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Local perceptions of Matsutake mushroom management, in NW Yunnan China

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ABSTRACT

Matsutake mushrooms are among the most prized and expensive mushrooms on earth. Since the 1980s NW Yunnan Province has become the largest exporter of Matsutake in China, and money from their sale has become crucial to local livelihoods and to the provincial tax base. Amid fears of declining productivity, regulations have been enacted to control Matsutake harvest, though enforcement remains largely in the hands of harvesters themselves. Here, we measure local harvesters' perceptions of the ecological determinants of mushroom productivity in contrast to that of the outsider conservation community. We interview 122 harvesters in eight villages in Diqing province, NW Yunnan to determine what is perceived to be detrimental to Matsutake yield, how yield can be improved in the future and who harvesters trust for information. Our results indicate that village leaders and forestry officials are overwhelmingly the most trusted sources for information. Mann and Whitney U tests show general consensus among villages, and MRPP analysis shows general consensus within villages. One village showed significantly higher levels of trust in NGOs. Of the 86% of harvesters who had perceived declining productivity trends over the past 10 years, soil disturbance, climate change, and habitat degradation were most often-cited as causal factors. Log-linear analysis showed almost no significant interactions between perceptions and harvester demographics. Environmental protection and reducing soil disturbance were most often-cited as potentially increasing future yields. We suggest that local and outsider knowledge are complimentary in this system, and that forestry officials and village leaders provide the best conduits for management information.

1. Introduction

1.1. Non-timber forest products in SW China

NW Yunnan Province and the Hengduan Mountains partially contained within lay claim to roughly one-fifth of China's vascular plant species, one-fourth of the nation's species of mammals and one-third of its bird species (Ou, 2003), ensuring this region's high rank in global conservation importance. This remarkable biodiversity, coupled with stunning scenery and rich cultural heritage, has led to the region's designation as a Global International Biodiversity Hotspot (Mittermeier et al., 1998), and a World Natural and Cultural Heritage Site.

Non-timber forest products (NTFP) are, and have long been, essential to livelihoods in this region of the Eastern Himalayas which lie along major Sino-Burma and Sino-Indian trading routes (Salick et al., 2005). Written records indicate that trade in the medicinal caterpillar fungus, *Cordyceps sinensis*, as well as other important medicinal plants, was brisk as early as the 19th and early 20th centuries as documented by plant explorers to the region (Winkler, 2003; Ward, 1990; Cooper, 1871). In fact, the Tibetan name for the mountain range which dominates this prefecture: *Menri*, translates to "Medicine Mountains" (Anderson et al., 2005), denoting their historical role as a source for Tibetan and Chinese *materia medica*.

Social policy, initiated under Chairman Mao, however, changed the trajectory of land-use patterns (Salick et al., 2005; Xu and Ribot, 2004; Shapiro, 2001; Richardson, 1990) and as late as 1993, although trade in non-timber forest products and other sources of income were prevalent, as much as 80% of Diqing prefecture's income came from logging (Melick et al., 2007; Weyerhaeuser et al., 2005; Yeh, 2000). In 1998, a series of disastrous floods prompted the Chinese government to enact a commercial logging ban in natural forests (Zhang and Wu, 2000), and trade in NTFP again rose in prominence. In areas of contemporary Diqing, estimates of the percentage of income earned from NTFP ranges from between 25% and 80% of total household incomes (Arora, 2008; Xu

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and Ribot, 2004; Zhang and Wu, 2000), the majority of which is from the export of Matsutake to Japan (He, 2003; Yeh, 2000).

1.2. Tricholoma matsutake, novel markets and conservation concerns

T. matsutake, an edible mushroom, has been revered in Japan for centuries for its distinguished flavor and iconic significance Hosford et al. (1997). The last century saw dramatic declines in Matsutake fruiting bodies in Japan. According to Kawai and Ogawa (1981), Matsutake productivity had declined to less than 10% of its pre WWII levels by the early 1980's, and Saito and Mitsumata (2008) present even starker declines. This decline may be attributed to a combination of Pine mortality due to the introduction of a pathogenic nematode, *Bursaphelenchus lignicolus*, and a change in forest demographics following the adoption of natural gas stoves as opposed to wood or charcoal. Scarcity combined with an unflagging demand among Japanese consumers has made Matsutake among the most sought after and expensive mushrooms in the world. As domestic production declined in Japan, imports of *T. matsutake* and closely-related congeners soared. By 1986, Diqing prefecture in the NW corner of Yunnan Province began to export fresh Matsutake and now exports more biomass than any other region in China (He, 2003). Despite Matsutake collection's relative novelty here, its impacts on local villages and on the environment have been marked. Today, revenues from Matsutake are the highest of any NTFP or agricultural export in Yunnan, totaling $44 million for 1300 metric tons in 2005 (Yang et al., 2006).

At present, regulations governing matsutake have been established at several political levels. Federally, *T. matsutake* has been placed on China's CITES Category II protected list, requiring permits for export (Arora, 2008; Xu et al., 2008). At the prefecture level, harvesting mushrooms smaller than 5 cm is subject to fine. Most villages have also legislated against destructive harvesting habits such as removing leaf litter to detect emerging buttons, or excessive excavation to ensure harvest of the entire stipe. Some villages have enacted harvesting rotations, or have restricted times and areas that are open to harvest (Yang et al., 2006). Access to village forests is based on kinship ties, and some villages hire sentries to patrol forests to guard against poachers. Because many of the villages in Diqing prefecture are fairly remote, some without road access, enforcement of harvesting regulations is either self-imposed or is reliant on mushroom buyers. These efforts are somewhat confounded by an economic premium placed on young mushrooms with intact partial veils, which can fetch as much as three times as much money by weight as more mature specimens. Further disincentive for harvesters to allow mushrooms to reach maturity prior to harvest is the intense competition among harvesters, leading to the likelihood that undersized specimens left to mature by one harvester will be harvested by another.

Matsutake collection presumably ameliorates illegal logging activity, generates tax income for infrastructure, and improves the living condition and education opportunity of harvesters (Yeh, 2000). For this reason, many organizations dedicated to environmental conservation and economic development have devoted resources towards projects, propaganda and education programs directed towards managing a profitable Matsutake harvest. The most prevalent of these entities are government agencies (provincial and forestry), local and international non-governmental organizations (NGOs), academics and scientists from national institutions and from abroad, and representatives of the higher ranks of Matsutake business, including conglomerate exporters and their associates in Japan.

1.3. Complimentary ecological information from outside and within

There is ample literature suggesting that local knowledge and outside scientific knowledge may be complementary for biological monitoring and conservation efforts (Moller et al., 2004; Sheil and Lawrence, 2004; Gadgil et al., 2003; Mackinson and Nottestad, 1998). Community based observations may provide increased temporal longitude and sampling effort, while outside scientific observations may confer a wider geographic perspective and statistical precision. Effective communication between and within these entities, in theory, leads to consensus, which facilitates community organization and conservation action (Ostrom, 2005). Furthermore, the perception that outside scientific knowledge is "empirical" or "true" may help legitimize community-generated knowledge to land managers. In this way, community-generated knowledge may be validated and re-crafted, an important step for an ethnic minority which historically has been socially and economically marginalized.

Validation of local knowledge is particularly poignant in China due to the intricacies of land tenure. While all land in China is the property of the national government, the actual trees growing in forests are managed by various levels of national or provincial government, are collectively managed at the village level, or are leased to individuals (Xu and Ribot, 2004; Dachang, 2001). Access to NTFP themselves are collectively managed in this region however, governed neither by land nor forest tenure (although in other areas of Yunnan NTFP are managed by individual or family units).

Local knowledge of fine-scale mushroom ecology may be in its embryonic stages. Despite Diqing's long history of NTFP collection, mushroom harvest for commercial export is a relatively novel enterprise, and many aspects of the reproductive biology of fungi are cryptic and not directly analogous to those of vascular plants. We suspect that harvesting paradigms and protocols which have served villages for generations in trading medicinal plants may not be effective for optimizing short and long-term mushroom harvest. While collectors may be very sensitive and reactionary to anthropogenic affects on plant population demography, the stochastic nature of mushroom productivity from year to year likely inhibits efforts to establish "best practice" techniques in the relatively short time that commercial harvest has been viable in Yunnan.

Conversely, scientific observation of mushrooms on a landscape scale can be problematic. Assessing what is likeliest the most fundamental issue to Matsutake conservation – whether or not productivity is in fact declining – is complicated by several factors. Life-history characteristics common to all ectomycorrhizal mushrooms (which include many of the economically important edible species: Morels (*Morchella* spp.), Chanterelles (*Cantharellus* spp.), and Porcinis/Boletes (*Boletus* spp.)) make it challenging to estimate annual biomass productivity based on field sampling. These fungi form ephemeral mushrooms, and can be difficult to detect in natural environments, yet their patchy distributions require fairly large study plots in diverse habitats. Furthermore, experimental controls have shown that annual productivity (measuring both biomass and mushroom number) can vary by orders of magnitude (Luoma et al., 2006), weakening the statistical power of productivity models. While estimates based on trade records are possible in theory, variable factors such as market price, access to markets (i.e. airport and road construction), changes in collection regulations (i.e. minimum size requirements), harvesting habits or even an increase in local consumption may affect harvester effort and confound estimates of productivity trends (Arora, 2008). Furthermore, trade estimates can vary by agency, as exemplified in Yang et al.'s (2008) reports of Matsutake production in 2003 noted by the County Government (280 tons) and the Provincial CITES office (138 tons). While this discrepancy is the most extreme example reported in their paper, it points to the fact that artifacts inherent in biomass estimates derived from commercial records may diminish the utility of such metrics for conservation and scientific uses.

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Therefore, we suggest that outsider and local knowledge may be complimentary by each's focus on different scales. Outsider scientific knowledge may provide insight in ecological processes at the molecular, physiological, plot-level or global scale, whereas local knowledge may provide insight into ecological processes at the landscape scale over the three decades of commercial Matsutake harvest. Facilitating the bi-directional transfer of ecological knowledge between Matsutake harvesters and the wider conservation community provides an avenue to transform system paradigms and address perceived degradations. Devising ways to link those distinct groups may be the first step in building consensual management strategies.

First, we evaluate the variance among groups in regards to the knowledge and perceptions of Matsutake ecology. To compare local with outsider knowledge sources, we compare harvester perceptions with a survey of scientific literature. Additionally, we address variance in knowledge that exists among harvesters, and test whether those differences correlate with demographic variables. Previous research has shown enormous variance in ecological knowledge and perception partitioned by ethnicity (Atran et al., 1999), occupation (Tompkins et al., 2002), education (Salick et al., 2006), gender (Joyal, 1996) and age (Quinlan and Quinlan, 2007). Recent work in NW Yunnan Province has also shown significant variance in ecological knowledge among Tibetan doctors despite geographic proximity (Law and Salick, 2007).

Second, we evaluate the potential for the linking these different knowledge systems by quantifying harvesters' relative trust in outside entities and media. Our hope is that by characterizing how trust and perceptions are partitioned among harvesters, we can assess the potential to build consensus among the larger Matsutake trade and research networks.

1.4. Mushroom conservation: a scientific background

Matsutake is among the mycorrhizal mushrooms which associate with vascular plants in a mutually-obligate symbiosis. Due to this complicated chemical and physiological relationship across kingdoms, attempts to cultivate Matsutake in artificial scenarios have not been successful, although there is the expectation that genome sequencing of other ectomycorrhizal mushrooms such as *Laccaria bicolor* (Martin et al., 2008), and an unpublished draft genome of *T. matsutake* may make such efforts more feasible in the future. In Yunnan, as in other parts of the world, the mushroom is known to associate with a variety of species in the family Pinaceae (including *Pinus armandii, Pinus yunnanensis*, and *Pinus densata* in our study sites), as well as broadleaf trees and shrubs in the family Fagaceae (Chapela and Garbelotto, 2004). The North American species, *Tricholoma magnivelare* also associates with a myco-heterotrophic plant in the tribe Monotropeae (Ericaceae): *Allotropa virgata*, although similar relationships between Asian mushroom species and sympatric Monotropeae have not been determined. Although "Matsutake" *sensu latu* refers to an unresolved taxonomic complex of economically-important mushrooms including *T. matsutake* and *T. bakamatsutake*, symbiont preference within this group appears to be phylogenetically diffuse at an intraspecific level. Xu et al. (2008), for example, found that Conifer versus Oak association describes only 9% of the genetic variation among populations of *T. matsutake* in SW China.

While Matsutake host preference is diffuse, it is unclear how host association or forest demography affects mushroom productivity, although observational reports suggest that intermediate forest age may be optimal. Ogawa (1977) and Tominaga (1978) both report optimal productivity in Japanese Pine forest stands ranging from ~10 to ~50–60 years old. Determining the longevity of Matsutake patches, however, requires a reliance on site rather than temporal replication, and stand-level productivity is difficult to test empirically.

A handful of studies have shown that human activity can diminish mushroom productivity. Arnolds (1995, 1991), conducted a study using data from mushroom forays in Europe dating from 1912. His study found a general decline in ectomycorrhizal abundance and diversity throughout Europe. Determining the cause of that decline has proven difficult, however. Arnolds suggests that air pollution may be to blame. Multiple studies have shown that climate change has profound effects on fungal communities (see Cairney and Meharg, 1999 for a review of pertinent literature). Several long-term harvest studies found no significant affect of mushroom harvest *per se* on subsequent productivity in ectomycorrhizal species (Egli et al., 2006; Luoma et al., 2006; Pilz et al., 2003). Luoma et al. (2006) did find significant differences in mushroom number and wet weight of *T. magnivelare* among treatments where leaf litter was raked above Matsutake fairy rings and not replaced, and patches where mushrooms were harvested with minimal disturbance and non-harvested non-disturbed controls. Likewise, Egli et al. (2006) found that soil compaction does negatively affect the subsequent biomass production of some ectomycorrhizal species.

Conserving the genetic diversity of Matsutake may also be a concern. Matsutake mushroom spore dispersal is physiologically constrained in early mushroom development by a thin tissue which covers the gills (known as the partial veil). As the mushroom matures, the veil partially disintegrates, exposing the gills for wind dispersal of spores. Several recent studies (Amend et al., 2009a, 2009b; Xu et al., 2008; Lian et al., 2006; Murata et al., 2005) have used population genetic measures of variance and spatial analyses to demonstrate that sexual reproduction via spores (as opposed to hyphal or vegetative reproduction) is the predominant means of reproduction in Matsutake, suggesting that maintaining spore rain is important for conserving genetic diversity and gene flow. While genetic diversity may provide resilience and adaptability to a population, there is no evidence that genetic diversity correlates with mushroom productivity in the short term.

2. Research design

2.1. Study area

Research was conducted in seven villages located in Xiangelila and Weixi counties in Diqing Prefecture, NW Yunnan Province, China, 27.6°N, 99.5°E. This region lies on the eastern slope of the Himalayas, notable for its extreme topographical variance resulting from an uplifting event of the Tibetan plateau 1.1–0.6 Ma, concurrent with increased moisture and watercourse diversification (Zhang and Wu, 2000). The steep elevational gradients contain ecotypes ranging from subtropical shrub, to oak and mixed conifer forests up to alpine meadows and glaciers. Yunnan Province contains some 25 distinct cultural minority groups, although the mountainous area covered in this study is dominated by ethnic Tibetans who utilize the steep elevation gradient to diversify agriculture and NTFP resources (Salick et al., 2005).

2.2. Survey design

Based on preliminary research we had conducted in the area, a survey was developed. Surveys consisted of 16 questions written in Mandarin, 10 of which related to demography, and the rest related to perceptions of matsutake ecology, and finally trusted sources of Matsutake ecological knowledge. For this last task, harvesters were asked to rank eight sources of ecological knowledge from the most trusted source (one) to the least trusted source (eight). Second,

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harvesters were asked whether or not they trusted each of the same eight sources for useful ecological information about Matsutake. These answers were coded in a binary matrix as either Yes or No. Two open-ended questions were asked: (1) assuming harvesters noticed a negative trend in Matsutake productivity; to what do they attributed that trend? (2) What could be done to increase Matsutake productivity in the future?

2.3. Informant selection and informed consent

In consultation with NGOs and forestry officials, villages in the region were first selected based on known high production of Matsutake. From that list we established a subset that were accessible by road, and which had daily Matsutake markets. Within each village we attempted to conduct as many interviews as possible during the market, and to interview roughly equal numbers of male and female harvesters from as diverse an age spectrum as possible (12–60 years old; Table 1). Although discerning the representative demographics of harvesters is problematic since some harvesters send family members to sell mushrooms for them, we estimate that harvesters are evenly represented by all age classes. There may be slightly more women harvesters since men are likelier to work outside of the village or in high-mountain pastures. In one village (village number two) we were only able to interview two harvesters, for this reason these two harvesters were included in pooled qualitative analyses, but were not included in statistical tests which included variance partitioning by village.

Prior to completing surveys, permission and approval was sought from village leaders. A brief description of the project and its goals, including the contact information and affiliation of the first author were provided to each participant. Harvesters were informed that all information, as well as the identity of villages surveyed would remain anonymous, and that participation was optional.

Table 1
Demographics of matsutake harvesters interviewed. Decline to State is abbreviated DS.

Village	1	2	3	4	5	6	7	8	Total
Gender									
Males	18	0	8	11	10	8	5	1	61
Females	4	2	10	9	29	3	1	3	61
Education									
College	1	0	3	0	0	3	0	1	8
Elementary	10	0	10	7	20	3	2	1	53
High school	0	0	0	1	2	5	0	0	8
Junior high	8	1	4	10	14	0	4	2	43
Not educated	2	0	0	0	3	0	0	0	5
DS	1	1	1	2	0	0	0	0	5
Age									
0–25	11	0	8	3	18	6	1	3	50
26–40	6	1	6	13	8	3	4	1	42
41+	4	0	4	4	13	2	1	0	28
DS	1	1	0	0	0	0	0	0	2
Ethnicity									
Tibetan	20	0	18	4	39	9	5	4	99
Lisu	0	0	0	9	0	0	0	0	9
Han	0	0	0	7	0	0	0	0	7
Naxi	0	2	0	0	0	0	0	0	2
DS	2	0	0	0	0	2	1	0	5
Years harvesting									
1–5	4	1	3	5	6	0	0	2	21
6–10	5	0	4	9	11	5	3	1	38
11–20	7	1	8	6	10	6	3	1	42
20+	4	0	3	0	9	0	0	0	16
DS	2	0	0	0	3	0	0	0	5

2.4. Data collection

Surveys were conducted in July and August of 2006. Most surveys were conducted in Matsutake markets, although surveys were occasionally conducted before and after markets in cafes or homes. Surveys were written in Mandarin and, depending on the literacy and fluency of the informant, were either self-completed, or completed with the assistance of bilingual (Mandarin–Tibetan or Mandarin–Yi) translators.

2.5. Statistical analysis

Rankings of trusted sources were compiled in a matrix. Some informants preferred not to rank all eight trusted sources, therefore the number of responses for each source varied. For this reason, each rank was reported as a percentage of the total response for that category rather than as a raw response number (Fig. 1). For the sake of clarity of presentation, only the percentage of the responses ranked in the top three were represented. A second matrix was compiled with binary data relating to whether or not a harvester trusted each of the eight sources. This matrix was used for cluster analysis in the software package PAST (Hammer et al., 2001), using Euclidian distance measurements and bootstrap values calculated with 10,000 resamples.

The relationship between trusted sources and gender, and trusted sources and village affinity were partitioned using non-parametric statistics in SPSS version 16 (SPSS Inc., Chicago, USA). Chi-square tests were used to test gender-specific trust of NGOs, and Kruskal and Wallis H tests were used to test for village-specific confidence in village leaders, forestry officials and NGOs.

Mann and Whitney U tests were used to isolate significantly-different means among pairwise comparisons of villages. Following Bonferroni-correction, none of the p values of the Mann and Whitney U tests were found to be significant.

The multi-response permutation procedure (MRPP) available in PC-ORD was conducted to detect whether villages aggregate into distinct groupings based on trusted sources. MRPP tests the hypothesis that there are no differences in trusted sources within villages. For this statistic, A values range from 1 to <0, with an A value of 1 signifying complete consensus within groups, an A of 0 signifying a level of heterogeneity within groups expected by chance, and an $A < 0$ signifying more heterogeneity within groups than would be expected by chance.

Answers to open-ended question (1), how were negative productivity trends attributed? were placed in categories (Fig. 2a) based on the following: any answer relating to soil or soil disturbance such as "digging" or "raking" was categorized as "soil". Any answer relating to disturbances in plant communities such as "deforestation" was classified as "habitat". "Human Influence" encompassed any answer indicating that humans were an agent, but no causal factors were indicated: an example of an answer in this category is "because of humans".

Answers to open-ended question (2), how to increase future yields? were likewise categorized. The largest category of responses included non-specific answers such as "protect the environment" or "protect the forest," these responses were categorized as "environmental protection" (Fig. 2b). It is not clear which specific measures were intended in the responses under this category.

To test the relationship between human demographics, perceptions of Matsutake declines and perceptions of measures to increase yields, general log-linear analysis was performed using SPSS 16. Log-linear analysis considers main and interaction effects to find the most parsimonious model which can account for categorical cell frequencies in a crosstable. Hierarchical log-linear tests of k-way interactions indicated that two-way interactions fit the

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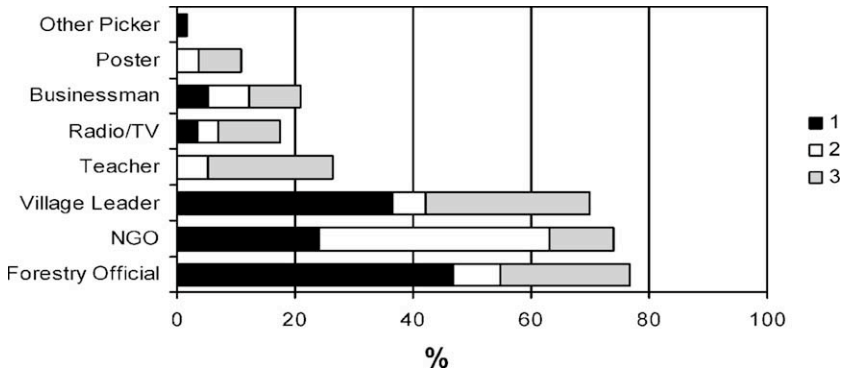

Fig. 1. Harvesters ranked sources from most trusted (1) to least trusted (8). Because not all harvesters ranked all eight sources, results are presented here as percentages of the total response for each source (i.e. of those who ranked forestry officials, 48% ranked it highest, 8% ranked it second highest, and 22% ranked it third highest). For clarity, only the percentages of the three highest ranks are presented.

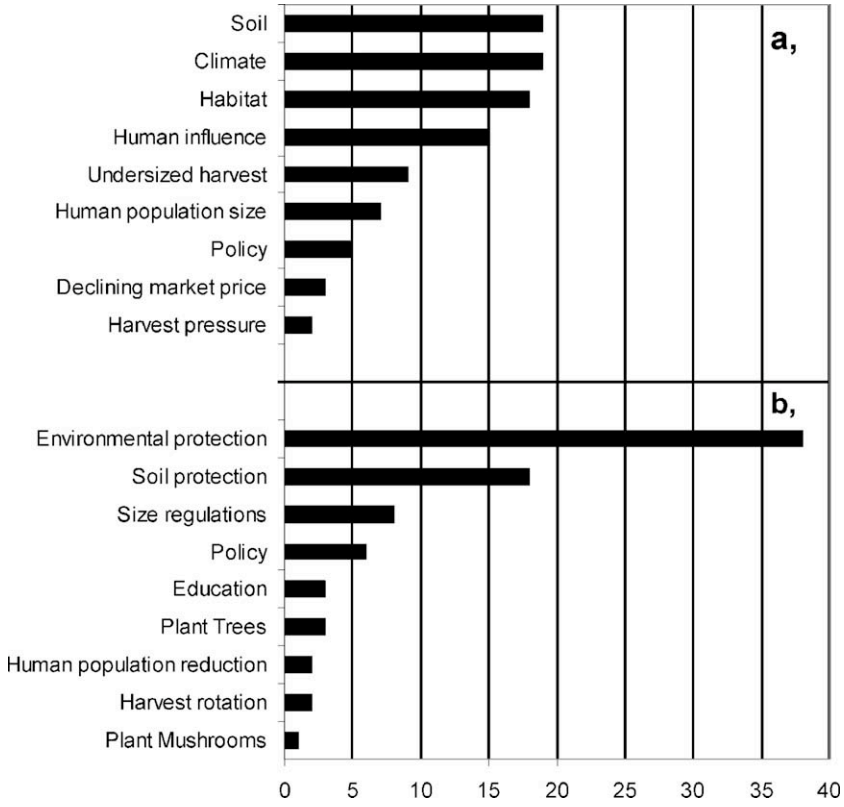

Fig. 2. The frequency of respondents listing their perceptions of why Matsutake productivity was declining ($n = 97$ (a)), and what could be done to improve future yields ($n = 81$ (b)). Answers were categorized by the authors (see methods for details). "Harvest rotation" refers to the practice, in some villages, of rotating times or location of harvest. outplanting mushrooms, "Plant mushrooms", was suggested by only one respondent.

most parsimonious model. Therefore, interactions between the two open-ended questions and the following demographic variables were tested: level of education, gender, age class (0–25, 26–40, 41+ years old), village affinity, and years harvesting Matsutake (1–5, 6–10, 11–20, and 20+ years).

3. Results

3.1. Harvester demographics

One hundred twenty two questionnaires were completed by harvesters and Matsutake dealers from four ethnic groups (Han, Tibetan, Yi, and Lisu) in eight villages located in Xiangelila and Weixi counties in Diqing Prefecture, NW Yunnan Province, China. Our surveys were heavily biased towards ethnic Tibetans (84%), the predominant ethno-linguistic group in Diqing.

3.2. Perceptions of productivity trends

Eighty-six percent of those responding to whether there was more, less or the same amount of Matsutake now compared with 10 years ago indicated that there was less, compared to only 5% who responded that there was more, the remaining 9% were either unsure or felt there had been no change.

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3.3. Trusted sources for Matsutake ecological knowledge

Cluster analysis (Fig. 3) demonstrated that trusted sources aggregated into four well-supported clades with village leader and forestry officials in separate clades, posters, radio/television messages and NGO workers in the third, and the others in the fourth. Because village leaders and forestry officials were the overwhelmingly most trusted sources, with trust in NGOs also significant, we focused subsequent analyses on these three sources.

3.4. Partitioning variance of trusted sources

MRPP was significant at $p = <0.001$, with an A value of 0.112, suggesting a significant, though low level of community consensus. There were only a few significant deviations from the null model of no partitioning of ecological knowledge which are detailed below.

Trust in NGOs was partitioned both by village and gender. Males were likelier to trust NGOs than females by a ratio of (11:1). While one or two correspondents claimed to trust NGOs in four villages, seven of 22 respondents in village 1 (31.8%) claimed to trust NGOs, the only village to deviate from the expected proportion (Pearson chi-square 17.385, DF 7, $p = 0.015$).

Kruskal and Wallis H tests showed that neither the proportion of villagers trusting the village leader ($H_{corr} = 16.17$, $p = 0.1442$), nor NGO ($H_{corr} = 17.21$, $p = 0.4871$), nor forestry officials were significantly different among villages ($H_{corr} = 20.04$, $p = 0.054$).

3.5. Reasons for decline and conservation strategies

Nineteen of 97 harvesters listed soil disturbance as the primary cause for declining productivity, an equal number listed climate, and habitat destruction was mentioned third (Fig. 2a). Log-linear analysis showed only two significant interactions: elementary-school educated harvesters were less likely to suggest habitat as a reason for declining productivity (parameter estimate = 17.7, std. error = 1.076, $Z = -16.5$, $p < 0.01$), and harvesters aged 10–25 were less likely to suggest soil disturbance (parameter estimate = −3.2, std. error = 1.55, $Z = -2.028$, $p = 0.043$).

Potential solutions listed by harvesters for declining Matsutake productivity were varied, but "environmental protection" and reducing soil disturbance were the most frequently-cited solutions (Fig. 2b). Solutions directly involving harvest protocols were mentioned less frequently.

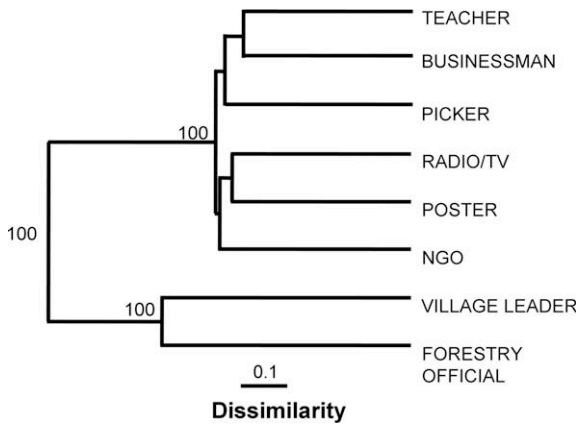

Fig. 3. Cluster analysis shows that rankings of trusted sources are well resolved in a dissimilarity cladogram. Forestry officials and village leaders comprise well-supported clades; NGOs, posters and radio and television messages comprise a third, while other pickers, Matsutake businessmen and teachers make up a fourth. Bootstrap values were calculated with 10,000 resamples.

4. Discussion

4.1. Local and outsider knowledge, perceptions and solutions

In most respects, local perspectives on Matsutake productivity concurred with findings from the scientific community. This has not been the case in other studies within the region, such as that of Law and Salick (Law and Salick, 2007) who found significant differences between medicinal plant conservation priority between Tibetan doctors and conservation officials.

We found that 86% of respondents perceive that Matsutake abundance is less now than 10 years prior. This concern may or may not contradict the findings of a study in the same region by Arora (2008) who found that declining prices, rather than natural abundances, were most concerning to local harvesters (David Arora, personal communication). In this study, reasons stated for declining productivity varied and included factors both endogamous and exogamous. Climate change was one of two most-cited reasons. Ethnic Tibetans in NW Yunnan are not just cognizant of global climate change, but in some cases feel culpable for it (Byg and Salick, 2009). In fact, some of the respondents interviewed in this study believe that climate is associated with resident deities, whose appeasement or provocation can affect local weather patterns. To this effect, village number six conducts a ritual perambulation of a sacred mountain every summer to ensure a successful Matsutake season.

Nearly as many respondents cited habitat degradation as a reason for declining productivity. Because of the commercial logging ban imposed by the national government in 1998, harvesting trees in natural forests has effectively ceased. By one estimate this ban covers two-thirds of the total area of the prefecture (He, 2003). Habitat degradation in other forms however, includes logging for local use, and trimming branches and saplings for fodder (Melick et al., 2007). Elementary-school educated harvesters were less likely to suggest this reason for declining productivity.

Lack of significant differences found between villages in the non-parametric tests indicates a general consensus among villages surveyed, and MRPP analysis demonstrated consensus within villages as well. Likewise, there was almost complete lack of significant interaction coefficients between demographic variables and perceptions of Matsutake ecology as demonstrated in the log-linear analyses. Similar to the MRPP and U tests, log-linear results point towards general homogeneity in perceptions among the harvesters interviewed.

4.2. Trusted sources and conservation efforts

Across all demographic groups sampled, harvesters overwhelmingly trusted their own village leaders and forestry officials for information about Matsutake conservation. Cluster analysis suggests that these two categories were contingent, and that informants who ranked one source highly were likely to rank the other highly as well.

Similar to the variance patterns found in perceptions of Matsutake ecology, we found that surveys were largely homogeneous in terms of trusted sources. Village one was the only village to show significant confidence in NGOs. It should be noted that this village has interacted with NGOs on several long-term and ongoing projects, including several research projects relating to Matsutake monitoring. It is likely that village one's unusual level of trust in NGOs stems from that village's exceptional exposure to NGO staff on a personal level. Among all villages, information from NGO personnel was ranked among the top two trusted sources by fifteen correspondents. While this is less than half of the percentage compared to the two highest ranks (village leaders and forestry

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officials), we do not believe that the role that NGOs play in the Matsutake conservation community is redundant. The fact that cluster analysis places NGOs in a separate clade from the other high ranked sources, and the fact that confidence in NGOs seems to be village-specific, provides evidence of NGOs' capacity to reach alternative audiences. Furthermore, many NGOs regularly interface with forestry officials and village leaders, and likely act as an important intermediary between those sources and academics. Because NGOs are not officially affiliated with the government, and lack power to impose fines or land-management decisions, their role may be viewed as less threatening than other entities with more direct authority.

4.3. Future directives for Matsutake conservation and profitability

This study has highlighted a diversity of knowledge bases, which may be drawn upon to sustain Matsutake productivity and profit. While harvester perceptions largely mirrored results found in the scientific literature, the most obvious exceptions were a differential emphasis on population-level genetic diversity. It should be noted that the scientific and conservation community likely offer divergent perceptions as well (see Tsing and Satsuka, 2008), although measuring variance among these entities was beyond the scope of this paper.

While the concept of genetics may be relatively abstract, drawing analogies with facets of livelihood strategies could make the idea more accessible to harvesters. Tibetan culture is renowned for its expertise in animal husbandry, an occupation requiring a fairly sophisticated understanding of core genetic theories such as inbreeding depression, narrow-sense heritability and hybrid vigor.

While the harvest of small mushrooms was a regulation cited in free list by 58% of respondents (data not shown), the fact that so few listed this as plausible means of increasing future yields points to a perceived disjunct between harvesting regulations aimed at economic livelihoods with those aimed at environmental conservation. The equivocal nature of resource "ownership" facilitates a conflict of interest when habitat protection and profit are at odds, and in isolated instances has lead to conflicts between harvesters and villages (Yeh, 2000) which can only be exacerbated as Matsutake becomes more integral to livelihood strategies. Access issues have also played a part in conflicts arising from the sudden increases in prices of the caterpillar fungus *C. sinensis* in the high Himalaya, where conflicts over territory and access have resulted in armed conflict.

Diminishing yields was the most consensual response of all harvesters in our study, and provides evidence that Matsutake biomass has declined over the past decade in Diqing. While this type of assessment presumably lacks the precision of a plot-based study, it offers the high replication and temporal longitude necessary to track mushroom demographic trends. Without a better understanding of what processes or drivers are involved in waning productivity, however, establishing sustainable management practices is problematic. Political and land-tenure complications offer further barriers to conservation implementations.

Ultimately, the precariousness of the Matsutake industry in Diqing rests on more than just biological determinants. Although Matsutake are a lucrative resource, their value is pegged to the economy of Japan, and to their status as non-cultivable. For these reasons, it may behoove locals and conservationists to use locally-generated data which projects diminishing biomass in promoting a more diversified economic and habitat conservation model.

Diversification of knowledge sources has been shown to increase the potential for innovation and conservation action (Folke et al., 2005). Because there is no significant partitioning of environmental knowledge among harvesters, opportunities for such diversification lie between harvesters and outsiders. There has been much discussion of the effects of collaborative and participatory management on local cultures and people. Though we support the diversification of Matsutake knowledge networks to empower local harvesters to develop their own management plans, others have questioned the fundamental basis, political ramifications and efficacy of conservation and development popularly labeled "collaborative" (Chapin, 2004; Cooke and Kothari, 2001). Furthermore, Arnold and Pérez (2001) and numerous others question the fundamental assumption that environmental conservation and economic development is such a natural pairing as is commonly assumed. The last century's top-down resource management schemes in China proved somewhat ominous for the country's forests and waterways (see Shapiro, 2001) however, and the opportunity for local management of Matsutake and other non-timber forest resources is an opportunity for villages to reclaim and exercise autonomy. We hope that with careful and considerate planning, diversified knowledge networks and consensus building may prove beneficial to the Matsutake industry, habitat and harvesters. Based on the results of this study, we suggest that future efforts to build Matsutake conservation strategies utilize links of forestry officials and village leaders with harvesters. NGOs may be effective in villages where they are known and trusted, but on a large scale they may better serve as intermediaries between academic and political entities.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.biocon.2009.09.022.

References

Amend, A., Keeley, S., Garbelotto, M., 2009a. Forest age correlates with fine-scale spatial structure of Matsutake mycorrhizas. Mycological Research 113, 541–551.

Amend, A., Garbelotto, M., Zhendong, F., Keeley, S., 2009b. Isolation by landscape in populations of a prized edible mushroom *Tricholoma matsutake*. Conservation Genetics. doi:10.1007/s10592-009-9894-0.

Anderson, D.M., Salick, J., Moseley, R.K., Xiaokun, O., 2005. Conserving the sacred medicine mountains: a vegetation analysis of Tibetan sacred sites in northwest Yunnan. Biodiversity and Conservation 14, 3065–3091.

Arnold, J.E.M., Pérez, M.R., 2001. Can non-timber forest products match tropical forest conservation and development objectives? Ecological Economics 39, 437–447.

Arnolds, E., 1991. Decline of ectomycorrhizal fungi in Europe. Agriculture, Ecosystems and Environment 35, 209–244.

Arnolds, E., 1995. Conservation and management of natural populations of edible fungi. Canadian Journal of Botany 73, S987–S998.

Arora, D., 2008. The houses that matsutake built. Economic Botany 62, 278–290.

Atran, S., Medin, D., Ross, N., Lynch, E., Coley, J., Ek, E.U., Vapnarsky, V., 1999. Folkecology and commons management in the Maya Lowlands. Proceedings of the National Academy of Sciences 96, 7598–7603.

Byg, A., Salick, J., 2009. Local perspectives on a global phenomenon – climate change in Eastern Tibetan villages. Global Environmental Change 19, 156–166.

Cairney, J.W.G., Meharg, A.A., 1999. Influences of anthropogenic pollution on mycorrhizal fungal communities. Environmental Pollution 106, 169–182.

Chapela, I.H., Garbelotto, M., 2004. Phylogeography and evolution in matsutake and close allies inferred by analyses of ITS sequences and AFLPs. Mycologia 96, 730–741.
Chapin, M., 2004. A challenge to conservationists. World Watch 17, 17–31.
Cooke, B., Kothari, U., 2001. Participation: The New Tyranny? Zed Books, London, UK.
Cooper, T.T., 1871. Travels of a Pioneer of Commerce in Pigtails and Petticoats: or, an Overland Journey from China Towards India. John Murray, London, UK.
Dachang, L., 2001. Tenure and management of non-state forests in China since 1950: a historical review. Environmental History 6, 239–262.
Egli, S., Peter, M., Buser, C., Stahel, W., Ayer, F., 2006. Mushroom picking does not impair future harvests – results of a long-term study in Switzerland. Biological Conservation 129, 271–276.
Folke, C., Hahn, T., Olsson, P., Norberg, J., 2005. Adaptive governance of social–ecological systems. Annual Review of Environment and Resources 30, 441.
Gadgil, M., Olsson, P.E.R., Berkes, F., Folke, C., 2003. Exploring the role of local ecological knowledge for ecosystem management: three case studies. In: Berkes, F., Colding, J., Folke, C. (Eds.), Navigating Social–Ecological Systems: Building Resilience for Complexity and Change. Cambridge University Press, Cambridge, UK, pp. 189–209.
Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001. PAST: paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4, 1–9.
He, J., 2003. Cross-scale institutional linkages of commercial matsutake mushroom management and marketing: a preliminary study of an NTFP in Zhongdian County, Yunnan. Yunnan Science and Technology Press, Lijiang, China.
Hosford, D., Pilz, D., Molina, R., Amaranthus, M., 1997. Ecology and Management of the Commercially Harvested Matsutake Mushroom. Forest Service: Corvallis Oregon. General Technical Report PNW-GTR 412.
Joyal, E., 1996. The palm has its time: an ethnoecology of *Sabal uresana* in Sonora, Mexico. Economic Botany 50, 446–462.
Kawai, M., Ogawa, M., 1981. Some approaches to the cultivation of a mycorrhizal fungus, *Tricholoma matsutake* (Ito & Imai) Sing. In: Nair, N.G., Clift, A.D. (Eds.), Mushroom Science XI. Proceedings of the 11th International Scientific Congress on the Cultivation of Edible Fungi. Sydney, Australia, pp. 869–883.
Law, W., Salick, J., 2007. Comparing conservation priorities for useful plants among botanists and Tibetan doctors. Biodiversity and Conservation 16, 1747–1759.
Lian, C., Narimatsu, M., Nara, K., Hogetsu, T., 2006. *Tricholoma matsutake* in a natural *Pinus densiflora* forest: correspondence between above- and below-ground genets, association with multiple host trees and alteration of existing ectomycorrhizal communities. New Phytologist 171, 825–836.
Luoma, D.L., Eberhart, J.L., Abbott, R., Moore, A., Amaranthus, M.P., Pilz, D., 2006. Effects of mushroom harvest technique on subsequent American matsutake production. Forest Ecology and Management 236, 65–75.
Mackinson, S., Nottestad, L., 1998. Points of view: combining local and scientific knowledge. Reviews in Fish Biology and Fisheries 8, 481–490.
Martin, F., Aerts, A., Ahren, D., Brun, A., Danchin, E.G., Duchaussoy, F., Gibon, J., Kohler, A., Lindquist, E., Pereda, V., Salamov, A., Shapiro, H.J., Wuyts, J., Blaudez, D., Buee, M., Brokstein, P., Canback, B., Cohen, D., Courty, P.E., Coutinho, P.M., Delaruelle, C., Detter, J.C., Deveau, A., DiFazio, S., Duplessis, S., Fraissinet-Tachet, L., Lucic, E., Frey-Klett, P., Fourrey, C., Feussner, I., Gay, G., Grimwood, J., Hoegger, P.J., Jain, P., Kilaru, S., Labbe, J., Lin, Y.C., Legue, V., Le Tacon, F., Marmeisse, R., Melayah, D., Montanini, B., Muratet, M., Nehls, U., Niculita-Hirzel, H., Oudot-Le Secq, M.P., Peter, M., Quesneville, H., Rajashekar, B., Reich, M., Rouhier, N., Schmutz, J., Yin, T., Chalot, M., Henrissat, B., Kues, U., Lucas, S., Van de Peer, Y., Podila, G.K., Polle, A., Pukkila, P.J., Richardson, P.M., Rouze, P., Sanders, I.R., Stajich, J.E., Tunlid, A., Tuskan, G., Grigoriev, I.V., 2008. The genome of *Laccaria bicolor* provides insights into mycorrhizal symbiosis. Nature 452, 88–92.
Melick, D., Yang, X., Xu, J., 2007. Seeing the wood for the trees: how conservation policies can place greater pressure on village forests in southwest China. Biodiversity and Conservation 16, 1959–1971.
Mittermeier, R.A., Meyers, N., Thomsen, J.B., da-Fonseca, G.A.B., Olivieri, S., 1998. Biodiversity hotspots and major tropical wilderness Areas. Conservation Biology 12, 516–520.
Moller, H., Berkes, F., Lyver, P.O.B., Kislalioglu, M., 2004. Combining science and traditional ecological knowledge: monitoring populations for co-management. Ecology and Society 9, 1–15.
Murata, H., Ohta, A., Yamada, A., Narimatsu, M., Futamura, N., 2005. Genetic mosaics in the massive persisting rhizosphere colony "shiro" of the ectomycorrhizal basidiomycete *Tricholoma matsutake*. Mycorrhiza 15, 505–512.
Ogawa, M., 1977. Microbial Ecology of "Shiro" in Tricholoma matsutake (S. Ito et Imai) Sing. in pine forest IV. The shiro of *T. matsutake* in the fungal community. Japanese Government Forest Experimental Station, Bulletin of Forestry and Forest Product Research Institute. 193, 105–170.
Ostrom, E., 2005. Understanding Institutional Diversity. Princeton University Press.
Ou, X., 2003. To reach the goal of biodiversity conservation and sustainable development: a general introduction to the biodiversity protection module of the Great Rivers project. In: Jianchu, X., Mikesell, S. (Eds.), Landscapes of Diversity: Indigenous Knowledge, Sustainable Livelihoods and Resource Governance in Montane Mainland Southeast Asia. Proceedings of the III Symposium on MMSEA. Yunnan Science and Technology Press, Lijiang, Kunming, China, pp. 199–204.
Pilz, D., Norvell, L., Danell, E., Molina, R., 2003. Ecology and management of commercially harvested chanterelle mushrooms. In: [USDA General Technical Report No. PNW-GTR 576]. USDA, Portland, OR.
Quinlan, M.B., Quinlan, R.J., 2007. Modernization and medicinal plant knowledge in a Caribbean horticultural village. Medical Ethnobotany Quarterly 21, 169.
Richardson, S.D., 1990. Forests and Forestry in China: Changing Patterns of Resource Development. Island Press, Covelo, CA.
Saito, H., Mitsumata, G., 2008. Bidding customs and habitat improvement for matsutake (*Tricholoma matsutake*) in Japan. Economic Botany 62, 257–268.
Salick, J., Yongping, Y., Amend, A., 2005. Tibetan land use and change near Khawa Karpo, Eastern Himalayas. Economic Botany 59, 312–325.
Salick, J., Byg, A., Amend, A., Gunn, B., Law, W., Schmidt, H., 2006. Tibetan medicine plurality. Economic Botany 60, 227–253.
Shapiro, J., 2001. Mao's War Against Nature: Politics and the Environment in Revolutionary China. Cambridge University Press, Cambridge, UK.
Sheil, D., Lawrence, A., 2004. Tropical biologists, local people and conservation: new opportunities for collaboration. Trends in Ecology & Evolution 19, 634–638.
Tominaga, Y., 1978. *Tricholoma matsutake*. In: Chang, S.T., Hayes, W.A. (Eds.), The Biology and Cultivation of Edible Mushrooms. Academic Press, New York, pp. 683–697.
Tompkins, E., Adger, W.N., Brown, K., 2002. Institutional networks for inclusive coastal management in Trinidad and Tobago. Environment and Planning 34, 1095–1112.
Tsing, A., Satsuka, S., 2008. Diverging understandings of forest management in matsutake science. Economic Botany 62, 244–253.
Ward, F.K., 1990. Plant hunters in paradise. In: Ward, F.K. (Ed.), Himalayan Enchantment: An Anthology. Serindia Publications, London, UK.
Weyerhaeuser, H., Wilkes, A., Kahrl, F., 2005. Local impacts and responses to regional forest conservation and rehabilitation programs in China's northwest Yunnan Province. Agricultural Systems 85, 234–253.
Winkler, D., 2003. Forest use and implications of the 1998 logging ban in the Tibetan Prefectures of Sichuan: case study on forestry, reforestation and NTFP in Litang County, Ganzi TAP, China. In: Jiang, Z., Centritto, M., Liu, S., Zhang, S. (Eds.), The Ecological Basis and Sustainable Management of Forest Resources. Informatore Botanico Italiano.
Xu, J., Ribot, J., 2004. Decentralisation and accountability in forest management: a case from Yunnan, Southwest China. The European Journal of Development Research 16, 153–173.
Xu, J., Sha, T.A.O., Li, Y., Zhao, Z., Yang, Z., 2008. Recombination and genetic differentiation among natural populations of the ectomycorrhizal mushroom *Tricholoma matsutake* from southwestern China. Molecular Ecology 17, 1238–1247.
Yang, X., He, J., Li, C., Ma, J., Yang, Y., Xu, J., 2006. Management of Matsutake in NW-Yunnan and key issues for its sustainable utilization. In: Kleinn, C., Yang, Y., Weyerhaeuser, H., Stark, M. (Eds.), The Sustainable Harvest of Non-timber Forest Products in China. World Agroforestry Center-ICRAF, SE Asia.
Yang, X.F. et al., 2008. Matsutake trade in Yunnan province, China: an overview. Economic Botany 62, 269–277.
Yeh, E.T., 2000. Forest claims, conflicts and commodification: the political ecology of Tibetan mushroom harvesting villages in Yunnan Province, China. The China Quarterly 161, 212–226.
Zhang, Q., Wu, S., 2000. Mountain Geoecology and Sustainable Development of the Tibetan Plateau. Kluwer Academic Norwell, MA, USA.

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