*Ophiocordyceps sinensis*) in the Sikkim Himalaya, India

Bharat Kumar Pradhan[1]*, Ghanashyam Sharma[2], Bindhya Subba[1], Santosh Chettri[2], Arun Chettri[3], Dhani Raj Chettri[3], and Aditya Pradhan[3]

** Corresponding author: bharatprdhn@gmail.com*

[1] Sikkim Biodiversity Board, Forest and Environment Department, Deorali 737102, Gangtok, East Sikkim, India
[2] The Mountain Institute India, Tadong 737102, Gangtok, East Sikkim, India
[3] Sikkim University, Tadong 737102, Gangtok, East Sikkim, India

Cordyceps *has significantly improved the socioeconomic status of the mountain people in the Sikkim Himalaya, India, but an upsurge in demand and its price has resulted in overexploitation and degradation of the fragile alpine habitat in which it grows. This study aimed to shed light on the distribution, resource abundance, harvesting practices, commercialization, and trade of* Cordyceps *through household surveys and open-ended interviews with the collectors, sublocal and local traders, and local officials. Significant differences ($p < 0.001$) in average collection and income per household were observed. The income from* Cordyceps *ranged from US$ 0.03 to 0.23 million for the 3 villages studied. We conclude that there is a strong need to understand the market of* Cordyceps *and develop the value chain to regulate its price in Sikkim.*

Keywords: *caterpillar fungus; commercialization;* Ophicordyceps sinensis; *Sikkim Himalaya*; sustainability*;* yartsa gunbu.

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Introduction

The collection and marketing of forest products have cumulatively diversified economics and resulted in dramatic livelihood changes in the Himalaya and around the world (Olsen and Larsen 2003; Kandari et al 2012). Such products are important for alleviating poverty, in addition to sustaining and improving rural livelihoods (Edwards 1996; Olsen 1998; Belcher and Ruiz-Perez 2005; Karki et al 2005; Kep 2007; Shackleton et al 2007; Rasul et al 2008, 2012; Hickey et al 2016). Rural households generate high environmental incomes (income generated by harvesting a diversity of resources from forests, wetlands, lakes, rivers, grasslands, etc; Angelsen et al 2014) in developing countries (Wunder et al 2014), accounting for 28–45% of the total household income (Angelsen et al 2014; Asfaw and Etefa 2017). Of this, medicinal plants and fungi alone contribute 3–58% of the total annual household income and 78% of the cash income to the Himalayan rural populace (Olsen and Larsen 2003; Rasul et al 2012; Timmermann and Smith-Hall 2019).

Ophiocordyceps sinensis (syn. *Cordyceps sinensis*, henceforth *Cordyceps*), or caterpillar fungus, is endemic to the alpine region and is distributed in India, Bhutan, Nepal, and the Tibet Autonomous Region along an elevation profile 3000 to 5000 m above sea level (masl) (Winkler 2009). It is believed to cure several diseases (Devkota 2006; Panda 2010) and is mainly traded as an aphrodisiac and powerful tonic (Holliday and Cleaver 2008). As one of the most expensive biological commodities in the world (Winkler 2009), its harvest and sale have significantly improved the socioeconomic status of local communities across its distribution range, contributing 50–100% of household cash income (Winkler 2009; Wangchuk et al 2012; Kuniyal and Sundriyal 2013; Woodhouse et al 2013; Childs and Choedup 2014; Shrestha and Bawa 2014a, b; Shrestha et al 2017; Laha et al 2018; Pouliot et al 2018; Yadav et al 2018; Karki et al 2020).

The recent upsurge in demand and price has led to its overexploitation, endangering its natural population and habitat across its distribution range (Negi et al 2015), and thereby severely impacting its reproduction. Competition among collectors has given rise to social problems, such as banditry, corruption, resource conflict, robbery, and even murder, especially in the remote mountains of Nepal.

Several studies have been undertaken to understand the impact of increasing demand on the local economy and local ecology across its distribution range (Namgyel 2003; Aryal et al 2008; Winkler 2008; Weckerle et al 2010; Wangchuk et al 2012; Thapa et al 2014; Wangchuk and Wangdi 2015). However, few studies have been done on *Cordyceps* in the Indian Himalaya (Pant and Tewari 2014; Negi et al 2015; Laha et al 2018; Yadav et al 2018), despite the importance of this resource in the area. Basic data on its distribution, population, habitat, trade, etc, are lacking. This knowledge is important to orient policies that can tap its potential for

local economic development while ensuring sustainable management and conservation of this resource.

This study aimed to shed light on the distribution, resource abundance, harvesting practices, commercialization, and trade of *Cordyceps* in the Sikkim Himalaya, India.

Methods

Study area

The study was carried out in the villages of Lachen, Lachung, and Gnathang in Sikkim, Northeast India (Figure 1). All 3 study sites were located along the Indo-China border; entry to these areas required special permission.

Lachen (ca. 2750 masl; 27.7167°N; 88.5577°E), meaning "big pass," and Lachung (ca. 2700 masl; 27.6891°N; 88.7430°E), meaning "little pass," are unique villages in North Sikkim (Risley 1894). They have a population of 3200 (Lachen) and 2495 (Lachung) (in November 2017, as per the *panchayat* register). These villages are inhabited by Lachenpas and Lachungpas and are governed according to the traditional *Dzumsa* system, with their own set of customary laws. The Lachenpas and Lachungpas are hard-working people who practice agropastoralism; however, with globalization, there has been a swift transformation to the tourism industry.

Gnathang (ca. 4200 masl; 27.2979°N; 88.8181°E) is a part of the old Silk Road connecting India and Tibet through Nathu La. It also connects India and Bhutan through Jelep La. It comprises 5 villages: Tsomgo-Thegu, Yakla-Serethang, Kupup, Gnathang, and Dzuluk. Their total population is 2138, mostly made up of tribal communities (ie Sherpa and Bhutia, 70%); the Nepali community constitutes 30% (in April 2018, as per the *panchayat* register). Tourism, and associated business, is the main source of income for the people; nevertheless, many work as menial laborers with the Border Road Organisation.

Data collection

Prior to data collection, an awareness program of meetings was organized. A list of households involved in *Cordyceps* collection was compiled with the help of *Dzumsa*, biodiversity management committees, and village *panchayats*. Each household was given a number, and 50% of the households were randomly chosen using the RANDBETWEEN function in Excel. The corresponding households were interviewed.

Data were collected using a predesigned, semistructured questionnaire format in Lachen and Lachung during October–November 2017 and in Gnathang during March–April 2018. The questionnaire consisted of 53 questions formulated to assess the extent of *Cordyceps* collection, local price, marketing channels, harvesters' perceptions on availability, perceived threats, and local management practices (Appendix S1, *Supplemental material*, https://doi.org/10.1659/MRD-JOURNAL-D-19-00039.1.S1). Information on the history of its collection and trade was sought through open-ended interviews with 4 sublocal/local traders and 3 local officials from the Sikkim Forest and Environment Department (FED).

The survey was performed during the evening because the local people were busy with routine work during the day. The interview targeted the person involved in the collection of *Cordyceps* or, in their absence, the head of the family. Respondents were made aware of the main objective of the survey, and their verbal consent to use the collected data for research was obtained.

Subsequently, we visited 4 nearby habitats in Gnathang (ie 2 each in Yakla and Serethang) during August 2018 to assess the availability of *Cordyceps*. We used opportunistic sampling: When *Cordyceps* was encountered, we laid out a rectangular plot of 20 m × 2 m size (Cannon et al 2009). In total, we laid out 12 plots, 3 in each of the 4 habitats. Each plot was thoroughly scanned, and individual *Cordyceps* were counted with the help of a collector.

Simultaneously, various initiatives undertaken by the state government were reviewed by organizing meetings with FED, other relevant agencies, and *Dzumsa*. In addition, 3 workshops and 3 focus group discussions were organized with FED officials and other stakeholders involved in *Cordyceps* trade to review the policies and constraints of implementation.

Data analysis

Pradhan (2016) reported that *Cordyceps* was distributed over an area of 1900 km^2 in Sikkim. Though widely distributed, it is found in specific pockets (Cannon et al 2009); hence, on the basis of this information, we demarcated the area in Google Maps with the help of collectors, calculated the area of its actual distribution, and prepared a distribution map using ArcGIS 10.5.1. We procured 20 large and 20 small pieces of dried *Cordyceps* from Lachen for research. The number of *Cordyceps* per gram was recorded for 6 replicates using a precision analytical balance for both sizes. The average values obtained were converted to number of pieces per kilogram for both sizes. From these values, we estimated the overall average number of pieces per kilogram.

Analyses of variance (ANOVA), *t*-tests, Bonferroni post hoc tests, and chi-square tests were performed to assess the difference in responses among the villages. Annual average collection per person was calculated using the equation:

$$\text{Total collection per person per day} \times \text{No. days spent in the field per visit} \times \text{No. field visits} \quad (1)$$

The size of harvest for each village was assessed using the equation:

$$(\text{Annual average collection per person} \times \text{No. collectors per household} \times \text{Total no. collecting household}) \div (\text{Average pieces per kg}) \quad (2)$$

Income from *Cordyceps* was calculated on the basis of average price received by collectors from Lachen for direct sale facilitated by FED in 2018 and the size of the harvest per village.

Results

In total, 149 respondents in the age group of 19–75 years were interviewed. Of these, 98 respondents were male, and 51 were female (Table 1).

FIGURE 1 Distribution map of *Ophiocordyceps sinensis* in Sikkim, Northeast India (based on survey with harvesting households, $n = 149$). (Map by Hemlata Rai)

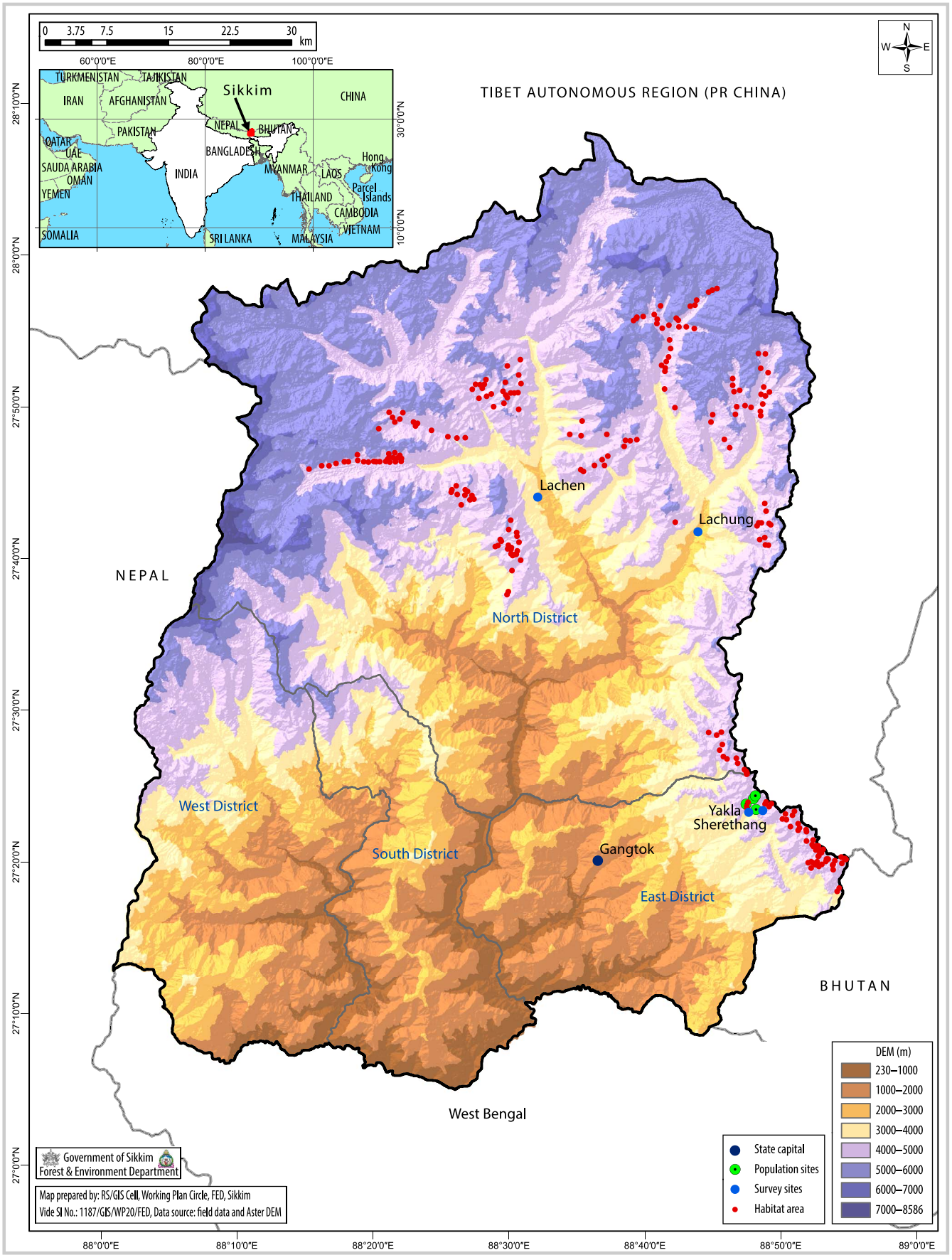

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TABLE 1 Characteristics of harvesting households surveyed in the villages of Lachen, Lachung, and Gnathang in Sikkim, Northeast India (based on survey with harvesting households, $n = 149$).

Characteristics	Lachen	Lachung	Gnathang
Total households surveyed (*n*)	49	40	60
Gender (male/female)	37/12	32/8	29/31
Average age (years)	32	33	40
Harvesting experience (years)	3 ± 1	6 ± 1	2 ± 1
No. collectors per household	1 ± 0	2 ± 1	1 ± 0
Average time taken to reach the harvesting site from village on foot (hours)	7 ± 2	4 ± 1	–
No. days spent in the field during collection season	6 ± 1	5 ± 1	–
No. field visits made during collection season	3 ± 1	2 ± 1	–

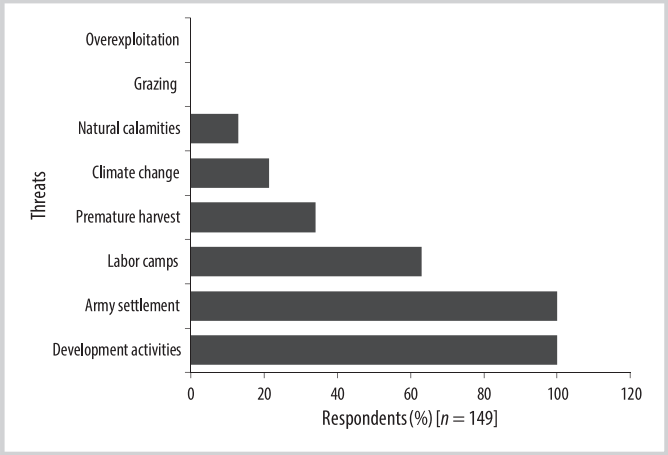
Distribution and abundance

Based on collectors' information, *Cordyceps* is distributed in about 72 km^2 (1.01% of the total geographical area, 7096 km^2) of Sikkim and is confined to the North (56 km^2) and East districts (16 km^2) along 3800–5000 masl (Figure 1). In the East District, it is found in and around Yakla, Thegu, Serethang, Nathu La, Doklam, Bhutan La, and Lam Pokhari; in the North District, it is found in and around Zemu, Thay La, Kyongsey La, Yathang Lagyab, Samdong Lagyab, Toga Lagyab, Thumbyak, Thyapa, Goma Phu, Singhi Phyak, Dozem, Katao, Yumthang valley, Momey Samdong (commonly Yomey Samdong) valley, Lachung Thosa, Kishong valley, Singho Lake, and the Paanch Pokhari area.

The perceptions on the availability of *Cordyceps* varied among the collectors. According to Lachungpa collectors, its natural population is diminishing, while Lachenpa collectors opined it to be high and stable. Additionally, 75% of collectors from Gnathang perceived a decrease in the natural population, while 22% felt it to be stable, and 3% claimed it to be high.

The collectors felt that developmental activities, specifically, the building of a road network, army settlements, and labor camps in the alpine areas, were the main threats to the natural habitat of *Cordyceps*, while premature harvest, climate change, and natural calamities had little effect. They denied overexploitation and stressed that grazing cannot be considered a threat to its natural population (Figure 2).

FIGURE 2 Threats to *Ophiocordyceps sinensis* perceived by the collectors in Lachen, Lachung, and Gnathang in Sikkim, Northeast India (based on survey with harvesting households, $n = 149$).



In total, 104 stromata of *Cordyceps* were recorded in 4 population sites covering 480 m^2 area in total (density: 9 ± 1 per 40 m^2 or 0.22 ± 0.02 per m^2), the elevation of which ranged from 3938 to 4282 masl. The habitat was gentle slope with luxuriant grassy vegetation. In these population sites, the yield was estimated to be 2167 individuals (0.471 kg) per hectare.

Harvesting practices, processing, and storage

Analysis of survey data on harvesting experience ($P < 0.001$) and number of collectors per household ($P < 0.01$) revealed significant differences among Lachung, Lachen, and Gnathang (Table 1). On an average, Lachenpas covered more distance ($P < 0.001$) to reach the harvesting site and spent more days ($P < 0.05$) in the field, while Lachungpas made more field visits ($P < 0.001$) to collect *Cordyceps* (Table 1). In Gnathang, collectors did not make field visits exclusively to collect *Cordyceps*; instead, they spent 1–2 hours per day on its collection.

Our survey showed per day collections to be higher ($P < 0.001$) for Lachung (30 pieces) than Lachen (20 ± 6 pieces) and Gnathang (16 ± 6 pieces). Average collections per household varied significantly ($P < 0.001$) among the 3 villages (Table 2).

Around 90% of collectors in Lachen and Lachung disclosed that they usually went to the field in a group of 5–10 people; however, they spread across the slope for harvesting *Cordyceps* to avoid congestion, ensure maximum harvest, and prevent damage to the habitat and *Cordyceps* stroma through overcrowding, trampling, and soil compaction. They made sure that holes were filled with soil after digging out *Cordyceps*. The collectors in Gnathang said that they collected *Cordyceps* opportunistically on a daily basis and had done so for decades.

Cordyceps was collected from the second week of May to the first week of August. The collectors started foraging for *Cordyceps* early in the morning and continued as long as the weather was conducive or until evening. They either kneeled or lay on the ground and intensively scanned the area. When the *Cordyceps* was traced, the grasses and soil were gently removed from around it, and, holding the caterpillar firmly with fingers, it was carefully pulled out along with the soil

TABLE 2 Annual volume of collection of and estimated income from *Ophiocordyceps sinensis* in the villages of Lachung, Lachen, and Gnathang in Sikkim, Northeast India (based on survey with harvesting households, $n = 149$). On average, 1 kg is about 4600 pieces (small: 4800; large: 4400; 100% dried). The per-piece price averages US$ 2.70 (small: US$ 2.33; large: US$ 3.06).

Village	Total collectors per village (actual)	Average annual collection per person (pieces)	Average annual volume of collection per household (kg)	Average annual volume of collection per village (kg)	Estimated annual income per household (US$)	Estimated annual income per village (million US$)
Lachung	160	540	0.23	18.78	2916	0.23
Lachen	98	200	0.04	4.26	662	0.05
Gnathang	120	128	0.03	3.34	518	0.04

without breaking it. In the evening, the soil particles adhering to *Cordyceps* were removed softly with a toothbrush, and the cleaned materials were spread on a plate for air drying till the collectors returned to the village or camp. On reaching the village, the materials were sold to the sublocal trader on a per-piece basis. The trader thoroughly cleaned and dried them at room temperature by spreading them on a newspaper, which was changed from time to time. The dried materials were then wrapped in tissue paper and stored in an airtight container until they were sold.

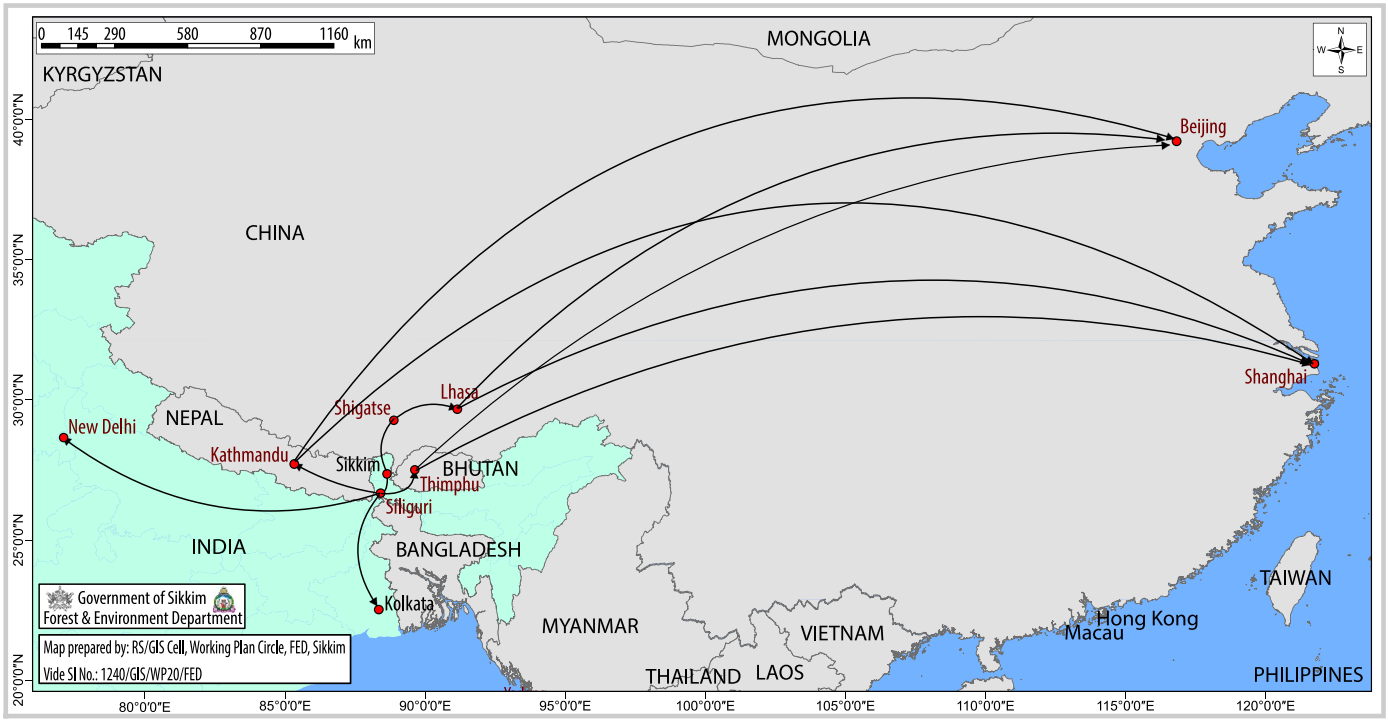
In Gnathang, the cleaned materials, as a local practice, were wrapped in muslin cloth and hung over the *bhukari* (room heater) for drying and storage. Some collectors dried them by spreading them directly over *bhukari*, before storing them in an airtight container for future use or sale.

Commercialization and trade

The collectors revealed that the informal trade of *Cordyceps* in Sikkim was initiated by herders from Nepal, who were hired for yak herding in Lachung in the early 1990s. They had prior knowledge of the international market, as *Cordyceps* had been traded in Nepal since the late 1980s. Later on, the Lachungpas took over the trade. Use of *Cordyceps* increased from 1964, as it was listed in the official Pharmacopeia of the Chinese Ministry of Health, and gained further momentum in 2003, when it was listed by the Chinese Ministry of Education's Committee of Herbs during the outbreak of severe acute respiratory syndrome (SARS) in China (Zeng et al 2019). In Lachen, its collection and trade started after the area opened for tourism in 2005, while in Gnathang, its popularity increased after the reopening of the Nathula trade route in 2006.

The collectors sell their harvest to the sublocal trader, who sells it to the local trader. Through them, it reaches national and international markets by various routes as depicted in Figure 3. At the source of origin, raw *Cordyceps* is sold at an average price of US$ 1.34 per piece (small: 0.97; large: 1.67) to the sublocal trader, who sells it (semidried; ca. 2300 pieces per kg, as disclosed by the sublocal trader) to the local trader at a lump-sum rate. This depends on the color; *Cordyceps* found in Sikkim can be pale yellow or golden, and the lump-sum rate paid by the local trader amounts to US$ 2975 (ca. US$ 1.29 per piece) for the pale yellow variety and US$ 3967 per kg (ca. US$ 1.72 per piece) for the golden

FIGURE 3 National and international trade routes of *Ophiocordyceps sinensis* (based on open-ended interview with sublocal and local traders). (Map by Hemlata Rai)



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variety. The local trader sells it to the international traders from Nepal, Bhutan, and Tibet at US$ 7934 (US$ 3.45 per piece) to US$ 10,579 per kg (US$ 4.6 per piece) locally and at US$ 33,059 (US$ 14.37 per piece) to US$ 39,671 per kg (US$ 17.25 per piece) in Kathmandu. Occasionally, the sublocal trader sells it to a local company or a nonlocal company through their agent at US$ 1.88 per piece (small: US$ 1.39; large: US$ 2.09), but the limited quantity requested means that this is not a preferred route.

On the basis of the price obtained in 2018 (average: US$ 2.70 per piece or US$ 12,420 per kg), the income for 3 villages ranged from US$ 0.04–0.23 million. The income per household from the sale of *Cordyceps* was significantly higher for Lachung ($P < 0.001$) than Lachen and Gnathang (Table 2).

There has been about 100% increase ($P < 0.05$; $r = 0.514$) in the per-piece price of *Cordyceps* in Sikkim between 2005 (US$ 0.68) and 2019 (US$ 1.34); nevertheless, the collectors from Lachen reported a 27% fall in the per-piece price of *Cordyceps* from US$ 1.56 in 2016 to US$ 1.16 in 2017. Similarly, local traders reported a 30% fall in the average per-kilogram price from US$ 7498 (US$ 3.26 per piece) to US$ 5244 (US$ 2.28 per piece) within a 15 day period in 2019.

Local norms and state policies

In Lachen and Lachung, it is mandatory for the collectors to inform *Dzumsa*; nonresidents are strictly prohibited from collecting *Cordyceps*. Activities such as cutting down of rhododendron shrubs, harvesting of medicinal herbs, wildlife poaching, and collection of firewood while camping are restricted by *Dzumsa*. Further, the collectors must ensure the cleanliness of the alpine habitats. The Lachen *Dzumsa* along with community members carry out frequent patrols in the alpine habitats to check for illegal activities.

In Sikkim, the commercial trade of *Cordyceps* was formally legalized in 2009. This authorizes members of the joint forest management committee (JFMC) and ecodevelopment committee (EDC) of the respective habitat area to collect *Cordyceps* after obtaining prior permission from FED; collection is restricted in the national park. The rule stresses that harvest should be processed through open auction and usufruct sharing on a 25:75% basis between FED and JFMCs/EDCs (Pradhan 2016). To give effect to the rule, a guideline was introduced in 2016 that restricts the collection duration to 1 month and issue of collection permits to a specific number of people, strictly from among the local residents (Pradhan 2016–17). The traders are required to pay a royalty (INR 10 or US$ 0.31 per g; values as on 20 March 2020), which is subject to a 10% increase every 2 years. As per the guidelines, 101 collection permits were issued to the collectors from Lachen (51 permits) and Lachung (50 permits) in 2016. A *Cordyceps* auction was organized, but there was negligible participation by the collectors, as a result of which the state lost a revenue of about US$ 0.026 million (1 US$ = Rs. 66.98 on 31 August 2016). Based on our calculation, the collection for the year was estimated to be 8.09 kg worth US$ 0.10 million.

Among the respondents ($n = 149$), 42% were aware of existing policies on the legal collection and sale of *Cordyceps* in Sikkim, while 58% lacked awareness. Further, 44% felt that there was a need for such policies, while the perception was negative for 56% of the respondents. According to 21% of the respondents, government intervention would certainly help them get a better price, but 79% were not in favor of government interventions.

Discussion

Availability, harvesting, and trade

Our preliminary study of the 4 population sites revealed high yield per hectare (2167 stromata) as compared to Uttarakhand, India (600; Negi et al 2015), Bhutan (156; Cannon et al 2009), and Nepal (833; Damodar 2019). This suggests that Sikkim still hosts a good population, in contrast to other Himalayan regions, where there are reports of continuous decline (Cannon et al 2009; Shrestha and Bawa 2014a).

Few people were involved in collecting *Cordyceps* in Sikkim (Lachung, 6%; Lachen, 3%; Gnathang, 6%), as the majority of the local populace had alternative sources of income, such as government jobs or private businesses (tourism, transport, and trade). Several schemes have been launched in Sikkim, such as One Family One Job and the National Rural Employment Guarantee Scheme, to ensure at least 1 family member is salaried. Further, there is a unique system of an annual distribution of funds accumulated with *Dzumsa* in Lachen and Lachung, resulting from developmental works or other activities carried out under their jurisdiction. These are shared equally among households, irrespective of their social status, thus ensuring no household undergoes financial trauma. Hence, the collection and sale of *Cordyceps* represent a part-time business, which explains the low number of people involved and the low volume of collection per household (0.03–0.23 kg); their livelihood is not dependent on *Cordyceps* or any other bioresource (Pradhan 2016), unlike in other regions (Garbyal et al 2004; Winkler 2009; Devkota 2010; Weckerle al 2010; Wangchuk et al 2012; Kuniyal and Sundriyal 2013) where few alternative options (Wu et al 2014) have made people totally dependent on *Cordyceps*, leading to its overexploitation (Shrestha and Bawa 2013; Pant and Tewari 2014; Thapa et al 2014; Pouliot et al 2018). *Cordyceps* accounts for a major share of household income in other parts of the Himalaya (Wangchuk et al 2012; Childs and Choedup 2014), but we lack official data on this for our study area; nevertheless, our data indicate that the collectors are making a substantial income from its collection and sale.

In contrast to other parts of the Himalaya and Tibet (Devkota 2008; Winkler 2008; Cannon et al 2009; Weckerle et al 2010; Negi et al 2015), the collectors in Sikkim spend less time in the field, for a number of reasons: (1) Sikkim is a famous tourist destination, and most of the local communities, including those from the study villages, are involved in tourism and associated business. The *Cordyceps* collection time coincides with the tourist season, restricting the ability of people to leave the village for a long time. (2) The collection of firewood during camping to collect *Cordyceps* is restricted by *Dzumsa*; hence, collectors carry firewood/kerosene stoves and packaged food, mainly noodles, which can be cooked easily with minimum fuel requirements, and also *Tsampa* or *Champa* (roasted powdered barley), which is mixed with hot water and consumed. Relying on such food for long periods is detrimental to

health. Also, collectors plan in advance for the number of days they are going to stay in the field and carry only enough food for that period. (3) During summer, the forest department intensifies their patrols in the alpine areas to regulate the illegal activities, and, if caught, illegal collectors will be severely punished and fined.

The existing informal trade of *Cordyceps* fetches a meager price (US$ 1.34 per piece) for the collectors in Sikkim, compared to US$ 4–7 in other parts of India (Yadav et al 2017), US$ 2.60 in China (Woodhouse et al 2013), and US$ 3.53 in Nepal (Pouliot et al 2018). In Makalu Barun National Park in Nepal, collectors receive US$ 10 per piece (Damodar 2019), while in Baima Xueshan Nature Reserve, Southwest China, collectors sell their harvest in pairs at about US$ 14 (low quality), US$ 25 (medium quality), and US$ 48 (high quality) (Weckerle et al 2010). Comparatively, the per-kilogram price of *Cordyceps* is much lower in Sikkim (US$ 6164) than in other parts of India (ca. US$ 3000–21,000 per kg; average: US$ 12,000 per kg) and Nepal (US$ 1500–17,000 per kg; average: US$ 9250 per kg) (Kharakwal 2016). The price on the international market in 2018 was US$ 56,000 per kg (Damodar 2019), while medium-quality *Cordyceps* fetched US$ 50,000 per kg in Shanghai in June 2018 (Liang 2018), and high-quality *Cordyceps* was auctioned at about US$ 29,000 per kg in Bhutan in August 2019 (DAMC 2019).

Sustainability, threats, and policies

The sustainability of *Cordyceps* is a concern across its distribution range due to overexploitation and habitat degradation (Stone 2008; Winkler 2009; Shrivastava et al 2010; Weckerle et al 2010; Shrestha and Bawa 2013; Negi et al 2014; Thapa et al 2014; Laha et al 2018; Yadav et al 2018). However, the collectors in Sikkim perceived *Cordyceps* to be in a good state with minimal exploitation, which corroborates the response recorded by Weckerle et al (2010) in their studies. Moreover, most of the Lachenpas and Lachungpas are settled in the capital for jobs and their children's education; elderly citizens mainly remain in the village. Properties are leased to outsiders for running their hotel business during tourist season. They are restricted from harvesting *Cordyceps*, unlike in Uttarakhand, India (Yadav et al 2018), and Nepal (Shrestha and Bawa 2013; Thapa et al 2014; Pouliot et al 2018); hence, the pressure on the natural population is insignificant. Other factors also ensure its protection from overexploitation, such as difficult terrain, long distance from habitation, and the harsh climatic conditions, in addition to the vagaries of nature causing illness and injury, which discourage people from going to collect *Cordyceps* specimens. The natural habitats of *Cordyceps* are, in essence, "naturally protected" by their geographic locations (Caplins and Halvorson 2017).

Studies have indicated that climate change is a factor in the population decline of *Cordyceps* (Shrestha and Bawa 2014c; Caplins and Halvorson 2017; Hopping et al 2018; Laha et al 2018). The collectors in Sikkim also indicated a change in climate, for example, a more erratic rainfall pattern, less snowfall, warm winters, etc, over the past 10 years. However, their primary concern was habitat destruction due to ongoing development activities, army settlement, and the setting up of labor camps in the *Cordyceps* habitat. They were also concerned about its premature harvest, as in Nepal (Shrestha and Bawa 2013; Thapa et al 2014). Simultaneously, they were satisfied with the initiatives being taken by *Dzumsa* for biodiversity conservation and minimization of ecological damage to the alpine habitat, which included issuing guidelines and orders with heavy penalties for violators and community boycott in extreme cases. Cannon et al (2009) reported grazing as a reason for the degradation of *Cordyceps* habitat in Bhutan, but, according to the collectors, yak rearing in Lachen and Lachung has been drastically reduced. Furthermore, they practice rotational grazing, where the yaks are brought down during winter and moved to alpine pasture during summer, thus allowing the rejuvenation of the natural habitat. Another emerging threat to *Cordyceps*, as revealed by the collectors in Gnathang, is its illegal collection by the army porters and, occasionally, the trespassing of Tibetan yak herders to Sikkim for its collection.

The informal trade of *Cordyceps* in Sikkim came to light in 2008; consequently, the local government codified rules and framed guidelines to regulate its trade (Pradhan 2016), but the trend continues. Hence, all efforts by FED to regulate the trade of *Cordyceps* have failed in Sikkim as in other regions (Negi et al 2006; Cannon et al 2009; Winkler 2009; Weckerle et al 2010; Childs and Choedup 2014; Baral et al 2015; Wallrapp et al 2019). This indicates a serious issue of lack of trust and coordination between the local communities and the authorities. Nonetheless, the high price received (US$ 2.07 per piece; usual price: US$ 1.34 per piece) by collectors through direct sale of *Cordyceps* facilitated by FED in 2018 made people realize that the government interventions would certainly curtail the market chain, check the monopoly of the traders, and fetch them a better price for their harvest, but some are satisfied with their own established system of trade.

The Lachenpas and Lachungpas have a strong sense of ownership over the alpine pastures; some of them argued that such policies are unwarranted because they have over a hundred years' experience in resource management through local institutions. They stressed that the views and suggestions of local communities are crucial, as such policies will directly impact them and threaten their existing traditional practices. Wallrapp et al (2019) recorded similar responses from the local communities in Uttarakhand. They suggested that the collection duration and auction time need to be fixed through consultation with local communities. The guidelines restrict collection to preserve forest in Sikkim, but *Cordyceps* is mostly distributed in protected areas, and the government rules cannot be strictly enforced in such remote locations with open access to the resources. Similar findings were reported by Negi et al (2015) from Uttarakhand. In Gnathang, by contrast, most people are nonnative migrant settlers residing in the restricted area, and they do not have land ownership. Hence, the collectors did not have much to comment on government policies and interventions because the local government had been fair by not enforcing the laws strictly. If the laws were enforced, collectors would lose the additional income they make from the collection and sale of *Cordyceps*, because the guidelines restrict the issue of permits specifically to local citizens.

Generally, the traders preferred to avoid administrative hurdles, but strict implementation of the policies would legally bind the collectors and the traders, and it also would generate revenue for states such as Sikkim that have such high-priced resources. Nevertheless, it will take some time

for local communities to understand the true essence of such policies, for which a convincing value chain model needs to be developed. Until then, issuing a limited number of collection permits will serve the purpose. For example, by issuing 50 permits per village, the projected annual collection of *Cordyceps* from Sikkim would be about 9.43 kg, worth about US$ 0.12 million, generating around US$ 0.032 million in revenue annually.

Conclusion

Our study is a first attempt to analyze the harvesting trends, trade, and commercial prospects of *Cordyceps* in Sikkim. We conclude that *Cordyceps* offers huge potential to boost the economy of the state, which has limited sources of revenue generation—provided it is exploited sustainably. This requires a bottom-up approach, involving local communities in policy decision-making, resource management, and recognizing access rights, as an incentive for their conservation efforts.

While there is concern over the scarcity of this important natural resource due to overexploitation across its entire habitat range, Sikkim currently has little decline in its reserve. Simultaneously, there is a strong need to understand the market of *Cordyceps* and develop the value chain to regulate its price so that the local communities can enjoy the full economic benefit from its sale. Further, coordination among local communities, authorities, traders, policymakers, and conservationists is vital for the long-term effective management of this economically valuable bioresource in the Sikkim Himalaya.

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Supplemental material

APPENDIX S1 Questionnaire for the survey.

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