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Economic contribution of Chinese caterpillar fungus to the livelihoods of mountain communities in Nepal

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ABSTRACT

Harvesting of Chinese caterpillar fungus, one of the most expensive biological commodities in the world, has become an important livelihood strategy for mountain communities of Nepal. However, very little is known about the role of Chinese caterpillar fungus in household economy. We estimated the economic contribution of Chinese caterpillar fungus to the household income, quantified the extent of "Chinese caterpillar fungus dependence" among households with different economic and social characteristics, and assessed the role of cash income from the Chinese caterpillar fungus harvest in meeting various household needs including education, debt payments, and food security. Results show that Chinese caterpillar fungus income is the second largest contributor to the total household income after farm income with 21.1% contribution to the total household income and 53.3% to the total cash income. The contribution of Chinese caterpillar fungus income to total household income decreases as the household income increases making its contribution highest for the poorest households. There is significant correlation between Chinese caterpillar fungus dependency and percentage of family members involved in harvesting, number of food-sufficient months, and total income without Chinese caterpillar fungus income. Income from Chinese caterpillar fungus is helping the poorest to educate children, purchase food, and pay debts. However, reported decline of Chinese caterpillar fungus from its natural habitat might threaten local livelihoods that depend on the Chinese caterpillar fungus in future. Therefore, sustainable management of Chinese caterpillar fungus through partnership among local institutions and the state is critical in conserving the species and the sustained flow of benefits to local communities.

1. Introduction

Biodiversity and human well-being are linked through ecosystem services (MEA, 2005). Provisioning ecosystem services, particularly wild plants and animals, make a significant contribution to the livelihoods and well-being of rural people in developing countries (Vira and Kontoleon, 2013). Globally, about 1.6 billion people including 60 million indigenous people depend directly on forest products for their livelihoods (World Bank, 2004; Vedeld et al., 2007). A meta-analysis of 54 case studies shows that biological resources may contribute as much as 20–25% of income to rural people in developing countries (Vedeld et al., 2007). During the last two decades significant progress has been made in understanding the role of biological resources in the lives of poor people, particularly their contribution to the household economy, and their role in alleviating poverty (Vira and Kontoleon, 2013).

It is generally assumed that income derived from wild species meets subsistence needs, provides a valuable safety net by offering a buffer against risks and shocks, and offers a possible pathway out of poverty (Cavendish, 2002; Shackleton and Shackleton, 2004; Vedeld et al., 2004; Angelsen and Wunder, 2003; Babulo et al., 2009; Vira and Kontoleon, 2013). However, there are limited data to determine how the lowest income groups among poor societies actually benefit from biological resources. Some studies suggest that dependency on forests (household income relative to the income from forest resources) among poor households is relatively higher than more well-to-do households (Cavendish, 2000; Fischer, 2004; Mamo et al., 2007; Vedeld et al., 2007; Babulo et al., 2009; Kamanga et al., 2009; Heubach et al., 2011) whereas others indicate that the dependency on forest resources increases with wealth (Adhikari et al., 2004; Coomes et al., 2004; Fischer, 2004; Narain et al., 2008). In addition to household wealth, income derived from

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the extraction of wild resources depends upon organizational, institutional, and social factors including household size, caste, sex of the household head, education of family members, land and livestock holdings, and distance to the resources as well as the markets (Adhikari et al., 2004; Viet Quang and Nam Anh, 2006; Uberhuaga et al., 2011; Zenteno et al., 2013).

Ecosystem services include provisioning and the harvesting of wild species (resources). Poor forest dwellers depend on these resources for their livelihoods. In order to sustain such ecosystem services, we require case studies about the role of each resource in the household economy. Managing such a resource would require ecological data on the abundance and demographic trends of the plant or animal species and how the abundance is affected by current levels of harvesting. Effective management also requires data on the harvesters: their social and economic status, and how each affects the amount of the resource harvested. Because harvesters have so much potential income from resources like Chinese caterpillar fungus, the harvest might begin earlier and last later, depleting the resource. Co-management of the resource might be the answer, but effective co-management depends in part on how close the harvesters live to the resource being harvested. However, information about extraction of wild resource is often fragmentary, confined either to the ecology, economics, or management of extraction. We simply do not have much data on the social, economic, and demographic characteristics of harvesters, or where they live.

Chinese caterpillar fungus, an endemic species complex of the high altitude grasslands of Himalaya and the Tibetan Plateau, has several unique features. Locally called *Yarsagumba* in the Dolpa dialect which is derived from Tibetan word *yartsa gunbu* (meaning summer grass winter worm), it is a parasitic complex formed by parasitic fungi (*Ophiocordyceps sinensis*) and host caterpillar of the moth species belonging to genus *Thitarodes* (Winkler, 2009). Although there no consensus about the nomenclature of this parasitic complex, we adopted Zhang et al. (2012) nomenclature of "Chinese caterpillar fungus" for "*Ophiocordyceps sinensis*-ghost moth caterpillar complex" in this paper. This species complex is used as a medicinal fungus to strengthen lung and kidneys, increase energy and vitality, stop hemorrhage, decrease phlegm and treat fatigue (Holliday and Cleaver, 2008; Zhou et al., 2009). However, it is widely traded as an aphrodisiac and a powerful tonic in the name of "Himalayan Viagra" (Holliday and Cleaver, 2008; Winkler, 2009; Shrestha and Bawa, 2013). Although the Chinese caterpillar fungus, with the current market price of US$ 140,000/kg for the best quality product in China (Xuan et al., 2012) constitutes as one of the most expensive biological resources in the world, it is harvested by hundreds of thousands of some of the poorest people in Nepal, China, Bhutan, and India.

These rural poor depend upon the harvest for their livelihoods. Based on previous studies (Devkota, 2010; Shrestha and Bawa, 2013) and our own calculation, we estimate about 100,000 harvesters are currently involved in harvesting of Chinese caterpillar fungus every year in Nepal. With the current annual production, the estimated trade of Chinese caterpillar fungus globally is US$ 5–11 billion (Shrestha, 2012). The price in international market has increased by 900% in ten years from 1997–2008 (Winkler, 2009) and in Nepal, the price has increased up to 2300% between 2001 and 2011 (Shrestha and Bawa, 2013). In the Dolpa district, where this study is based, about 473.8 kg Chinese caterpillar fungus worth of US$ 6.0–8.5 million (based on the local market price) was traded in 2011 (Shrestha and Bawa, 2013). Due to its enormous market value, it is widely believed that Chinese caterpillar fungus plays an important role in local and national economies. However, we do not know how much it contributes to local household incomes. Neither do we know the extent to which the harvesters depend on Chinese caterpillar fungus for cash income, nor the socio-economic factors that determine the harvesters' income from the fungus.

Here, we quantify the economic contribution of Chinese caterpillar fungus to household economy of mountain communities of Dolpa district of Nepal. Specifically we addressed three questions: (1) How much does Chinese caterpillar fungus contribute to the household income? (2) How much do households depend on Chinese caterpillar fungus, and does that dependence vary among households with different economic and social characteristics? (3) Does the income from the fungus help to reduce poverty and hunger in this area? We discuss the implications of our results on the regulatory mechanisms set up by local institutions for conservation of species.

Our study on the contribution of this unusual species complex to household economy is novel in two respects. First, it provides insights into the conservation and sustainable use of biological resources of an extremely valuable species complex that occurs in extreme environments. Almost all of the previous work on provisioning services provided by non-timber forest products comes from the tropics or sub-tropics and much of it is on low-value species. Second, our economic analyses, in conjunction with our ecological (Shrestha and Bawa, 2013) and institutional analyses, (Shrestha and Bawa, 2014; Shrestha et al., 2014) seeks to provide the basis for monitoring and management of this valuable resource and the associated fragile ecosystems that are also highly vulnerable to climate change.

2. Materials and methods

2.1. Study area

Chinese caterpillar fungus is reported from 27 northern districts of Nepal and of those is widely collected from only seven districts (Devkota, 2010; Thapa et al., 2014). Dolpa district is regarded as a major warehouse of Chinese caterpillar fungus in Nepal, contributing 40% of Chinese caterpillar fungus supply in 2011 in Nepal (GoN, 2011). In Dolpa, the Chinese caterpillar fungus is collected from 24 alpine pastures (DFO, 2010); five of these (Saikumari, Pokepani, Ruppatan, Chinarangsi, and Batule) are located in the Majphal Village Development Committee (VDC) – the lowest administrative unit of Nepal. Although about half of the area of Dolpa is covered by Shey-Phoksundo National Park and its buffer zone, the study area is neither part of Shey-Phoksundo National Park, nor its buffer zone (see Fig. 1).

Dolpa is the largest district of Nepal with an area of 7932 km^2, inhabited sparsely, with a population density 5/km^2 (DDO, 2010). In terms of poverty, it ranks twelfth poorest district out of 75 districts of Nepal; about 42.8% population of Dolpa lives below Nepal's national poverty line (CBS, 2013) Although 90% of 36,700 inhabitants of Dolpa depend primarily on agriculture, only 1.18% of the area of this district is currently farmed (DDO, 2010; CBS, 2012). Because of the lower proportion of land suitable for agriculture and because of low productivity of the land, only 6.4% the households grow sufficient food for the whole year and more than 50% of the households of Dolpa grow sufficient food for only half the year (DDO, 2010). Therefore, Dolpa is regarded as one of the most food insecure districts of Nepal, and subsidized rice is distributed to the poor families by the Government of Nepal and other aid agencies every year. Approximately 31.48% of the land in Dolpa is covered by alpine and subalpine grasslands (DDO, 2010) making Dolpa a very suitable habitat for Chinese caterpillar fungus. It occurs in the south facing slopes of the alpine and sub alpine grasslands and shrublands of an altitude 3000–5200 m that receive a minimum of 350 mm average annual precipitation (Winkler, 2009; Devkota, 2010).

Fig. 1. Map of the study area.

2.2. Data collection

Data were collected through key informant interviews and focus group discussions. We interviewed 216 harvesters from 17 VDCs spread over 50 villages in four districts at three harvester camp sites (Tarpare, Opa, and Baghdanda) located in the Majphal VDC, Dolpa. We excluded 15 responses due to incomplete information and included the remaining 201 responses for further analysis. Consent from the respondents was secured before the interviews and discussions by explaining the study objectives. This study was conducted among the harvesters extracting Chinese caterpillar fungus in Saikumari, Chinarangsi, Ruppatan, and Batule pastures of Majphal VDC, Dolpa between May and July 2011 (Supplementary data are available at http://dx.doi.org/10.1594/PANGAEA.833518).

We first prepared a list of all harvesters with at least five years' harvesting experience by visiting every hut in the three camps. Name slips were placed in a box and the interviewees were randomly chosen through the lottery method and without replacement. Only one harvester from a household was chosen. We chose a substitute if the randomly drawn respondent was not available or did not want to be interviewed. Interviews were conducted in the evening when harvesters returned back to their camps from the pasture. All interviews were conducted in Nepali—the common language of communication in the region. The socio-economic characteristics of the Chinese caterpillar fungus harvesters are given in Table 1.

2.3. Income accounting

Total income is defined as the sum of income from environmental, agricultural, and off/non-farm activities, and calculated by using reported local prices of agricultural products (Vedeld et al., 2007). Following Zenteno et al. (2013 and literature cited therein), we applied the monetization of all economic activities to calculate total household income contributed by various income sources (agriculture, horticulture, livestock, off-farm income which includes seasonal labor, business, service, remittance, and miscellaneous). Apart from monetization of subsistence farm income, we calculated cash income derived from the sale of agricultural and horticultural crops separately. We did not convert livestock value into total monetary value to calculate total household property; however, cash earned by the sale of livestock in last

Table 1
Socio-economic characteristics of the Chinese caterpillar fungus harvesters.

Household characteristics	Sample (N = 201) Mean (SD)	Poorest (N = 50) Mean (SD)	Poor (N = 52) Mean (SD)	Less poor (N = 50) Mean (SD)	Least poor (N = 49) Mean (SD)
Age (year)	30.9(10.9)	31.6(10.3)	31.3(10.9)	30.2(10.9)	30.5(11.9)
Education of the respondents (year)	7.3(3.5)	6.4(3.1)	7.2(3.7)	7.0(3.4)	8.5(3.7)
Experience of Chinese caterpillar fungus harvesting (year)	7.7(3.9)	7.2(2.8)	8.6(4.4)	7.1(2.9)	7.9(4.9)
Family size (person)	6.0(2.2)	5.4(1.7)	5.7(1.7)	5.9(2.0)	6.9(3.0)
Family members involved in Chinese caterpillar fungus harvesting (%)	48.4(24.0)	49.3(25.2)	46.7(24.8)	49.9(23.2)	47.8(23.4)
Number of children bringing for Chinese caterpillar fungus harvesting locality	0.6(0.9)	0.5(0.8)	0.5(0.9)	0.7(0.9)	0.6(1.0)
Time spending for collecting Chinese caterpillar fungus 2010 (day)	20.7(10.3)	17.7(8.1)	21.5(11.0)	22.0(10.4)	21.6(11.1)
Food sufficiency in 2010 (month)	8.1(3.1)	6.4(2.3)	7.6(2.8)	8.3(3.4)	10.1(2.7)
Unit of livestock	4.3(4.7)	2.2(2.4)	3.8(4.0)	4.6(4.1)	6.9(6.3)

12 months' period was accounted in total household income. Based on past study (Adhikari et al., 2004) and current local prices, one livestock unit is considered to be equivalent of 1 buffalo/mule/horse, 3 cows, and 6 goats/sheep.

The reported income of Chinese caterpillar fungus harvesting was validated by the total number of collected pieces and per unit market price. Cash income derived by selling of forest products (firewood, fodder for cattle, poles, thatching and construction materials, and medicinal plants) was included. However, we did not monetize household use of those forest products; nor did the family labor cost incurred for agricultural activities as well as Chinese caterpillar fungus harvesting (Sjaastad et al., 2005; Kamanga et al., 2009; Nielsen et al., 2012). Furthermore, none of the respondents' used hired labor for any of those activities; a mutual labor-sharing system called *parma* is practiced in this region.

2.4. Statistical analyses

Total household income was calculated in Nepalese rupee (exchange rate US $1 = 88.67 Nepalese Rupee, NRs). Based on the total household income without Chinese caterpillar fungus income, the whole sample was divided into four income quartiles: 0–25% (poorest), 25–50% (poor), 50–75% (less poor), and 75–100% (least poor) and the validity of this grouping was tested by comparing the means using one-way ANOVA (analysis of variance).

The dependency of household on Chinese caterpillar fungus harvesting was quantified by calculating the ratio of the total household income to Chinese caterpillar fungus income. The dependency in different income groups was explored by the comparison of means using one way ANOVA. An ordinary least-square (OLS) regression model was fitted to determine effect of demographic variables (independent variables) on the percentage of the total household income shared by Chinese caterpillar fungus income (dependent variables). We assume that economic status of households (total off-farm income, livestock units, total household income without caterpillar fungus, number of food sufficient months) might have impact on dependency because economically better-off households might have little interest in harvesting caterpillar fungus. Allocation of total labor in harvesting (family size and percentage of family members involved in harvesting) are also assumed to have an impact on dependency because the greater the number of people engaged in harvesting, the greater the income. Similarly the number of days spent in harvesting would also influence income. Searching for Chinese caterpillar fungus that protrudes just four or five centimeters above the ground depends on sharp vision. Therefore, it can be predicted that children find more Chinese caterpillar fungus than the elderly people.

3. Results

3.1. Average household income, and average Chinese caterpillar fungus income

We categorized income sources of Chinese caterpillar fungus harvesters into four major categories: farm, off-farm, forest, and Chinese caterpillar fungus. The average total household income of the harvesters is NRs 163,477 (SD = 132,361) [Average = US$1843.66, SD = 1489.02] per year. For the whole sample, farm income comprises the biggest share of the total household income, accounting for 63.8 (SD = 19.0)% of the total household income on average. Chinese caterpillar fungus income is the second biggest contributor (21.1%, SD = 14.5) and forest income being the least (0.6%, SD = 2.4). Chinese caterpillar fungus plays a significant role in the household's cash income, accounting for 53.3 (SD = 31.8)% of the household's cash income on average. Off-farm income constitutes the second largest (28.1%, SD = 30.5) portion of the household cash income after the cash income from Chinese caterpillar fungus harvest. In our sample, 11.4% harvesters (23 of 201) reported that Chinese caterpillar fungus harvesting is the only source of cash income for their family.

3.2. Chinese caterpillar fungus dependency

The average figures for the total household income and cash income in different income groups are given in Table 2. The dependency on Chinese caterpillar fungus decreases as the total household income increases indicating that the contribution of Chinese caterpillar fungus to households in the lowest income quartile (poorest) households is the most, and it is the least for the households in the highest income quartile (least poor) (Fig. 2A and B). On average, Chinese caterpillar fungus contributes 31.5 (SD = 15.4)% of the total household income and 71.7 (SD = 23.3)% of the total cash income for the poorest households whereas corresponding figures are 10.9 (SD = 8.7)% and 24.2 (SD = 17.8)% respectively for the least-poor households. For the poorest households, Chinese caterpillar fungus harvesting is the second most important livelihood strategy after farm income, contributing 58.3 (SD = 18.1)% of the total household income. For the least poor households, off-farm activities such as business, seasonal labor, service, and remittance are the second important source of income after farm income (contributes 24.7%, SD = 21.7 of the total household income). Furthermore, results of one-way ANOVA show that the differences in all income sources among four income groups are statistically significant except the income derived from Chinese caterpillar fungus (Table 2). Despite the unequal contribution of Chinese caterpillar fungus to our four income groups, total income from Chinese caterpillar fungus among them does not differ at a statistically significant level.

Table 2
Mean source of income (in Nepalese Rupee) and income share by different sources among different income group.

Income group	Poorest (0–25%) (*N* = 50)		Poor (25–50%) (*N* = 52)		Less poor (50–75%) (*N* = 50)		Least poor (75–100%) (*N* = 49)	
Income source	Mean (SD)	Mean percentage contribution (SD)	Mean (SD)	Mean percentage contribution (SD)	Mean (SD)	Mean percentage contribution (SD)	Mean (SD)	Mean percentage contribution (SD)
Cash income								
Farm**	1890(3941)	7.8(16.8)	4231(7815)	9.3(14.7)	18740(22437)	24.7(25.4)	41857(70803)	27.7(29.3)
Off-farm**	5554(6552)	19.7(20.9)	11077(17014)	20.9(30.1)	21162(25536)	26.3(28.5)	76367(80754)	46.2(34.0)
Forest*	304(988)	0.9(2.5)	615(2046)	1.3(4.2)	1322(5167)	1.8(6.0)	1980(8043)	2.0(7.5)
Chinese Caterpillar fungus	25444(24210)	71.7(23.3)	29072(22496)	68.5(30.3)	31274(22877)	47.6(29.0)	30327(25627)	24.2(17.8)
Total**	33192(23286)	100.0	44995(25350)	100.0	72498(36167)	100.0	150531(115419)	100.0
Total income								
Farm	40309(14993)	58.3(18.1)	73250(18835)	65.6(17.0)	108286(29662)	67.4(17.9)	202500(165386)	63.7(22.1)
Off-Farm**	5554(6552)	9.7(11.5)	11077(17014)	10.6(16.6)	21162(25536)	13.6(16.7)	76367(80754)	24.7(21.7)
Forest*	304(988)	0.5(1.6)	615(2046)	0.6(1.8)	1322(5167)	0.8(3.1)	1980(8043)	0.7(2.8)
Chinese Caterpillar fungus	25444(24210)	31.5(15.4)	29072(22496)	23.3(13.6)	31274(22877)	18.2(11.3)	30327(25627)	10.9(8.7)
Total**	71611(29399)	100.0	114014(24420)	100.0	162044(26321)	100.0	311173(192515)	100.0

Significant difference between four groups (*F*-test).
* $P \leqslant 0.05$.
** $P < 0.001$.

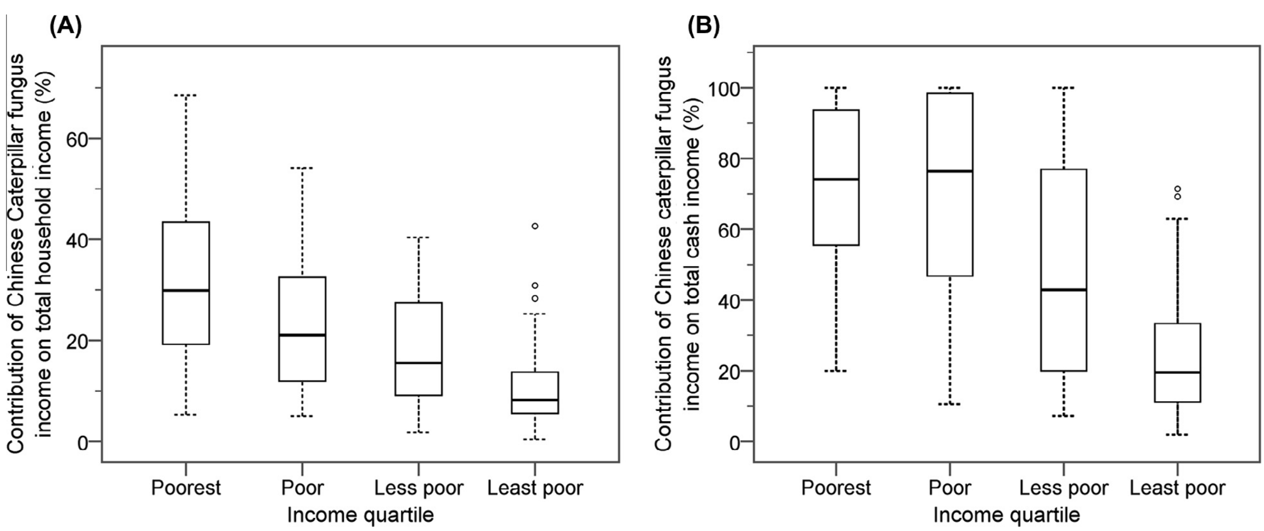

Fig. 2. Percentage contribution of Chinese caterpillar fungus income (A) on total household income and (B) on total cash income.

3.3. Socioeconomic factors influencing Chinese caterpillar fungus dependency

This OLS model yielded a statistically significant model with harvester's age, years of education, harvesting experience, family size, percentage of family members involved in harvesting, number of days spent in harvesting in the year 2010, number of food sufficient months, livestock unit, total off farm income and total income without Chinese caterpillar fungus income. The model explains 27.5% of the variance in dependent variables by independent variables ($R^2 = 0.275$).

Ordinary least-square regression shows that there is no significant correlation between dependency and harvester's age, years of education, harvesting experience, family size, number of days spent in harvesting, livestock units, and total off-farm income (Table 3). However, there is a significant positive correlation between dependency and percentage of family members involved in harvesting and significant negative correlation between dependency and total income without caterpillar fungus income as well as with number of months with sufficient food (since this region is a food insecure area, we asked harvesters how many months are they without their own agricultural produce).

3.4. Expenditure of Chinese caterpillar fungus income

We asked harvesters to split the total amount earned from caterpillar harvesting into different expenditure categories. The major categories of expenses are: food, clothing, children's education, debt payments, savings, celebration of festivals, healthcare, building/repairing house, purchasing land, buying material goods, and entertainment. On average, children's education (25.7%), food (21.3%), and clothing (19.6%) are the top three spending categories whereas entertainment (1.0%), purchasing land (1.2%), and celebrating festivals (2.3%) are the bottom three spending categories

Table 3
Percentage of Chinese caterpillar fungus income in total income (dependency) by socio-economic variables.

Variables	Coefficients estimate	Std. error	*t* Ratio	*p* Value
(Constant)	24.893	7.378	3.374	0.001
Age (year)	0.096	0.115	0.837	0.404
Education of the respondents (year)	0.378	0.353	1.070	0.286
Experience of Chinese caterpillar fungus harvesting (year)	0.021	0.275	0.077	0.939
Family size (person)	0.064	0.504	0.127	0.899
Family members involved in Chinese caterpillar fungus harvesting (%)	0.111	0.044	2.537	0.012
Time spending for collecting Chinese caterpillar fungus 2010 (day)	−0.046	0.096	−0.483	0.630
Food sufficiency in 2010 (month)	−1.179	0.325	−3.628	0.000
Unit of livestock	−0.002	0.226	−0.008	0.994
Total off farm income	0.000	0.000	−1.092	0.276
Total income without Chinese caterpillar fungus income	0.000	0.000	−3.106	0.002

$n = 195$; $R^2 = 0.275$; R^2 adj = 0.236; $F = 6.977$, $P = 0.000$.

for the sample population (Table 4). There is no significant difference between the expenditure patterns of the four income groups except in children's education, buying material goods, and entertainment. Expenditure in children's education of households in lower income categories (poorest = 22.8%, poor = 35.0%) is higher than that of households in higher income categories (least poor = 18.4%, less poor = 25.9%) ($f = 2.32$, $P = 0.08$). Interestingly, poorest households do not spend money earned from Chinese caterpillar fungus on entertainment; however, the spending on entertainment increases significantly with households' income ($f = 3.77$, $P = 0.01$). Both the poorest and the least-poor households spend fungus income on luxury goods such as mobile phones and color television sets that are easily noticeable in the remote villages. Although statistically insignificant, expenditure of poorer households in food and clothes is higher than that of richer households. Likewise, richer households also save more money than the poorer households (Table 4).

4. Discussion

This study represents the first effort to quantify the contribution of Chinese caterpillar fungus to the household economy of mountain communities in Nepal. Our results show that Chinese caterpillar fungus harvesting has become an integral part of the livelihoods of mountain communities within a decade after its trade became legal. Although Chinese caterpillar fungus has been used in traditional health care systems of China for centuries, it is now extensively collected for trade due to its high demand as tonic and aphrodisiac "herb". The government revenue generated by Chinese caterpillar fungus is the highest among all other species of NTFPs; Chinese caterpillar fungus contributed 40.5% of the total revenue generated from 62 NTFPs species in Nepal in the year 2011 (GoN, 2011). In Dolpa alone, trade in the fungus was US$ 6–8.5 million in the same year. Our results show that the contribution of Chinese caterpillar fungus to the household economy is huge: it provides 53.3% of the cash income and 21.1% of the total household income in average.

Although the share of NTFPs in cash income varies among socio-economic groups, it appears that contribution of caterpillar fungus, as a single species complex, to local economies is the highest among the entire array of NTFPs. A study in Nepal reported that NTFPs may contribute as much as 90% of the household income (Bista and Webb, 2006). In Sangdui Valley of Daocheng County, China, Chinese caterpillar fungus contributes 72% of household cash income on average (Woodhouse et al., 2013), higher than that of in Dolpa. However, in another village—Sushi of China, the contribution of Chinese caterpillar fungus to the total household cash income is up to 27.4% (Huber et al., 2014). The contribution is much higher in Bhutan; up to 80–100% of the harvesters income comes only from the sale of Chinese caterpillar fungus (Wangchuk, 2011; Wangchuk et al., 2012). The much higher contribution in some parts of China may be due to the greater amount of harvesting per household in China than in Nepal but we lack a comparable figure for the amount of harvesting per household in Bhutan. Woodhouse et al. (2013) reported that households collected an average number of 404 pieces in 2009 whereas in Nepal comparable number in the same year was 164 (Shrestha and Bawa, 2013). Furthermore, geographical location of the study area might make a difference in the proportion Chinese caterpillar fungus contributes to the household income. For example, for the households of higher elevation regions where Chinese caterpillar fungus occurs, harvesting of Chinese caterpillar fungus is more important than agricultural activities and harvesting of other medicinal plants (Huber et al., 2014).

Table 4
Mean of income spending (in Nepalese Rupee) by different income group.

	Poorest (0–25%) ($N = 50$)		Poor (25–50%) ($N = 52$)		Less poor (50–75%) ($N = 50$)		Least poor (75–100%) ($N = 49$)	
	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%
Food	6830(4705)	26.8	6817(5507)	23.4	5920(4379)	18.9	5143(6258)	17.0
Clothes	5600(4114)	22.0	6054(4728)	20.8	6000(3817)	19.2	5122(5949)	16.9
Children's education*	5800(8557)	22.8	10183(13495)	35.0	8110(8881)	25.9	5592(8573)	18.4
Paying debt	1820(5098)	7.2	1394(3033)	4.8	1460(4837)	4.7	1367(5964)	4.5
Savings	20(141)	0.1	635(2327)	2.2	1760(7156)	5.6	1816(6882)	6.0
Celebrating festivals	1080(3871)	4.2	596(2303)	2.1	750(1944)	2.4	859(3068)	2.8
Healthcare	2024(3168)	8.0	1494(3498)	5.1	2694(4572)	8.6	2276(6294)	7.5
Building/Repairing house	1840(6573)	7.2	1553(4739)	5.3	2600(7735)	8.3	3796 (11984)	12.5
Purchasing land	0(0)	0.0	96(693)	0.3	1200(7183)	3.8	102(714)	0.3
Buying material goods**	430(2832)	1.7	192(971)	0.7	460(1541)	1.5	3494(9353)	11.5
Entertainment*	0(0)	0.0	58(308)	0.2	320(1518)	1.0	759(2004)	2.5

Significant difference between four groups (*F*-test).
* $P \leqslant 0.10$.
** $P \leqslant 0.05$.

Chinese caterpillar fungus harvesting is the second most important source of income after farm income. For the duration of the harvest, entire villages of the Dolpa district and adjoining regions are literally empty, schools are closed, and other activities are slowed to allow people to harvest Chinese caterpillar fungus. In the surveyed areas, average 48.2 (SD = 24.0)% of the family members left home for Chinese caterpillar fungus harvesting; only old people, toddlers, and physically weak persons remained in the villages during the harvest.

Previous studies have shown inconsistent results for the relationship between income levels and harvest of NTFPs. In Nepal some researchers have reported findings contrary to ours. In community-managed forests, people belonging to the highest income quartile derive proportionately the most income from the harvest of non-timber forest products (tree and grass fodder, and leaf litter) than the lower income groups because of the latter's restricted access to the forests and their lower level of involvement in decision-making processes (Adhikari et al., 2004). Similarly, Gauli and Hauser (2011) found that the contribution of NTFPs to the income of the poorest households is low compared to other income groups, again due to limited access and participation of those households in NTFPs collection as well as due to lack of knowledge and confidence in marketing NTFPs. The same was true in Vietnam (McElwee, 2008), and Bolivia (Uberhuaga et al., 2011) whereas the opposite was observed in Zimbabwe (Cavendish, 2000), Malawi (Fischer, 2004), Ethiopia (Mamo et al., 2007), and Nepal (Rijal et al., 2011). In Cameroon, Ambrose-Oji (2003) found that the middle-income groups proportionately obtain more income from NTFPs than other income groups. Our results are in line with the findings of Cavendish, 2000; Fischer, 2004; Mamo et al., 2007; Narain et al., 2008; Rijal et al., 2011; we observed that households in the lowest income quartile (the poorest households) obtain a larger proportion of their income from Chinese caterpillar fungus than other groups. This does not, however, show that the total income from the Chinese caterpillar fungus for the poorest households is greater than that for the least poor households. In fact, the income from Chinese caterpillar fungus harvesting did not vary significantly among the four wealth groups. The income sources of the poorest households are also limited: farm income and off-farm income of poorer households is significantly lower than that of the well-to-do households.

In line with other authors (Adhikari et al., 2004; Gauli and Hauser, 2011; Uberhuaga et al., 2011; Heubach et al., 2011), we did not observe that the least poor households are better equipped to extract high value resources, have better access to the forest resources, or are better connected to trade infrastructure. Access to the pasture to collect Chinese caterpillar fungus is unrestricted (harvesters have to pay nominal fee to local institutions to enter the pastures) and is not based on income groups or social hierarchy. More importantly, the equipment required for harvesting the fungus is very simple and inexpensive. Furthermore, the difference between outsiders (outside Dolpa) and insiders (from Dolpa) in entrance fee charged to enter the pastures is nominal, and the duration of the stay in the harvesting camps depends on harvesters' ability to find Chinese caterpillar fungus, and not on economic status. Unlike other species of NTFPs that are readily accessible, physically noticeable, and easily collectible, the size of Chinese caterpillar fungus is very small, and its detection in the habitat depends on one's luck, and previous experience about the species complex and the habitat irrespective of the harvester's level of wealth.

Although there are a number of studies on the effect of various socio-economic factors on a household's NTFPs income (Kamanga et al., 2009; Coulibaly-Lingani et al., 2009; Timko et al., 2010), we do not see a consistent pattern. Five factors—access to forests and markets, wealth status, gender, education, and seasonality—are known to affect NTFPs income (Timko et al., 2010). In Africa, total income from NTFPs correlates negatively with education of the household head but correlates positively with family size and location (the distance to the forest) (Kamanga et al., 2009). For the Chinese caterpillar fungus, greater the percentage of family members involved in Chinese caterpillar fungus harvesting (not the family size) the more they earn. Similar results were observed in Tibet (Woodhouse et al., 2013). Weckerle et al. (2010) found that income from Chinese caterpillar fungus correlates with the number of harvesters per household, collection duration in days, and collecting experience (years). Unlike other NTFPs resources, collection of Chinese caterpillar fungus is seasonal, and collected by tens of thousands of harvesters for a limited time period. Thus the education level of the harvesters, age, or family size does not have any effect on the contribution of the fungus to the income of the household.

Our results on expenditure from Chinese caterpillar fungus income show that the highest amount of money derived from Chinese caterpillar fungus is spent on educating children, including tuition and purchase of books and school supplies. Because of the additional income, more families are able to send their children to school. Of the other major expenditures, purchase of food is the most important category. A significant amount of additional income is also used to pay loans and save capital. The western mountains region as a whole and Dolpa in particular fall in the lowest rank in different measures of poverty and human wellbeing in Nepal. Hunger is a problem in this region, one of the most food insecure areas in Nepal. Local production supports only 40% of the total food consumption; 57% food is purchased from outside (NPC, 2013). Beginning in 2002, the food security situation in Dolpa has improved (DDO, 2010). Although, urbanization and remittance income are considered to be the major drivers, reducing poverty and increasing food security in Nepal (NPC, 2013), the number of families receiving remittance is nominal and urbanization is minimal in Dolpa. No roads yet connect the district to the rest of Nepal.

In Nepal, the harvest of Chinese caterpillar fungus was banned till 2000 under the Forest Act 1993 and Forest Regulations 1995. However, the collection and trade of Chinese caterpillar fungus were done illegally and secretly making the ban ineffective. With the so-called ban, local people were precluded from earning money through the harvesting of Chinese caterpillar fungus and government was losing revenue. Therefore, the ban was lifted in 2001 with the provision of revenue of NRs 20,000 per kg and later that revenue is reduced to NRs 10,000 per kg in 2006 (Devkota, 2010). After legalization of trade of Chinese caterpillar fungus in 2001, earnings from the harvest have continuously increased due to the increase in market price. In 2011, approximately 473.8 kg of Chinese caterpillar fungus worth of approximately US$ 6.0–8.5 million was collected from Dolpa (Shrestha and Bawa, 2013). Therefore, in Dolpa where about 90% of the inhabitants are involved in Chinese caterpillar fungus harvesting, income from Chinese caterpillar fungus may play a key role in increasing investment in education, improving food security, and alleviating poverty.

We recognize that our work on the contribution of Chinese caterpillar fungus to household income and the factors influencing harvests has two limitations. First, we did not monetize subsistence contribution of firewood, medicinal plants, and construction materials derived from the forests. Second, we did not include the cost of labor in agriculture, forest-related activities, and Chinese caterpillar fungus harvesting. These limitations may have nominal impact on the overall results as almost the entire population obtains subsistence resources from forests and does not hire external labor in collection of resources and in agriculture.

Overall, in the western mountains region of Nepal, poverty correlates spatially with the distribution of the world's most valuable biological resource, Chinese caterpillar fungus. Our results on economics of the fungus complex show Chinese caterpillar fungus is helping the poorest in earning income that is devoted to education, purchase of food, and relief from debt. On the other hand, our ecological work shows that the fungus population and per-capita harvest in this region is declining, probably due to overharvesting, pre-mature harvesting, decrease in moth and larval populations, modification of the soil microhabitats congenial to fungal spores by the harvesters, increased grazing intensity and climate change (Shrestha and Bawa, 2013). Decline in per capita harvest has not caused reduction in overall fungus earnings as it is balanced by the increase in the price of fungus. However, the decline, if it continues, will have long-term consequences for the livelihoods of these impoverished rural people.

Chinese caterpillar fungus makes a relatively high contribution to income for the rural poor, and the significant role it plays in education and food security, makes the fungus complex a key economic resource in Nepal. Its economic importance, along with the fact that very large number of people harvest the fungus, makes it feasible to generate interest among local and federal authorities as well as people for conservation and management of Chinese caterpillar fungus and its habitat. Our economic and ecological analyses are geared towards providing key inputs to long term conservation of the species. Specifically, our results indicating a disproportionately higher role of this fungus complex in the cash economy of the poorest people and the role of this cash in alleviating poverty illustrate the stake such people have in preserving this "biological gold" and the important role they can play in implementing management plans.

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