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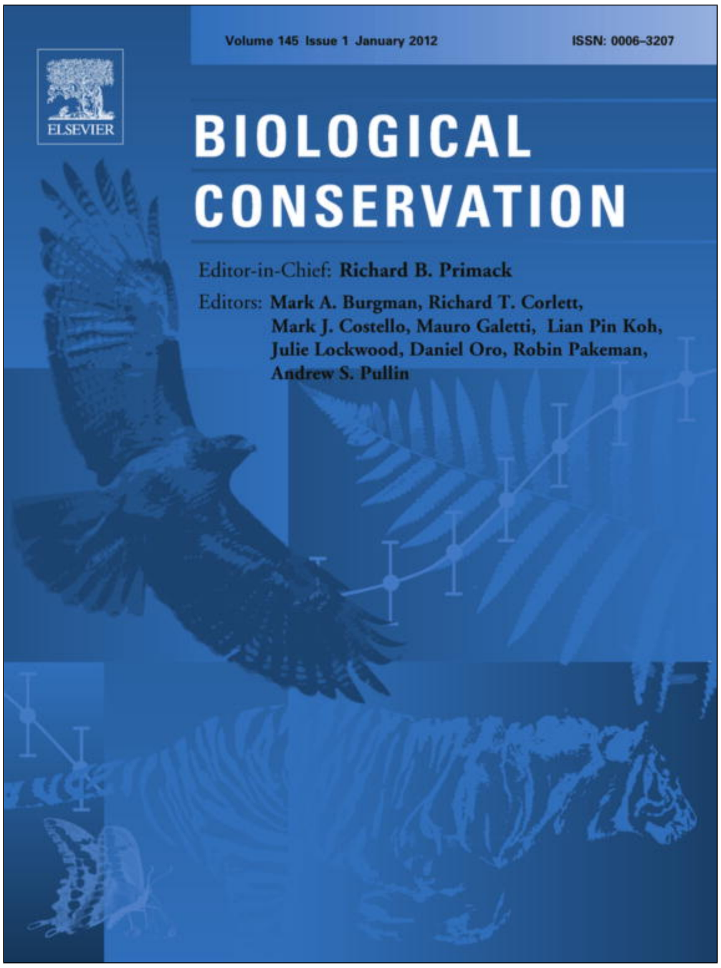

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Does science replace traditions? Correlates between traditional Tibetan culture and local bird diversity in Southwest China

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A B S T R A C T

A positive relationship between traditional cultures and biodiversity exists worldwide, but when traditional and formal conservation institutions coexist, how they interact and affect biodiversity remains poorly studied. From 2005 to 2007, we studied the relationship between Tibetan traditional practices and biodiversity. Specifically, how traditional ecological knowledge (TEK) and scientific ecological knowledge (SEK) affect local biodiversity by affecting people's attitudes and behaviors towards conservation. We interviewed 331 villagers in nine Tibetan villages in Sichuan Province, China. We used proxy questions to measure the traditional practices, TEK, SEK, conservation attitudes and behaviors of village residents. Meanwhile, we assessed the bird diversity around the villages by stratified sampling and point counts. The results indicate traditional practices exhibited a strong positive correlation with TEK, but a negative correlation with formal education and SEK. The villagers with high traditional practices had more positive attitudes towards conservation and more actively participated in conservation than villagers with low traditional practices, and villagers with medium traditional practices were the least concerned about, or participated in, conservation activities. Bird species richness, abundance, and the Shannon–Wiener diversity index were positively correlated with the traditional practice index of each village. The results of a negative binomial regression showed the traditional practice index was a positive correlative factor of bird species richness, while formal education was not a significant variable, after controlling for other potential sampling and environment factors. Government-sponsored conservation education was somewhat successful in raising people's environmental awareness, but these efforts have yet to correlate with enhanced biodiversity measures.

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1. Introduction

The linkage between traditional cultures and biodiversity has been studied and advocated by researchers during the last two decades for the potential application to conservation management (Gadgil et al., 1993; Loh and Harmon, 2005; Maffi, 2005). Traditional ecological knowledge (TEK) rooted in indigenous cultures plays an essential role in contributing to local biodiversity conservation (Berkes et al., 2000). Numerous case studies of indigenous groups in India (Bhagwat et al., 2005; Jamir and Pandey, 2003; Ntiamoa-Baidu, 2008), China (Anderson et al., 2005; Christopher, 2008; Luo et al., 2009), Southeast Asia (Wadley and Colfer, 2004), North America (Diemont and Martion, 2009; Turner et al., 2000), South America (Castro and Aldunate, 2003) and Africa (Decher, 1997; Mgumia and Oba, 2003) demonstrate the positive effects of traditional cultures in biodiversity conservation.

Previous studies that examined the linkage between TEK and biodiversity usually infer from examinations of beliefs and practices to conclusions about ecosystem condition without direct measurements of biodiversity. Studies that quantify the linkage between TEK and biodiversity have mainly focused on comparing areas under different conservation management (e.g., protected areas, sacred groves and community forests) (Bhagwat et al., 2005; Mgumia and Oba, 2003). Few studies have presented quantitative measures of both biodiversity and social perspectives (Liu et al., 2007). Furthermore, different communities within the same indigenous culture may differ in their level of TEK. The conservation outcomes of TEK have seldom been compared among sites within a similar culture in order to understand the effective role of TEK.

Dramatic economic development and urbanization has resulted in the rapid livelihood change and the loss of traditional values in many indigenous groups (Malhotra et al., 2001; Worldwatch Institute, 2010). The loss of TEK and the decline in traditional practices have coincided with evidence of serious habitat

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degradation and biodiversity loss (Sutherland, 2003). Preserving traditional knowledge and respecting the customary use of biological resources by indigenous people have been recognized as important solutions for preventing biodiversity loss (Rands et al., 2011). Some scholars also argue integration of traditional with scientific ecological knowledge (SEK, or so called ''western science'') can increase the resilience of the social–ecological systems by combining adaptations from different cultural traditions (Begossi, 1998). Studies have shown that a combination of TEK and SEK can strengthen conservation planning, and assist co-management for sustainable resource use (Becker and Ghimire, 2003; Drew, 2005; Moller et al., 2004), but there have been few attempts to demonstrate how an interaction of TEK and SEK impacts biodiversity.

Traditional Tibetan culture contains alternative knowledge and perspectives that contribute to the conservation of both wild fauna and flora, and their habitats and ecosystems (Anderson et al., 2005; Salick et al., 2007). Shaped by Tibetan Buddhism, which is a combination of Bon (a pre-Buddhist religion in Tibet) and Buddhism, Tibetans hold a world view in which humans are part of an interacting set of living beings and being kind to all other creatures will gain good karma for one self (Feng, 2005; He, 2005). These cultural values promote a harmonious relationship between humans and nature by respecting and protecting all life beings. Key elements of Tibetan cultural traditions that could facilitate conservation include: *ahimsa* (no killing), encouraging care of the wildlife, and the worship and protection of the sacred sites (the home of deities, natural spirits and spiritual leaders) (Nan, 2001). The importance of traditional Tibetan culture in conservation has been recognized by scholars and conservation NGOs in China, but has yet to be adopted by the Chinese government.

Tibetan communities differ in following their traditions due to historical events and variable exposure to commercialization (Xu et al., 2005). It is unknown how the pattern of biodiversity is correlated with the extent of the traditional practices in the Tibetan region. In recent years, local Tibetan people's attitudes and behaviors towards conservation have been influenced by the government's laws and regulations through formal education, including both school education and environmental education activities conducted by local government agencies (e.g., forestry bureaus and environment bureaus). Extensive financial and public resources have been devoted to the basic education of youth in the Tibetan area by the Chinese government during the last decades (Wu, 2001). There is a lack of understanding on how the traditional and official conservation paradigms interact and motivate rural residents to undertake actions that protect wildlife and their habitats, and whether these paradigms complement conservation measures in the region.

We present a quantitative study on the relationship between traditional practices and biodiversity and how traditional Tibetan culture (TEK) and formal education (SEK) affect biodiversity by changing people's conservation attitudes and behaviors in a Tibetan region. From 2005 to 2007, we used proxy questions to measure traditional practices, TEK, SEK, conservation attitudes and behaviors of residents, and measured the bird community richness and diversity in nine Tibetan villages with different levels of traditional practices. Our hypothesis was that both TEK and SEK have a positive impact on the attitudes of the villagers, which will be reflected in the conservation behaviors of individuals, and therefore have a measurable impact on biodiversity measures at a landscape level (Fig. 1). We discuss whether the traditional and conventional education could be complementary and integrated in order to promote regional environmental awareness and biodiversity outcomes.

2. Material and methods

2.1. Study area

Our study area was located in the eastern Tibetan plateau, including Ganzi Tibetan Autonomous Prefecture (hereafter called Ganzi) and Aba Tibetan-Qiang Autonomous Precture (hereafter called Aba) in Sichuan Province (Fig. 2). We identified nine Tibetan villages across this region as our study sites (Fig. 2). These villages were selected on the basis of similar profiles on geography, vegetation and social-economic background, but different levels of traditional practices (Table 1). All villages spanned an elevation between 3000–4000 m and exist within a similar landscape, including buckwheat/corn farmland, coniferous forest, sub-alpine oak/shrub, and alpine meadow (Zhang, 1997). All villages were similar in size and had similar household numbers (range 46–57), except for one village that had 74 households. Villagers in these nine villages subsist primarily on grain harvesting and livestock raising, while obtaining additional income from collecting/selling natural products and temporary employment in regional towns (Sichuan Bureau of Statistics, 2006). There had been no active industries or any other development projects around the villages. Residents of the study sites are all Tibetans except for a few Han people in three villages ($N = 1$ in Tangqiao (percentage Han = 0.4%), 3 in Jialazong (1.3%), and 11 in Zhatuo (5.1%)) (Fig. 2).

2.2. Estimation on traditional practices and conservation knowledge–attitudes–behaviors

At each village, we conducted face-to-face interviews with local villagers, and used a predesigned questionnaire to estimate the

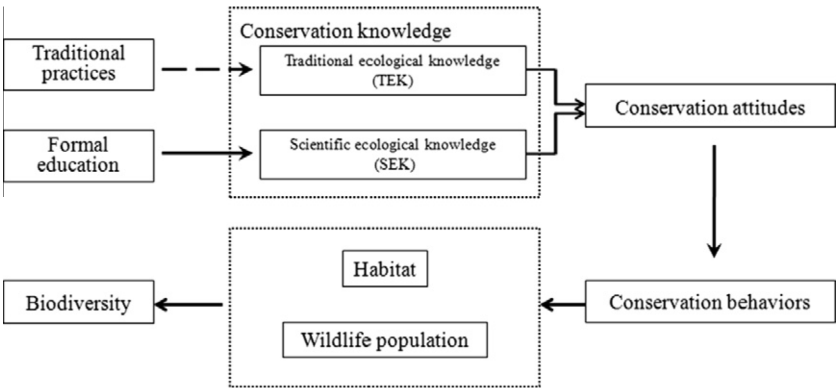

Fig. 1. A flow chart of how traditional practices and formal education link to local biodiversity. Traditional ecological knowledge (Berkes et al., 2000) is part of traditional knowledge, which correlates to traditional practice measures. SEK is determined by formal education. Both TEK and SEK will affect the conservation attitudes of the villagers, which furthermore affect the individual behaviors towards conservation. Conservation behaviors contribute to biodiversity measures at a landscape level through direct protection on wildlife population and indirect contribution on conserving their habitat.

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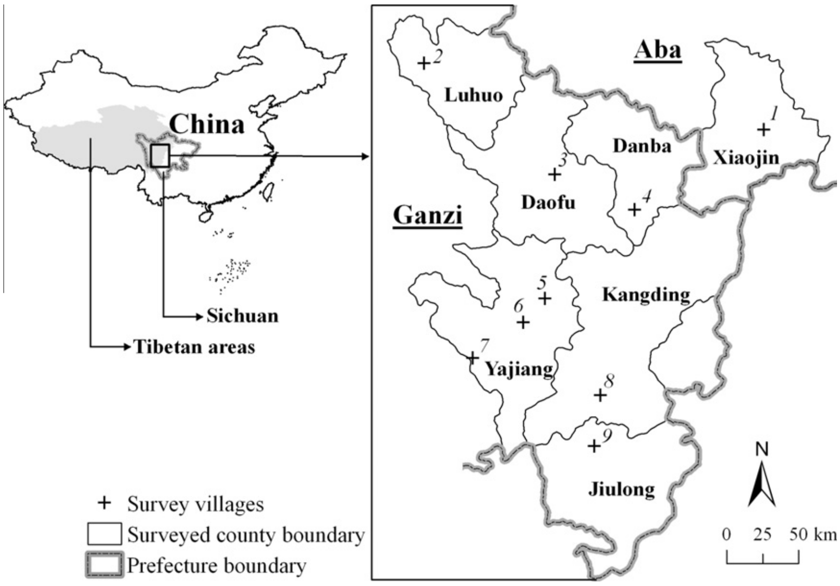

Fig. 2. The nine Tibetan villages surveyed in Sichuan Province, China. Village names: (1) Jiuza, (2) Quesuo, (3) Jialazong, (4) Dongma, (5) Riji, (6) Tangqiao, (7) Xiadecha, (8) Liuba, and (9) Zhatuo.

Table 1
Ecological and socioeconomic background of the nine surveyed Tibetan villages in Sichuan Province, China.

Village[a]	Elevation range (m)	Number of households	Distance to major road[b]	Average traditional practice index	Average years of formal education	Percentage who had completed elementary school (%)
Jiuza (JZ)	2800–4000	46	Far	0.18	4.1	30.9
Dongma (DM)	2800–3800	57	Medium	0.65	3.5	34.2
Jialazong (JLZ)	3300–4100	47	Close	0.67	2.3	25.0
Zhatuo (ZT)	3100–4000	46	Close	0.72	2.3	17.5
Riji (RJ)	3000–4200	74	Close	0.87	3.4	30.7
Tangqiao (TQ)	3100–4200	48	Far	0.88	1.0	6.2
Liuba (LB)	3500–4200	51	Far	0.93	2.1	30.0
Quesuo (QS)	3300–4100	51	Close	0.94	2.3	13.3
Xiadecha (XDC)	3600–4400	46	Far	0.96	1.6	13.2

[a] Initial of each village was listed in the parentheses.
[b] Distance categories: "close", when the major road went through the village; "medium", when the village was not crossed by the major road and <5 km from the major road; and "far", when the village was >5 km from the major road.

level of traditional practices and conservation knowledge–attitudes–behaviors. We stratified the interview sampling by the age and gender of the villagers. At each village we chose 6–8 interviewers in each age category:<26, 26–35, 36–45, 46–55, >55, and the ratio of male: female in each category was controlled approximately as 1:1. Interviews were conducted by the researchers and two assistants, two of which are Tibetans. Questions were asked in Mandarin, when the interviewers were conversant in the language; otherwise interviews were conducted in Tibetan.

We tested the draft questionnaire in May–September 2005 through discussion with local experts on Tibetan culture and with more than 60 villagers at four villages to identify potential problematic questions or ambiguous statements. The final questionnaire comprised 29 questions organized in six sections: (1) traditional practices, (2) TEK, (3) SEK, (4) conservation attitudes, (5) conservation behaviors and (6) socio-demographic background (Table A.1).

With regards to traditional practices, we asked villagers eight questions (Questions 1–8 in Table A.1) that reflected the traditional world view and practices in their daily life but do not touch directly on their attitudes toward animals and habitats. The eight questions were identified through literature research (Childs, 2003; Ma and Chen, 2005; Mills, 2002; Norbu Chophel, 1983; Yu, 1997), interviews with Tibetologists and local religious leaders, and an associated anthropological study (Chen, unpublished data). We included different questions as proxy measures to quantify the villager's awareness of TEK and SEK, as well as their conservation attitudes and behaviors (Table 2).

The question "Why do you think you can't hunt wildlife, such as musk deer or white-eared pheasant?" was used to detect whether the respondents were influenced by formal education or traditions/religion towards conservation. The answers were summarized into two categories: (1) for the reason of government laws (such as because "they were national protected animals", "afraid of the penalty for killing protected animals", or "hunting wildlife was prohibited after government confiscated the guns); and (2) for the reason of traditions/religion (such as because "killing any kinds of life was not allowed to a Buddhist", "not good to yourself", or

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Table 2
Proxy questions to measure conservation knowledge–attitudes–behaviors and scores allocated to possible answers.

Questions	Measure
Traditional ecological knowledge TEK [0, 2]*	
1. Do you believe that violating taboos on sacred mountains will bring harm to yourself?	1-Yes; 0-no or do not know sacred mountains or any taboos
2. Is there any difference between killing a big animal and a small animal?	1-Yes; 0-no or do not know
Scientific ecological knowledge SEK	
Scientific conservation terms [0, 6]	
3. Have you ever heard of: (1) class-I national protected animals; (2) law on the protection of wildlife; (3) nature reserve; (4) forestry department; (5) forest protection and fire prevention; (6) biodiversity?	1-Yes; 0-no. The answers of 6 terms make a total score ranging from 0 to 6
National protected animals [0, 5]	
4. Are the following animals listed as nationally protected: (1) musk deer; (2) white-eared pheasant; (3) large-billed crow; (4) mice; (5) blue sheep?	1-Correct answer; 0-do not know or wrong answer. The answers of 5 animals make a total score ranging from 0 to 5
Conservation attitudes [−3, 3]	
5. What would you do if you saw someone illegally cutting trees?	1-Stop it; 0-do not know; "−1"-do not care or leave it
6. What would you do if wild animals damaged your crops?	1-Non-lethal methods; 0-do not know; "−1"-lethal methods
7. What would you do if you met a wounded wild animal?	1-Rescue the animal; 0-do not know; "−1" = do not care or eat it
Conservation behaviors [0, 1]	
8. Have you ever taken part in the patrolling activities of your village?	1-Yes; 0-no or do not know there are patrolling activities

* Range of the scores summed from associated questions.

"prohibited by the Rinpoche and the monastery"). Villagers who provide both as their answers were counted equally in two categories.

The socio-demographic information included age, gender, ethnicity, religion, years of formal education, occupation, income, experience of employment outside of the village, and fluency in spoken Mandarin.

2.3. Bird survey

Point counts were used to record bird species occurring in the two major habitat types at each village: 30 points in conifer forest (thereafter called conifer), 30 in alpine oak and shrub (thereafter called shrub). Two teams of experienced investigators walked away the village along different trails each day, and set the points when they met suitable habitat on their trail. The survey lasted until 30 points were sampled in each habitat. Survey points were set >200 m apart for sampling independence. At each point, all birds sighted and heard within a 50 m radius were recorded during a 10 min sampling period (Hagan et al., 1997), while birds flying above the points were not counted. The movements of the birds were tracked to minimize duplicate counting. The sample sizes for both habitat types were determined by examining the species accumulation curves derived from our pilot study (Quesuo village, August 2006), and were a compromise between detecting rare species and reducing field effort to allow multiple sites to be sampled. The species accumulation curves reached asymptotes with about 25 points for both habitat types. The field survey was mainly conducted 6:00–10:00 and 16:00–18:00 during the post-breeding season (August–mid-September) in 2006 in nine villages, and repeated during the breeding season (May–June) in 2007 in five of the nine villages.

2.4. Data analysis

For questions about traditional practices, all answers were coded as binary variables, using 1 for 'Yes' and 0 for 'No'. The summed score of answers to the eight questions (range 0–8) was used as a traditional practice index (TPI) of individual respondents. We considered respondents with higher TPI held more traditional values and lived in a more traditional life. Years of formal education was used as the index of formal education. In regards to conservation knowledge, attitudes and behaviors, positive answers were coded as plus score, answers of 'Don't know' as neutral (0 score) and negative answers as a minus score (see "Measure" in Table 2). Summed scores were calculated for the questions in each section (i.e., TEK, SEK, attitudes and behaviors). The scores of the two questions of SEK, scientific conservation terms and national protected animals, were calculated separately (Table 2). We considered the higher scores to designate respondents that were more knowledgeable and held more favorable attitudes and behaviors towards conservation. We excluded female respondents from question 8 (Table 2), as women in local communities were not involved in patrolling activities.

We divided the respondents into three groups by their TPI value based on a posthoc examination of their responses: low (TPI = 0–2), medium (TPI = 3–5) and high (TPI = 6–8). We then used Mann–Whitney test to compare the formal education, TEK, SEK, conservation attitudes and behaviors among the three groups. We used the mean TPI score of all respondents in one village as village TPI, and used a Pearson correlation test to examine the correlations between the village TPI and the percentage villagers who reported not hunting animals for the reason of government laws or traditions/religion.

To explore the relationship between TPI and bird diversity, we calculated bird species richness, abundance (number of individuals) and Shannon–Wiener Index of both conifer and shrub habitats from the point count data of the post-breeding season for the nine villages. We did not consider detection probability as our analysis focused on relative differences in species richness and abundance within each habitat type across different villages and not on absolute estimates of these parameters. We used a Pearson correlation test to examine the correlations between village TPI and species richness, abundance and Shannon–Wiener Index of conifer and shrub habitats at the village level. Point count data of the breeding season were not included for this analysis as the bird survey was not repeated in all the nine villages.

We used all the point count data of nine villages from two survey seasons for the regression to detect whether TPI and formal education are significant factors to the bird richness after controlling for other potential sampling and environmental factors. We conducted a negative binomial regression for the 889 surveyed points. We used species richness as the dependent variable, and included 12 potential co-variables in the model: village TPI, mean value of years of formal education of the respondents in the village, season (breeding or post-breeding), time (6:00–10:00, 10:00–14:00, 14:00–18:00), elevation, habitat type (conifer or shrub),

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distance to village, distance to river, distance to monastery, slope, aspect (warm or cold), and distance of the village to major road (close, medium, far, Table 1). We included distance of the village to major road as a surrogate measure of remoteness. All models were examined and selected according to model AIC values (Akaike Information Criterion. Akaike, 1973). We ranked the model with the lowest AIC as the best model, and used differences in AIC between the best model and other candidate models (ΔAIC) to determine the relative ranking order. All models whose ΔAIC < 2 were considered as equivalent best models (Burnharm and Anderson, 2002). We ran a final negative binomial regression with the variables with most occurrences in all the likely models. We considered the variables in the negative binomial regression model with a $p < 0.05$ as factors that significantly affected the bird richness. We used SPSS 15.0 (SPSS, CA, USA) with a significance level of 0.05 for all statistical analyses.

3. Results

3.1. Socio-demographic characteristics

We completed 331 questionnaires in the nine villages, among which 328 were considered valid ($N = 328$, rejection rate 1.0%). Three questionnaires were excluded as the interviewees were not local residents.

Respondents had a mean age of 41.0 years (SD = 15.2) and 52.0% were male. There was no significant difference in sample sizes of different age categories ($\chi^2 = 1.726$, $df = 4$, $p = 0.786$). All the respondents were Tibetans and 84.6% reported "absolute faith in Tibetan Buddhism", 3.4% "partial faith in Tibetan Buddhism" (i.e., practicing some, but not all, tenets of Tibetan Buddhism) and 12% "little faith in Tibetan Buddhism". The average year of formal school education was 2.6, and 48.3% of the respondents did not receive any school education, 42.9% had ⩽6 years of formal education (elementary school), and 8.8% went to middle school, high school or college. The majority of the respondents (86.3%) were farmers or herdsman; others were students, lamas, workers or officers.

3.2. Traditional practices and conservation knowledge-attitudes-behaviors

Villagers with higher TPI received fewer years of formal education (Fig. 3a). Older villagers practiced more traditions and received less formal education (age × TPI, $r = 0.136$, $p = 0.015$; age × years of formal education, $r = -0.271$, $p < 0.001$). There was no difference between men and women in traditional practices (Mann–Whitney U, $Z = -0.908$, $p = 0.364$), although men received more formal education than women ($Z = -3.386$, $p = 0.001$).

All the measured conservation variables (i.e., TEK, SEK, and conservation attitudes and behaviors) differed significantly among individuals with different TPI scores (Fig. 3). The villagers with higher TPI scores were more aware of TEK, but less aware of scientific conservation terms and had a lower knowledge of national protected animals (Fig. 3b–d). With regard to conservation attitudes, villagers with high TPI scores had more positive attitudes towards conservation and more actively participated in conservation than villagers with low TPI scores, and villagers with medium TPI scores were the least concerned about or participated in conservation activities (Fig. 3e and f).

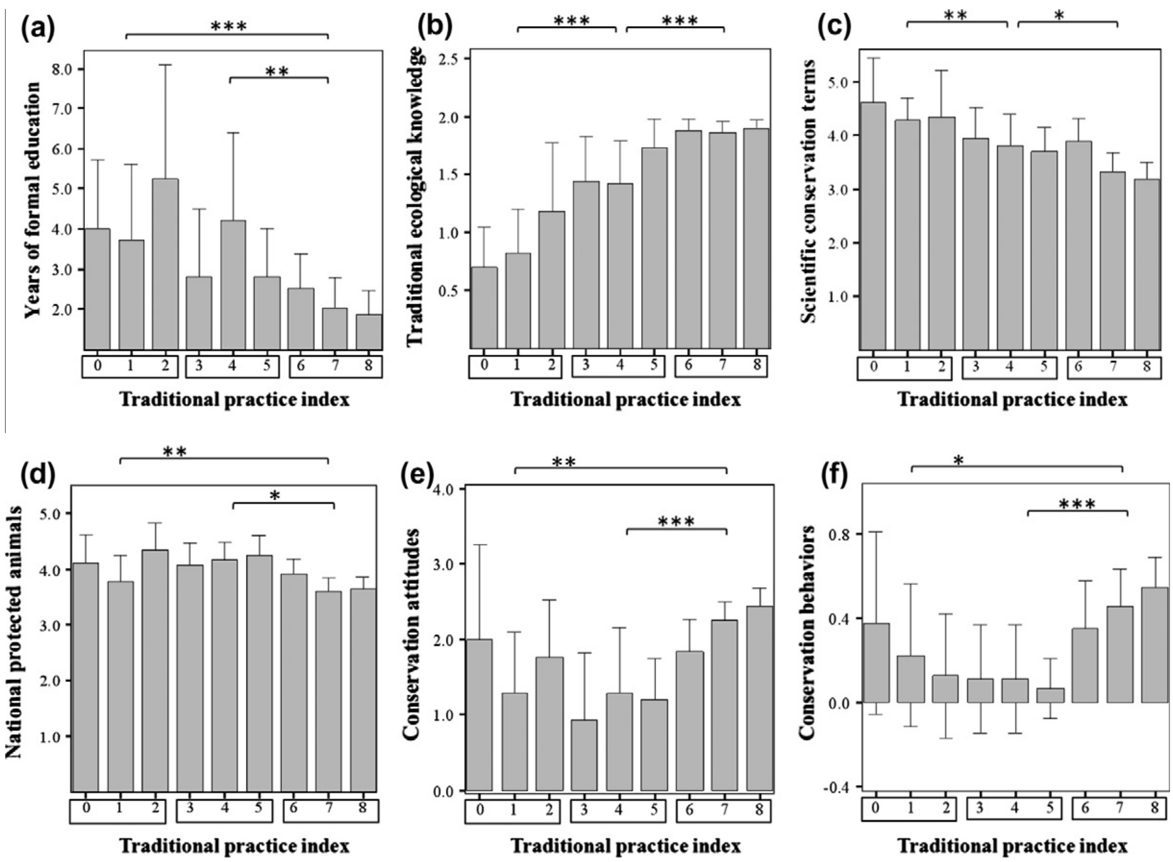

Fig. 3. Correlation between traditional practice index and formal education, traditional ecological knowledge, scientific ecological knowledge (scientific conservation terms and national protected animals respectively), conservation attitudes and behaviors in nine survey Tibetan villages, Sichuan Province, China. Mann–Whitney test was used. Differences among the three groups: low (traditional practice index, TPI = 0–2), medium (3–5) and high (6–8) are shown: *0.01 < p < 0.05; **0.001 < p < 0.01; ***p < 0.001.

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Regarding whether the respondents' conservation attitudes were influenced by formal education or traditions/religion, we found village mean TPI score had a negative correlation with the percentage of respondents in the village who reported hunting wildlife was not allowed for the reason of government laws ($r = -0.934$, $df = 9$, $p < 0.001$), but a positive correlation with the percentage of respondents who reported for the reason of traditions/religion ($r = 0.978$, $df = 9$, $p < 0.001$). Villages with medium mean TPI score had a roughly equal percentage of villagers who reported not killing wildlife for the reason of government laws and traditions/religion.

Patrolling activities were recorded in all the nine surveyed villages as the primary conservation response to threats to local wildlife and nature resources (e.g., wildlife poaching, timber logging and herb collecting). These patrolling activities were organized and funded by four different parties: (1) government agencies, (2) monasteries and religious leaders, (3) villagers and/or (4) outside conservation NGOs. Patrolling activities led by the local forestry department existed in all nine villages, during which men were hired as forest guards and conducted regular patrolling to protect forests and wildlife, and to report bushfire. Patrols conducted by monasteries and/or villagers existed in six villages (Fig. 4b). These two forms of community patrols were informally organized, mainly for protecting the sacred mountains and as a reaction to poaching threats in and around the village from outsiders. Monks or villagers walked around in their spare time checking for animal snares set by poachers. When local villagers encountered violators, or their signs, during their daily activities, they reported to the monastery and a search was organized. The percentage of respondents who knew about these activities varied among villages. In the villages with highest TPI scores, most villagers knew about the patrolling, while the least number of people were knowledgeable within the villages with medium TPI scores (Fig. 4a). The composition of patrols in the more traditional villages was more diverse, with higher involvement of community members and monasteries (Fig. 4b).

The percentage of the respondents who had sworn in front of the Rinpoche not to hunt (Question 20 in Table A.1) was positively correlated with the village TPI ($r = 0.808$, $df = 9$, $p = 0.008$). No villagers had pledged against hunting in the two least traditional villages.

3.3. Correlation between bird diversity and traditional practices

We recorded 128 bird species in the nine villages with a sampling effort of 889 survey points. We recorded more species and individuals of pheasants and raptors in the traditional villages (Table 3). Species richness, and the Shannon–Wiener index, of both the conifer and shrub habitats, and the number of individual birds detected in the shrub habitat, had a significant positive correlation with the village TPI (Fig. 5). The relationship between diversity measures and TPI was maintained when the village with the lowest TPI, which might have dominated the results, was removed (Conifer: species richness × TPI, $r = 0.754$, $p = 0.031$; Shrub: species richness × TPI, $r = 0.896$, $p = 0.003$, Shannon–Wiener index × TPI, $r = 0.762$, $p = 0.028$).

We selected the following variables for the final model: village TPI, slope, aspect and survey time (Table A.2). All four variables significantly contributed to the variability in species richness at the survey point (Table 4). We detected more bird species at points near villages with higher TPI scores. Sampling and environmental factors were also important for predicting species richness at points, as cold aspects exhibited 1.27 times the bird species of warm aspects; and more species was recorded in the morning than later in the day.

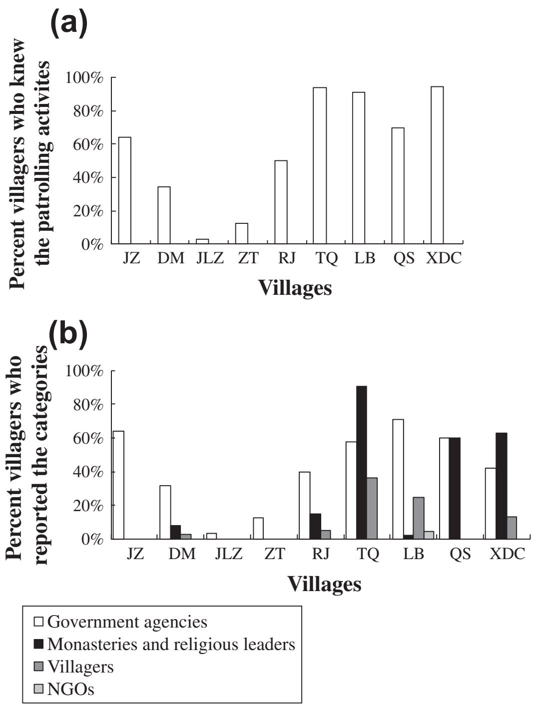

Fig. 4. Percent villagers who knew the patrolling activities in the village and percent villagers who reported the patrolling activities organized by four different parties. Villages on the X axis were ranked by increasing traditional practice index.

Table 3
Bird information of the post-breeding season of the nine surveyed Tibetan villages in Sichuan Province, China. Villages are presented in order of their TPI scores.

Village	Average traditional practice index	No. of species detected	Average no. of individuals per point count	Species and individuals (number in the parenthesis) of pheasants and raptors recorded
Jiuza	0.18	39	4.0	n/a
Dongma	0.65	41	4.2	Northern Goshawk (*Accipiter gentilis*, 2)
Jialazong	0.67	44	5.8	n/a
Zhatuo	0.72	46	3.4	n/a
Riji	0.87	49	5.7	White Eared-pheasant (*Crossoptilon crossoptilon*, 6), Koklass Pheasant (*Pucrasia macrolopha*, 1)
Tangqiao	0.88	60	7.7	Blood Pheasant (*Ithaginis cruentus*, 2), White Eared-pheasant (3)
Liuba	0.93	55	5.2	Blood Pheasant (7), Common Buzzard (*Buteo buteo*, 1)
Quesuo	0.94	51	7.1	Blood Pheasant (13), Chinese grouse (Bonasa sewerzowi, 1), Black-eared Kite (*Milvus migrans*, 1), Himalayan Vulture (*Gyps himalayensis*, 1), Northern Goshawk (1)
Xiadecha	0.96	58	7.4	White Eared-pheasant (15), Upland Buzzard (*Buteo hemilasius*, 1)

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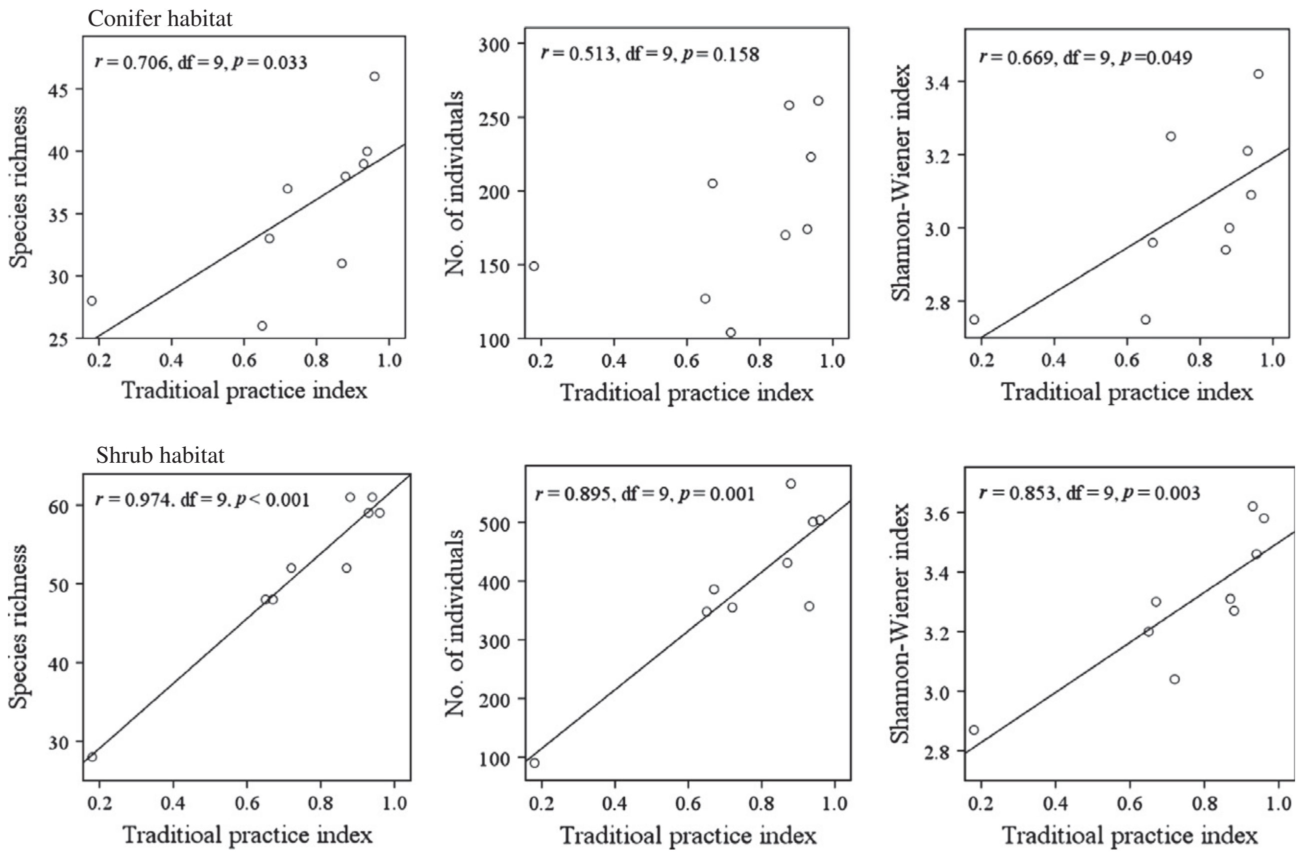

Fig. 5. Correlation between bird diversity indices (species richness, number of individuals and Shannon–Wiener index) within the conifer and shrub habitats and traditional practice index in nine survey Tibetan villages, Sichuan Province, China.

Table 4
Parameter estimates of variables in final negative binomial regression model used to predict the bird species richness.

Variables	β	S.E.	P	Exp. (β)
Traditional practice index	0.424	0.1285	0.001	1.53
Slope	−0.009	0.0035	0.008	0.99
Aspect: Warm[a]				
Cold	0.239	0.0640	0.000	1.27
Time: 6 am–10 am [a]				
10 am–2 pm	−0.339	0.0744	0.000	0.71
2 pm–6 pm	−0.484	0.0890	0.000	0.62

[a] The reference category of the variable.

4. Discussion

Previous empirical studies that examined the relationship between TEK and biodiversity often lack quantitative measurements of both biodiversity and social perspectives. We chose birds as a surrogate measure of biodiversity, as they are susceptible to landscape-level changes in the environment and relatively easy to monitor (Blair, 1999). Measuring bird diversity was straightforward in our study, as standard protocols exist, but the quantification of traditional practices was more challenging. Our proxy questions for TPI were developed based on literature review and tested during a trial period. We believed the TPI scores are an appropriate measure representing the actual traditional status of each village, which were also consistent with our subjective ranking. The formal education level was low in the study area, thus most villagers did not possess standard SEK. Instead, conservation education by the government was the predominant form of knowledge transfer in the local communities. Our SEK questions measured the villager's comprehension of the policy statements received from the government and were the local equivalent of SEK. Possibly future increasing formal schooling will promote villager's understanding of scientific ecological knowledge, but at the time of this study government policy statements were the extent of their formal conservation knowledge.

As expected, villagers with more traditional practices were more knowledgeable about TEK while less knowledgeable about SEK. We consider this difference is due to how the villagers gained their conservation knowledge: either primarily through community education or through formal education. Traditional villagers were more influenced by community regulations and religious education while isolated from formal education. This dichotomy was also supported by the answers to the question "Why do you think you cannot hunt any wildlife, such as musk deer or white-eared pheasant?" which showed traditional villages had a high percentage of people who followed the religious tenets against hunting and a low percentage of people who followed the government laws.

The attitude–behavior model is widely used in psychological studies to interpret the complex mechanisms behind observed social activities (Ajzen and Fishbein, 1977; Kaiser et al., 1999) and has been introduced to conservation biology researches as a knowledge–attitudes–behaviors framework (Barney et al., 2005; Kruse and Card, 2004). We adopted the knowledge–attitudes–behaviors framework to explore how and to what extent TEK and SEK determine local people's behavior towards conservation. The conservation attitudes and behaviors of the villagers reflected a combined influence of both TEK and SEK. The observed U-shape

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relationship between individual TPIs and the measurements of conservation attitudes and behaviors (Fig 3e and f) suggests that conservation education by the government was successful in raising people's environmental awareness, but traditional ways were comparatively more profound in promoting people's conservation attitudes. Villagers at the bottom of the U-shape curve were neither strongly influenced by the traditions nor by the government and their education should be considered a priority in future conservation efforts. The conservation behaviors at the village level showed similar trend as that of the individual level (Fig. 4).

In regards to bird diversity, we found a linear relationship between village mean TPI scores and species richness, abundance and Shannon–Wiener index. Our regression analysis showed similar results: traditional practice was a positive correlative factor of bird diversity, while formal education was not. We chose villages with similar geography, vegetation and social-economic status to control for environmental and social factors that could influence bird communities. The land use of each village was similar with farming, grazing, logging for fuel and housing materials, and collecting non-forest product as the main human activities. We included other anthropogenic factors, such as distances from roads and monasteries, as covariates, but these factors were not selected for our final models. We consider the correlation between the traditional practices and bird diversity significant, and these differences in bird diversity were a result of non-landscape attributes within the villages that we attribute to differences in the villagers' behaviors toward wildlife.

Traditional Tibetan culture has profound impacts on local people's attitudes and behaviors toward the protection of habitats and wildlife mainly through two aspects: protecting sacred sites and prohibiting hunting. We found a higher percentage of villagers who understood the taboos and had pledged against hunting in the traditional villages. Every Tibetan village has its sacred mountain where hunting, logging and farming are forbidden. Strict taboos often exist for core areas of sacred mountains, such as prohibition of livestock grazing and non-timber forest product collecting. These practices often have real impacts, for example more mature forests and endemic plant species are found on the sacred mountains than non-sacred areas (Anderson et al., 2005; Salick et al., 2007). We consider patrolling activities by the community an indicator of the extent of local conservation efforts. Patrolling activity with higher awareness and broader participation (Fig. 4) would be more effective in preventing poaching. As a result, economically valuable species, such as pheasants and raptors, were more often detected in the villages with stronger patrolling activities and these tended to be more traditional villages.

Although villagers in the lowest TPI villages had a higher score in conservation attitudes and behaviors compared to the medium TPI villages, these villages did not possess higher bird abundance and diversity. Possibly this inconsistency was due to the insufficient time of government conservation efforts. Most (50 out of 51) nature reserves in Ganzi were established after 1995 (MEP, 2010). Government regulation did not reach these villages until the late 1990s, with the logging ban in 1998, the prohibition of guns around 2000, and conservation education by government agencies (e.g., local forestry bureau and environmental protection bureau). Loss of TEK, and increases in government regulation, occur in conjunction with many other societal changes, such as loss of traditional livelihoods, changing economic status, influx of different cultures and individuals, which may also impact biodiversity measures in the region (Malhotra et al., 2001; Bhagwat and Rutte, 2006).

Another possible reason why traditional Tibetan practices were more tightly linked to local biodiversity is that traditions might be more effective at regulating and constraining people's behavior towards conservation than government laws and regulations (Bhagwat and Rutte, 2006; Xu et al., 2005). The rationale, enforcement and sanctioning mechanisms of traditional conservation system remarkably differ from those of an official conservation system (Colding and Folke, 2001). Traditional ecological knowledge exists as a knowledge-practice-beliefs complex passed down within the community through generations (Berkes et al., 2000). The practice of TEK is largely dependent on its cultural and institutional context. In traditional Tibetan villages, villagers obey traditional rules and regulations as they believe doing so is good for their own karma and the welfare of their community. Violations of these customs will bring bad karma and punishment from the deities and monasteries, and these violators will be looked down by others within the community. Every community member is not only the practitioner but the supervisor of their own behavior. Secondly, lack of legitimacy of current environmental laws and policies among villagers may limit the effectiveness of the formal conservation system (Wilshusen et al., 2002). Although formally educated villagers had a better understanding of conservation policies, they may put little effort into patrolling and other activities that would uphold these policies due to the lack of incentives and the conflicts that widely exist between the local livelihoods and government conservation activities (Xu and Melick, 2007). A wider participation in conservation (Fig. 4) and the self-enforced system found within the traditional villages are lacking in the formal conservation system, and may preclude a better conservation outcome (i.e., increased biodiversity).

The inverse relationship between TPI and formal education, and the correlation between bird diversity and TPI indicated the importance of Tibetan traditional practices in conservation, and scientific knowledge as a complement rather than a substitute of TPI for conservation in the study area. The negative correlation between traditional and scientific knowledge does not suggest that those two are incompatible. In fact, they have much in common since both knowledge systems derive from the systematic observation of nature (Berkes et al., 2000). Attempts and progress have been made in Tibet and other parts of the world to integrate traditional and scientific ecological knowledge in resource management and conservation (Armstrong et al., 2007; Becker and Ghimire, 2003; Fraser et al., 2006; Ma and Basang Lhamo, 2009). In the case of our study area this integration has not been successful. The shift from TEK towards SEK among our study sites has been reported in other traditional societies that are under outside pressures, whether they be a capitalist economy (Pretty et al., 2008), centralized political systems, or culturally-inappropriate education systems (Kothari, 2006).

Although traditional ecological knowledge and institutions were more effective in conserving biodiversity than formal institutions, they have been rarely recognized and involved in the conservation planning and implementation in China (Xu and Melick, 2007). We suggest a complementary role for both Tibetan TEK and government conservation efforts. Our most effective conservation tool is TEK and the maintenance of religious tenets toward wildlife. These practices should be encouraged and supported, with government assistance where possible. Secondly, it may be possible to increase SEK among Tibetan religious institutions by educating monks on ecological principles. Involving local religious institutions and leaders in conservation education has been advocated to enhance community participation in both collecting knowledge about and protecting biodiversity (Sheikh, 2006). Local communities are interested in formal conservation knowledge which they could use to stop outside violations of their traditional conservation practices (Ma and Basang Lhamo, 2009). Current conservation education presented through government programs in Tibetan area is more a policy statement than ecological education. More emphasis on the ecological principles and disseminating SEK through religious institutions can secure local conservation activities, and help traditional communities to cope with the

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changing environment (e.g., climate change and global warming) (Becker and Ghimire, 2003; Zhang, 2006). Thirdly, government conservation programs would benefit by the support of local institutions to complement its limited funding and human resources (Xie, 2004; Sheikh, 2006; Zhang, 2006; Xu and Melick, 2007). "Right actions" may have several underlying motivations that do not all need to be based in modern science. There are caveats to integrating these two systems, as it will require an initial effort on regional agreements, financial input, ethical guidelines and law/policy framework, and has a high risk of failure (Mauro and Hardison, 2000). Once established, however, the integrated management system would require low maintenance and few outside input (Ma and Basang Lhamo, 2009; Tian, personal communication).

Our study showed that both TEK and SEK support attitudes toward conservation, and when the two systems were weak, biodiversity measures were low. Government education could serve as an alternative way to guarantee people's behavior towards conservation in these areas, but reviving the cultural traditions and TEK should be considered a primary conservation goal. Our study has implications for the conservation of indigenous groups undergoing extensive social and economic change and the loss of tradition. When the "social taboos" (Colding and Folke, 2001) are weakening, and government conservation efforts are missing or ineffective, local communities are faced with habitat degradation and biodiversity loss. Assisting indigenous people in maintaining and practicing TEK is an urgent task. We recommend increased efforts to promote the cultural traditions in the Tibetan area, especially targeting the younger generation and local communities influenced by modern society. Those communities who are willing to maintain their traditions should be encouraged. Conservation training materials that appreciate the value of traditional Tibetan culture could be embedded into formal education (Kimmerer, 2002) and strengthened both to inspire people's pride on their own tradition and to have a direct benefit for biodiversity conservation. Meanwhile, given the variable strength of traditional practices among communities across the vast Tibetan region, any policy of uniformity will not be feasible (Ma, 2011). Policy makers and conservation managers should respect local autonomy for practicing their own conservation beliefs and practices and should not consider policy pronouncements a replacement for local traditions.

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Appendix A

See Tables A.1 and A.2.

Table A.1
Questionnaire on the traditional practices, conservation knowledge, attitudes and behaviors of villagers in nine survey Tibetan villages, Sichuan Province, China.

I. Traditional practices of the interviewee
1. Do you believe in reincarnation and karma?
2. Does pray or pilgrimage benefit yourself?
3. Is there a Buddhist shrine in your house?
4. Are you wearing an amulet?
5. Do you or your family burn incense at festival or in good days?
6. Was your name, or that of your child, given by the lama?
7. Do you or your family pray every morning?
8. Do you invite the lama to select the day for getting married or building new houses?

II. Knowledge–attitudes–behaviors of the interviewee
9. Are there any sacred mountains in and around your village?
10. Do you believe violating taboos on sacred mountains will bring any harm to yourself?
11. Is there any difference between killing a big animal and a small animal?
12. Have you ever heard of: (1) class-I national protected animals; (2) law on the protection of wildlife; (3) nature reserve; (4) forest department; (5) forest protection and fire prevention; (6) biodiversity?
13. Are the following animals listed as nationally protected: (1) musk deer; (2) white-eared pheasant; (3) large-billed crow; (4) mice; (5) blue sheep?
14. What would you do if you saw someone illegally cutting trees?
15. What would you do if wild animals damaged your crops?
16. What would you do if you met a wounded wild animal?
17. Are there any patrolling activities going on in your village? If yes, who organizes the patrolling?
18. Have you ever taken part in the patrolling activities of your village?

III. Others
19. Why do you think you can not hunt wildlife, such as musk deer or white-eared pheasant?
20. Have you ever sworn in front of the Rinpoche not to hunt?

IV. Social – demographic background of the interviewee
21. Age
22. Gender
23. Ethnicity
24. Religion
25. Years of formal education
26. Occupation
27. Income status in the village: rich; medium; poor (obtained from the village head)
28. Have you ever been employed outside of the village?
29. Is the interviewee fluent in spoken Mandarin?

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Table A.2
Candidate negative binomial models whose ΔAIC < 2 used to predict the bird species richness in the nine surveyed Tibetan villages, Sichuan Province, China. Models are ranked in order of their AIC.

Model	K^*	AIC	ΔAIC
TPI, time, aspect, slope	4	3739.147	0.000
TPI, time, aspect, slope, habitat	5	3739.905	0.758
TPI, time, aspect, slope, season	5	3739.916	0.769
TPI, time, aspect, slope, distance to village	5	3740.341	1.194
TPI, time, aspect, slope, season, habitat	6	3740.603	1.456
TPI, time, aspect, slope, season, distance to village	6	3741.020	1.873
TPI, time, aspect, slope, distance to village, habitat	6	3741.047	1.900

* K = number of estimable parameters in the model.

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