Contributed Paper

Role of Tibetan Buddhist Monasteries in Snow Leopard Conservation

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Abstract: *The snow leopard* (Panthera uncia) *inhabits the rugged mountains in 12 countries of Central Asia, including the Tibetan Plateau. Due to poaching, decreased abundance of prey, and habitat degradation, it was listed as endangered by the International Union for Conservation of Nature in 1972. Current conservation strategies, including nature reserves and incentive programs, have limited capacities to protect snow leopards. We investigated the role of Tibetan Buddhist monasteries in snow leopard conservation in the Sanjiangyuan region in China's Qinghai Province on the Tibetan Plateau. From 2009 to 2011, we systematically surveyed snow leopards in the Sanjiangyuan region. We used the MaxEnt model to determine the relation of their presence to environmental variables (e.g., elevation, ruggedness) and to predict snow leopard distribution. Model results showed 89,602 km² of snow leopard habitat in the Sanjiangyuan region, of which 7674 km² lay within Sanjiangyuan Nature Reserve's core zones. We analyzed the spatial relation between snow leopard habitat and Buddhist monasteries and found that 46% of monasteries were located in snow leopard habitat and 90% were within 5 km of snow leopard habitat. The 336 monasteries in the Sanjiangyuan region could protect more snow leopard habitat (8342 km²) through social norms and active patrols than the nature reserve's core zones. We conducted 144 household interviews to identify local herders' attitudes and behavior toward snow leopards and other wildlife. Most local herders claimed that they did not kill wildlife, and 42% said they did not kill wildlife because it was a sin in Buddhism. Our results indicate monasteries play an important role in snow leopard conservation. Monastery-based snow leopard conservation could be extended to other Tibetan Buddhist regions that in total would encompass about 80% of the global range of snow leopards.*

Keywords: conservation strategy, distribution, MaxEnt, nature reserve, *Panthera uncia*, sacred mountain

Papel de los Monasterios Budistas Tibetanos en la Conservación del Leopardo de las Nieves

Resumen: *El leopardo de las nieves* (Panthera uncia) *habita en las montañas escarpadas de 12 países de Asia Central, incluyendo la Meseta Tibetana. Debido a la caza furtiva, la disminución de la abundancia de presas y la degradación del hábitat, fue enlistado como en peligro por la Unión Internacional para la Conservación de la Naturaleza en 1972. Las estrategias de conservación actuales, que incluyen reservas naturales y programas*

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de incentivos, han limitado las capacidades para proteger a los leopardos de las nieves. Investigamos el papel de los monasterios budistas tibetanos en la conservación de la especie en la región de Sanjiangyuan en la provincia china de Qinghai en la Meseta Tibetana. De 2009 a 2011 buscamos sistemáticamente leopardos de las nieves en la región Sanjiangyuan. Usamos el modelo MaxEnt para determinar la relación de su presencia con variables ambientales (p. ej.: elevación, aspereza) y predecir la distribución de la especia. Los resultados del modelo mostraron 89,602 km^2 de hábitat del leopardo de las nieves en la región de Sanjiangyuan, de los cuales 7674 km^2 yacen dentro de las zonas núcleo de la Reserva Natural de Sanjiangyuan. Analizamos la relación espacial entre el hábitat del leopardo de las nieves y los monasterios budistas. Hallamos que el 46% de los monasterios están ubicados en el hábitat de la especie y el 90% están dentro de 5 km del hábitat. Los 336 monasterios en la región Sanjiangyuan podrían proteger más hábitat (8342 km^2), a través de normas sociales y patrullas activas, que las zonas núcleo de la reserva. Realizamos 144 entrevistas a hogares para identificar las actitudes y comportamiento de pastores locales hacia los leopardos y otra fauna. La mayoría de los pastores dijeron que no matan fauna Silvestre y el 42% dijo que no la matan porque es un pecado en la religión budista. Nuestros resultados indican que los monasterios juegan un papel importante en la conservación del leopardo de las nieves. La conservación de la especie basada en monasterios podría extenderse a otras regiones tibetanas budistas, que en total englobarían un 80% de la distribución global de los leopardos de las nieves.

Palabras Clave: distribución, estrategia de conservación, MaxEnt, montaña sagrada, *Panthera uncia*, reserva natural

Introduction

The snow leopard (*Panthera uncia*) occurs in rugged mountains across 12 countries in Central Asia and on the Tibetan Plateau (McCarthy & Chapron 2003). As a keystone species, its status can reflect the condition of the fragile alpine ecosystems. Due to poaching, retaliatory killing, decline in abundance of prey, and habitat degradation, the snow leopard was listed as endangered by International Union for Conservation of Nature in 1972 (McCarthy & Chapron 2003). Because of its rugged habitat and large home range and conflict between humans and leopards, snow leopard conservation presents many difficulties. The main conservation efforts include the designation of nature reserves by governments and incentive programs promoted by nongovernmental organizations (McCarthy & Chapron 2003; Mishra et al. 2003), but their capacities are limited. Incentive programs are usually difficult to replicate at large scales because they need a strong baseline of ecological and socioeconomic research and long-term involvement (Mishra et al. 2003). Only 0.3–27% of snow leopard habitat is covered by nature reserves in 11 of 12 range countries. Bhutan is the exception, where 57% of snow leopard habitat is protected (Hunter & Jackson 1997).

Belief in Tibetan Buddhism is widespread across the snow leopard's range. The basic tenets of Buddhism are love, respect, and compassion for all living beings. These tenets are shared with those who wish to conserve biodiversity (Karmapa & Dorje 2011), and adherence to them helps reduce killing of snow leopards and other wildlife (Mallon 1984; Schaller 1988; Bagchi & Mishra 2006). Such protection takes 2 main forms. First, there is a tradition of protecting sacred species and sacred natural sites such as sacred mountains, groves, and lakes near monasteries. Sacred species and natural sites are usually protected by monks or other designated persons (Shen et al. 2012). Second, the senior Rinpoche and Khenpos in the monasteries have a profound effect on their followers and shape their views of the natural world, thereby affecting their attitudes and behavior toward wildlife (Dudley et al. 2009).

We explored the role of Tibetan Buddhist monasteries in the conservation of snow leopards and sympatric wildlife in the Sanjiangyuan region in China's Qinghai Province along the eastern part of the Tibetan Plateau. We systematically surveyed snow leopards in the Sanjiangyuan region, used the MaxEnt model to determine the relation of leopard presence to environmental variables, and created a map of snow leopard distribution. On the basis of this map, we analyzed the gaps in nature reserves in the Sanjiangyuan region and the spatial relation between snow leopard habitat and monasteries. We interviewed local people about their attitudes toward wildlife and mention of snow leopards in Buddhist scriptures.

Methods

Study Area

The Tibetan Plateau is the highest and largest plateau in the world; it extends over 2,500,000 km^2 at an average elevation >4500 m. The Sanjiangyuan region is the source of the Yellow, Yangtze, and Mekong Rivers and provides water to over a billion people downstream (Editorial Committee of Ecological Environment of Sanjiangyuan Nature Reserve 2002) (Fig. 1). The terrain consists of plains, hills, and mountains, including the Kunlun, Anyemaqin, Tanggula, and Bayan mountain ranges.

Our study area covered almost the whole Sanjiangyuan region, an area of 360,000 km^2, except the northwestern Kekexili area (Fig. 1). Sanjiangyuan Nature Reserve (150,000 km^2) is the largest of the 2 nature reserves in our study area. The other reserve is the Longbao Nature

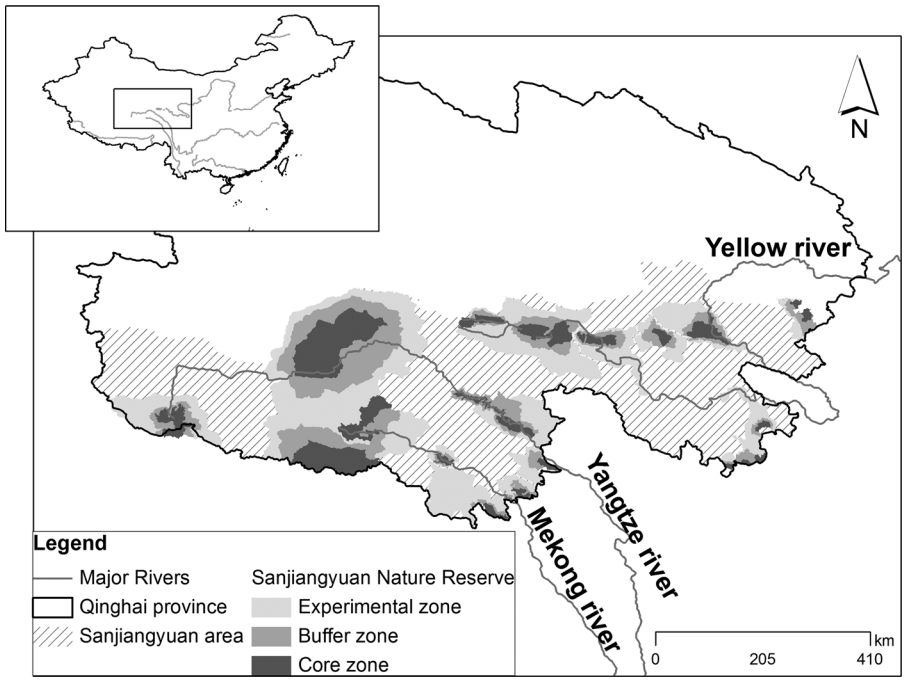

Figure 1. The Sanjiangyuan region in the eastern part of the Tibetan Plateau (covered in text). Approximately 150,000 km^2 of this area is the Sanjiangyuan Nature Reserve, which includes 18 protection districts, each with a core zone, buffer zone, and an experimental zone (defined in Methods).

Reserve, a wetland reserve with a total area of about 100 km^2.

Sanjiangyuan Nature Reserve includes 18 protection districts. Each district has 3 parts, a core zone, a buffer zone, and an experimental zone (Fig. 1). According to the Regulations of the People's Republic of China on Nature Reserves in 1994, core zones are to be maintained inviolate, buffer zones allow only scientific research activity, and experimental zones allow scientific experiments, teaching, tourism, and breeding of endangered wildlife. In reality, however, many reserves have people living inside and they are often plagued by the lack of adequate staff and financial support (Liu et al. 2003). About 76,000 people live in the Sanjiangyuan Nature Reserve, including in core, buffer, and experimental zones. Tibetans account for 90% of this population, and they follow Tibetan Buddhism. The remaining 10% of the population is composed of Han and other ethnic groups such as Hui. There are at least 336 Tibetan Buddhist monasteries formally recorded by the government in the Sanjiangyuan region. They are concentrated in the Yushu, Nangqian, and Chengduo Counties (Pu 1990; Zhu 2006).

Snow Leopard Records

We classified areas in Landsat images of our study area as grassland, water, rock, cloud, and cloud shadow and plotted them on a map with 15 × 15 km grid cells (1511 cells). Because snow leopards inhabit rocky mountains, we classified grid cells into 3 proportional levels of rock coverage: 0–0.27, 0.27–0.54, and 0.54–0.81.

We randomly selected 5% of grid cells in each level of rock coverage for sampling. In each survey site, we consulted with local hunters and Forestry Bureau personnel to identify probable snow leopard habitat. We then surveyed potential routes used by snow leopards for social marking. We searched these routes for snow leopard signs (feces, scrapes, scent marks, and pug marks) within a 10-m-wide strip on either side of the route. We recorded GPS locations and types of snow leopard sign encountered (Jackson & Hunter 1996).

We stored snow leopard scats in 15-mL centrifuge tubes with 12 mL of silica covered by a tissue to separate samples. We used a FecalGen DNA Kit (Cowin, Beijing) to extract DNA from the fecal material. The identity of the species to which the scat belonged was ascertained from a region of mitochondrial cytochrome *b* gene (Janečka et al. 2008).

We conducted field surveys from 2009 to 2011, during which we recorded 313 snow leopard signs across the Sanjiangyuan region. In our models, we used only records of fresh scrapes and pugmarks and feces verified through DNA. To avoid spatial autocorrelation, we considered only one record in each 1 × 1 km grid subcell. This filtering left us with 86 snow leopard records, which we used to build the snow leopard distribution model.

Snow Leopard Distribution Model

To simplify the model and reduce chances of random errors, we incorporated only the most relevant environmental variables: elevation, slope, ruggedness, distance to road (as a surrogate of remoteness), distance to human settlement, and land-cover category (arable land, woodland, grassland, water, urban land, unused land, snow, barren land [coverage of vegetation <5%], and no data) (Liao 1985; Schaller 1988; Hunter & Jackson 1997). Slope and ruggedness were calculated from SRTM (Shuttle

Radar Topography Mission) with the slope and VRM (vector ruggedness measure) tools in ArcMap (Sappington et al. 2007). Only settlements and roads at province, city, and county levels were considered because at the town and village levels herding people are dispersed throughout the landscape. We obtained land cover from 1:250,000 China National Geometrics Database. We created a raster of 1 × 1 km grid cells for niche modeling.

We used the default settings in MaxEnt (version 3.3.3k) software to build the snow leopard distribution model. We included the additional options of "create response curve" and "do jackknife to measure variable importance." Seventy-five percent of the data were randomly selected as training data, which left 25% for testing (Phillips et al. 2004). In this model, each 1 × 1 km grid cell was assigned a value from 0 to 1, indicating the habitat quality for snow leopards. We used the area under the curve (AUC) of training and testing data calculated by the MaxEnt software to evaluate the model's performance. A higher AUC value (close to 1) indicates the model's ability to differentiate habitat from nonhabitat, whereas an AUC around 0.5 suggests the prediction is no better than random (Phillips et al. 2006). With "maximum training sensitivity plus specificity" as the threshold (Manel et al. 2001), all the grid cells were reclassified to create the snow leopard distribution map. Grid cells with a value equal to or greater than the threshold were classified as snow leopard distribution areas, whereas other areas were classified as nondistribution areas.

Buddhist Monastery Records

We recorded the geographic locations of Buddhist monasteries across the Sanjiangyuan region in 3 ways. First, we determined the GPS location of 33 monasteries during field surveys. Second, we visually checked all the georeferenced photographs from our study area in the Panoramio photo-sharing community (http://www.panoramio.com) and located 31 additional monasteries. Third, we searched for the term *gongba* (*monastery* in Tibetan) in Google Maps (http://maps.google.com) and Baidu Maps (http://maps.baidu.com), and recorded 17 additional monasteries. In all, we obtained locations of 81 Buddhist monasteries in 13 out of 17 counties in the Sanjiangyuan region (25% of all Buddhist monasteries in the area).

Using ArcGIS, we randomly placed 81 points throughout the Sanjiangyuan region. To assess whether the monasteries were located disproportionately in snow leopard habitat, we used a Mann-Whitney *U* test to compare the distance of the monasteries and of random points to the nearest snow leopard habitat.

To get a rough estimate of the snow leopard habitat area protected by the monasteries in the Sanjiangyuan region, we made use of available information from the Plateau region of the adjoining Western Sichuan, where Shen et al. (2012) reported that each monastery on average owned 2.9 sacred mountains, each with an average size of 25.9 km^2. Thus, each monastery could protect approximately 75.1 km^2 of sacred mountains. In conjunction with the snow leopard distribution map, we used this figure to estimate the size of snow leopard habitat protected by monasteries in the Sanjiangyuan region. Most monasteries are responsible for protecting their sacred places, and monks patrol and monitor human activities in the area. When they encounter people violating scared places, they order the offenders to leave, hand out punishment according to traditional norms, or report illegal activities to local government. Thus, because monasteries protect scared places, they may also be protecting snow leopards. All the GIS work was carried out in ArcMap (version 10.0), and all the statistical analyses conducted in IBM SPSS 20.

Semistructured Interviews

From 2009 to 2011, we interviewed local herders across the Sanjiangyuan region to identify the number of retaliatory killings of snow leopards. We asked herders if there were any dead snow leopards in their area or if they knew of anyone who had killed snow leopards. As a mark of respect to local herders who are Tibetan Buddhists and thus forbidden to hunt, we refrained from asking them directly if they had ever killed snow leopards. We also asked herders to list the reasons why they do not hunt. Some herders stated multiple reasons for not hunting, and we calculated the percentage of each reason. We interviewed monks, especially the senior Rinpoche and Khenpos, the most learned men in monasteries, about the mention of snow leopards in Buddhist scripture. We also obtained data on the level of field staffing and size of the protection districts from the records of the Sanjiangyuan National Nature Reserve.

Results

Snow Leopard Distribution

Results of the AUCs of the training data and testing data, 0.974 and 0.962 respectively, indicated our model performed well. Elevation, ruggedness, and land-cover type were the environmental variables that most affected snow leopard distribution. They contributed 35.6, 26.5, and 20.0%, respectively, to this model. The response curves showed snow leopards tended to use rugged grassland and rocky areas at elevations >3334 m the most.

The maximum training sensitivity plus specificity of this model was 0.192. On the basis of this threshold, all the grid cells were reclassified to build the snow leopard distribution map. Snow leopards were distributed over 89,602 km^2, about 25% of the Sanjiangyuan region,

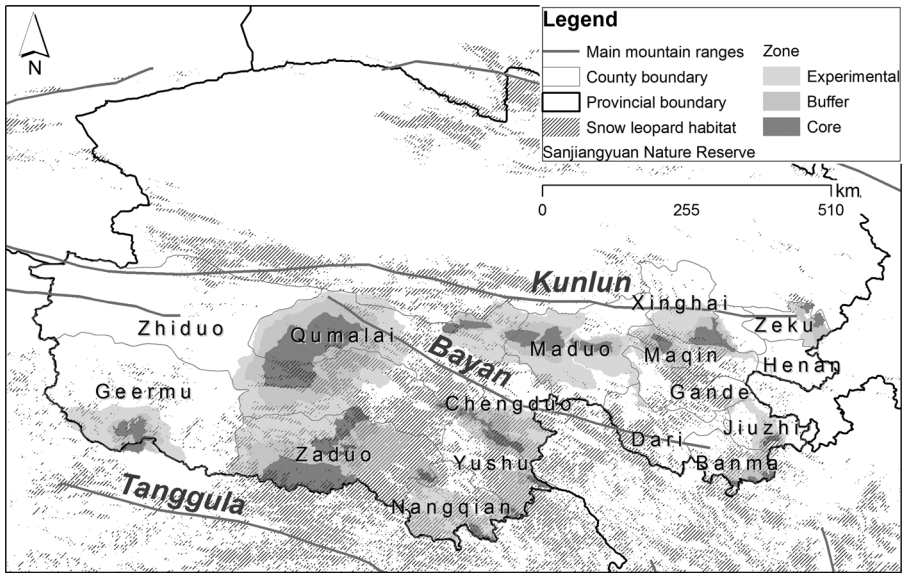

Figure 2. Snow leopard habitat distribution across the Sanjiangyuan Nature Reserve, Tibetan Plateau, China (zones defined in Methods).

principally in the Kunlun, Bayan, and Tanggula Mountains (Fig. 2).

Conservation Gaps

The buffer zones and experimental zones in Sanjiangyuan Nature Reserve covered 13,073 and 26,570 km^2, respectively, of the predicted snow leopard habitat. Core zones covered 7674 km^2, mainly in Zhiduo and Zaduo Counties (Fig. 2). Many areas of snow leopard habitat, including some of the large contiguous habitats in Zaduo, Maqin, Banma, and Yushu Counties, were omitted from the core zones, as were the smaller dispersed areas of habitat across the region (Fig. 2).

Besides the spatial coverage, the reserve system was highly understaffed. There were 21 conservation stations in the 18 independent districts of the Sanjiangyuan Nature Reserve, ranging in size from 516 to 41,620 km^2. The maximum distance between districts was over 1000 km (Fig. 1). Most areas in the reserve were remote and inaccessible by vehicles. In this expansive, rugged landscape, 2–3 employees were allocated per station, and half of them were full-time, rendering effective protection of the 150,000 km^2 nature reserve infeasible. For example, the Suojia-Qumahe district had an area of 41,620 km^2 and a mean elevation of 4,500 m. There were 3 employees stationed in this district, and it would take them at least 60 days on an average patrol to cover the entire district.

Snow Leopard Habitat Protection by Tibetan Buddhist Monasteries

All 81 Buddhist monasteries we located were either in or adjacent to snow leopard habitat. Ninety percent were located within 5 km of snow leopard habitat, 65% were within 1 km, and 46% were in snow leopard habitat

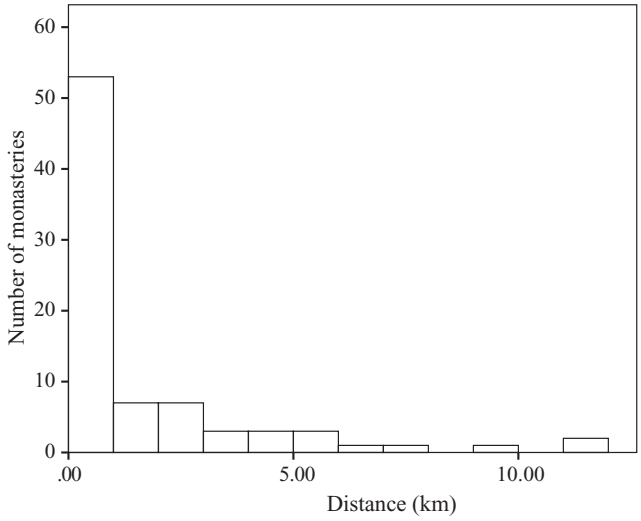

Figure 3. Distance of the 81 Buddhist monasteries from snow leopard habitat.

(Fig. 3). The distance between the monasteries and the nearest snow leopard habitat was significantly lower than the distance between 81 random points and the nearest snow leopard habitat in the study area ($p = 0.000$).

Each monastery protected, on average, a sacred mountain of approximately 75.1 km^2, which could be considered as a circle with a radius of 4.89 km. The 81 monasteries we recorded therefore potentially protected 6083 km^2 of sacred mountains. This included 2011 km^2 of snow leopard habitat predicted by our distribution model. In the entire Sanjiangyuan region, therefore, the 336 monasteries were estimated to protect 8342 km^2 of snow leopard habitat. This area is larger than the 7674 km^2 covered by the core zones of the Sanjiangyuan Nature Reserve.

Tibetan Buddhism and Local Herders' Attitudes Toward Wildlife

In our interviews, we found that monasteries not only organized patrols of their sacred mountains, but also educated the local communities about environmental protection. Rinpoche or Khenpos, for example, would routinely talk about the Buddhist edicts concerning reverence for all life.

We interviewed 144 herders throughout the Sanjiangyuan region. Most of them did not report they killed wildlife. Interviewees mentioned 3 herders were involved in killing 6 snow leopards in the previous 3 years. Among the 144 herders interviewed, 47% claimed they did not kill wildlife because the government prohibited it, 42% said they did not kill wildlife because it was a sin in Buddhism, and 28% said they did not kill wildlife because they did not have guns. Others added that living conditions had improved so much that they did not need wild meat anymore. Many locals swore an oath to their Rinpoche every year not to kill wildlife.

We recorded 2 legends about snow leopards in Buddhist scriptures that indicated snow leopards may have a sacred place in Tibetan Buddhism. According to Buddhist scripture, the snow leopard owns the rocky mountains, is the leader of all carnivores, and is one of the protectors of the sacred mountains.

Discussion

Sacred lands probably offer one of the oldest forms of habitat protection and are important repositories of biodiversity outside formal protected areas in many parts of the world (Dudley et al. 2005). Sacred groves in India and sacred forests in Mozambique and Indonesia have been designated important for the protection of local species (Gadgil & Vartak 1976; Virtanen 2002; Wadley & Colfer 2004). Results of previous studies also show that sacred mountains around Buddhist monasteries play an important role in biodiversity conservation on the Tibetan Plateau (Salick et al. 2007; Shen et al. 2012). We explored the possible role of Tibetan Buddhism in protecting a flagship species. Our motivation was to try and see if we could find linkages between formal conservation efforts in central Asian mountain ranges, built around the snow leopard, and an influential community institution in many parts of the snow leopard range, the Buddhist monastery.

Across central Asia, there is high overlap between snow leopard range and the prevalence of Tibetan Buddhism (Fig. 4). Snow leopards are thought to have originated on the Tibetan Plateau several million years ago and then to have colonized the surrounding areas in Asia during the Pleistocene (Deng et al. 2011). Tibetan Buddhism is one of the main branches of Buddhism, which originated in present-day northern India and Nepal in the fifth century BCE and then spread northward to dominate certain Himalayan regions and the Tibetan Plateau and beyond (Fig. 4). We estimated that roughly 80% of the global snow leopard distribution overlaps with regions influenced by Tibetan Buddhism. At a local scale, we found a high similarity between snow leopard presence (Jackson & Ahlborn 1984) and sites of Tibetan Buddhist monasteries. Monasteries were located disproportionately close to or in snow leopard habitat. Monasteries were often built in or near mountain bases with rivers on 1 or 2 sides (Gyatsho 1979). This geographic overlap results in improved protection for snow leopards and other wildlife, given current limitations of formal protected areas.

We suggest that monasteries could be especially effective conservation allies in the protection of snow leopards. The mountains where monasteries are located, which also contain snow leopard habitat, often serve as boundaries of counties, provinces, or even countries. It is usually difficult for governments to manage such areas effectively due to boundary issues, whereas the influence of monasteries often crosses administrative boundaries. Compared with nature reserves, which have a few centralized conservation stations, monasteries are numerous and scattered. They can be especially efficient in protecting numerous discontinuous and dispersed smaller snow leopard habitats that cannot be effectively protected by nature reserves. These dispersed habitats, when large, can support source populations, whereas smaller ones could provide temporary refuge and connectivity for snow leopards during dispersal (Newmark 1993; Sweanor et al. 2000; Wikramanayake et al. 2004).

Although our results underscore the actual and potential role of Buddhist monasteries in snow leopard protection, Monasteries also shelter other animals, such as stray dogs. During our study, we recorded packs of dogs preying on blue sheep (*Pseudois nayaur*), which are the snow leopards' main natural prey. Stray or feral dogs could directly compete with snow leopards and may act as disease reservoirs (Young et al. 2011). The potential threats of the stray dogs near monasteries to snow leopards are complicated and need to be further examined.

As shown previously, there are many sacred mountains and sacred lands that could form the basis or even constitute core areas for greater landscape protection of snow leopards and other wildlife. Buddhist monasteries have already played an important role in local protection, but religious leaders and monks possess little ecological knowledge and lack official rights to manage their sacred areas. In these respects, close cooperation between monasteries, local governments, and nongovernmental conservation organizations would be beneficial for conservation.

We suggest local governments and nature reserves could confer some management rights to monasteries and communities. It would, for instance, help monasteries

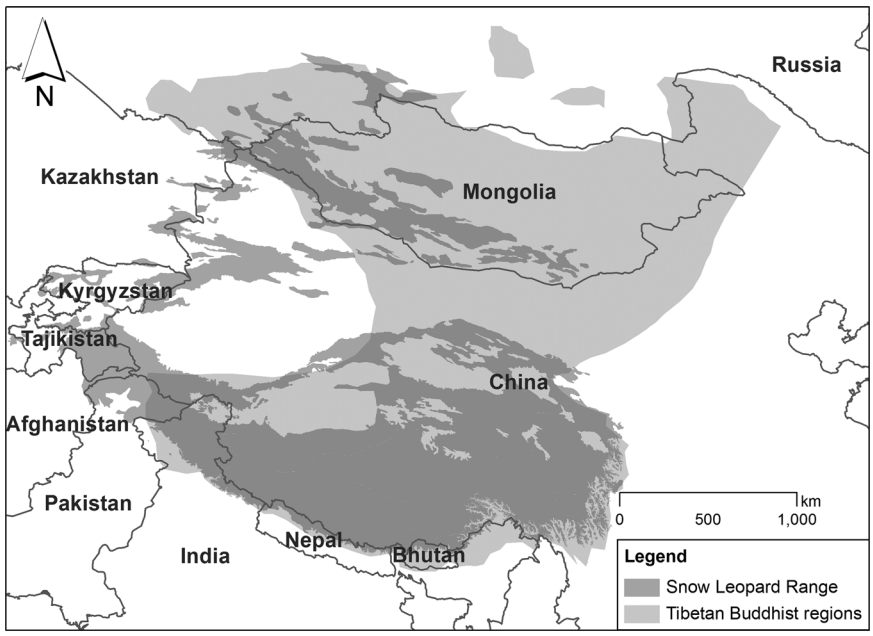

Figure 4. Global snow leopard distribution range (Panthera 2009) and regions under the influence of Tibetan Buddhism (adapted from the Atlas of Faiths and a map of Tibetan autonomous regions in China) (Encyclopedia Britannica 2003; National Fundamental Geographic Information System 2005).

and local communities if they had a legal right to evict poachers and illegal miners from their holy sites. Several local agreements to do this are already being implemented on the Tibetan Plateau (Shen et al. 2012). Nongovernmental organizations and local governments could teach monks, community members, and protection staff wildlife-monitoring skills, effective patrolling techniques, and ecology to supplement their knowledge of traditional conservation practices.

We have since 2009 initiated cooperative programs with 4 monasteries for snow leopard conservation in the Sanjiangyuan region. We provided funds for patrollers and for buying binoculars, cameras, and GPSs, as well as training monks to observe, monitor, and record wildlife systematically. The Rinpoche, Khenpos, and other high-ranking monks were requested to emphasize the special value of snow leopards and other wildlife in their religious convocations. At the same time we distributed snow leopard posters to encourage conservation of this iconic cat. Our findings suggest Buddhist monasteries may already be contributing substantially to snow leopard conservation on the Tibetan Plateau, and they may be able to contribute to conservation in other areas where they occur, for example, northern India, Nepal, Bhutan, and parts of Mongolia. The regions under the influence of Tibetan Buddhism cover about 80% of snow leopard range (Fig. 4).

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