LETTER

China's Collective Forest Tenure Reform and the Future of the Giant Panda

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Abstract

China has recently reformed its system of collective forest tenure to allow commercial logging, increased collection of firewood and nontimber forest products by outside enterprises, unmanaged tourism, and certain types of industrial development to occur in collective forests where these activities were previously restrained. The reform would also allow private or public agencies to buy back certain development rights from communities for conservation purposes ("eco-compensation"). We examine the impacts that the tenure reform could have on the survival of the giant panda, with or without eco-compensation in place. We estimate that $1,229 million in effective eco-compensation payments could prevent an estimated 15% decline in the giant panda population, whereas an additional $3,707 million for effective eco-compensation and restoration of potential habitat could restore the giant panda population to an estimated 40% above current levels. Specifically, we identify 14 key areas that link fragmented panda populations and habitats, and where approximately $779 million is needed for eco-compensation, matched with an additional investment of $131 million for the restoration of native forest habitat.

Introduction

The endangered giant panda (*Ailuropoda melanoleuca*) is most likely the best known global flagship species for biodiversity conservation. The panda's preferred habitat is old-growth forests. These forests, along with the presence of bamboo, are critical to the survival of the giant panda in the wild (Zhang *et al.* 2011). Historically, the giant panda lived across large areas of China as well as parts of Vietnam and Myanmar. However, forest loss and fragmentation, human disturbance, and climate change have greatly decreased the habitat of giant pandas. Panda habitat has declined nearly 60% in the last six decades, from 51,000 km^2 in the 1950s to 21,000 km^2 in 2006 (State Forestry Administration 2006). Today, giant pandas can only be found in six mountain ranges: the Qinling, Minshan, Qionglaishan, Daxiangling, Xiaoxiangling, and Liangshan Mountains (Ran *et al.* 2009). In

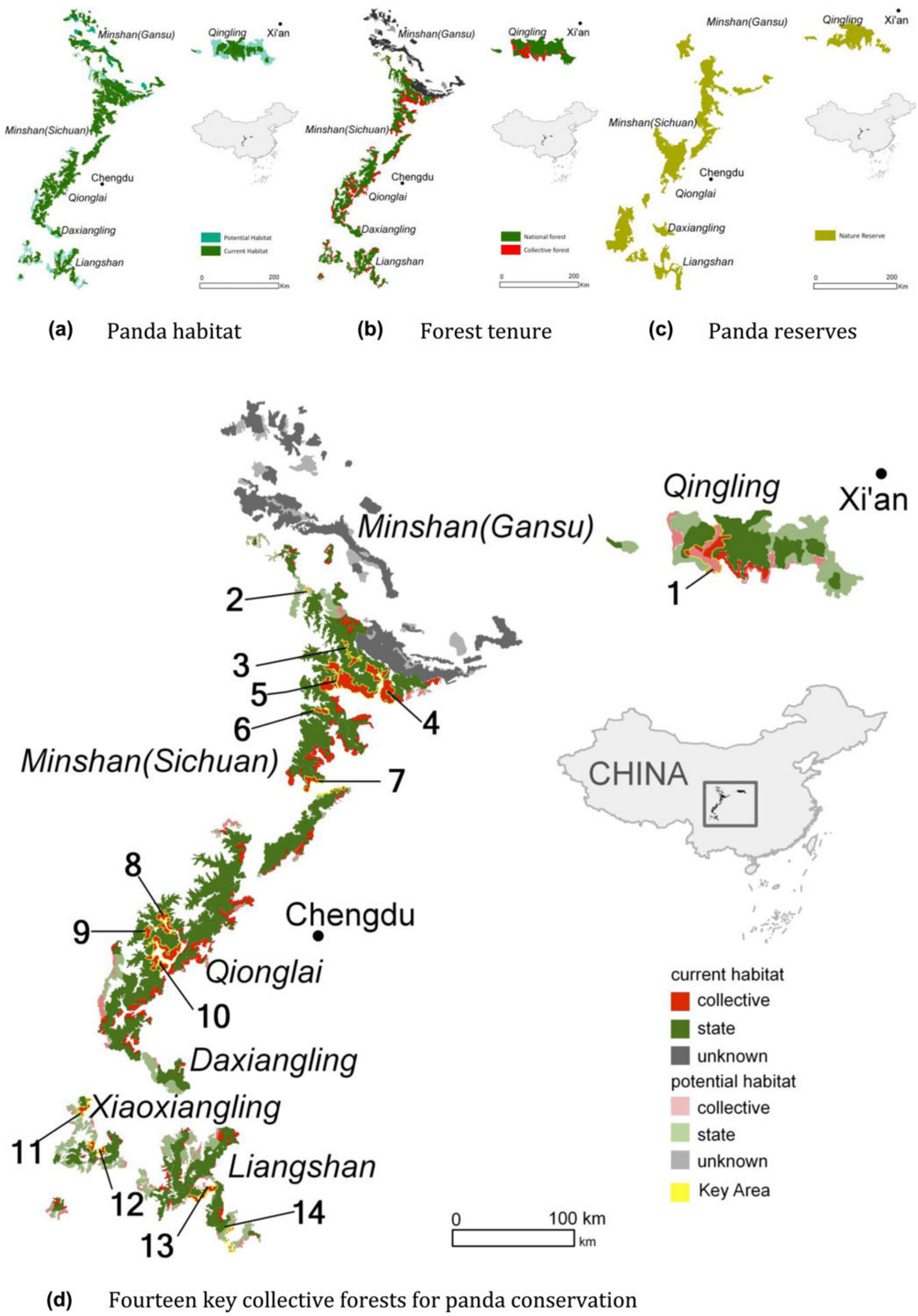

Figure 1 Fourteen key areas of current panda habitat and current and potentially restorable panda habitat in state and collective forests within each of the panda's seven mountain areas.

addition, there are significant genetic boundaries and spatial dynamic gaps resulting from the increasing fragmentation of the giant panda's habitat across southwest China (Loucks *et al.* 2001; Loucks *et al.* 2003; Viña *et al.* 2007; Zhu *et al.* 2011). For example, the panda habitat in the Minshan Mountains was divided into three isolated segments by two highways and newly expanding settlements. State Road 108 cut the Xiaoxiangling giant panda population into two isolated parts as well (Ran *et al.* 2005; Lin *et al.* 2010; Xu *et al.* 2006). To conserve the giant panda, the Chinese government has designated 63 reserves that protect pandas and their habitat, strengthened nature conservation by increasing the number and conservation skills of forestry staff, increased the penalty for poaching pandas, upgraded threatened panda habitat by reforesting or restoring native forests and restricting intrusive human activities, and pioneered captive breeding of pandas, including recent initiatives for panda reintroductions. As a result of these efforts, the number of giant pandas in the wild censused by national surveys has increased from fewer than 1,000 in the late 1980s to nearly 1,600 in 2006, though the methods have varied across surveys (O'Brien 1994; State Forestry Administration 2006).

Reform of collective forest tenure

China's investments and successes in giant panda conservation are now placed in jeopardy by a recent reversal in government policy: forest tenure reform for the 1.82 million km^2 of collective forest (Ping *et al.* 2011; Yang *et al.* 2013). China officially recognizes two categories of forests: state-owned forests, consisting of 3.04 million km^2, and collectively owned forests, consisting of 1.82 million km^2. State-owned forests may be used only for watershed protection, wildlife habitat conservation, and limited timber extraction, following the national logging ban in 1998 (State Forestry Department 2007). Within collectively owned forests, individual households in the village may obtain forestland contracts giving them rights to engage in a variety of allowable uses within their designated forest plots for up to 70 years. Households may also lease, share hold, mortgage, or transfer use rights, provided that the collective ownership of forests is not changed. Households' use of forestland is largely limited to livestock grazing, understory crop planting, household tourism, and collection of nontimber forest products (e.g., firewood, goldthread, mushrooms, medicinal herbs) at levels that have little impact on giant panda habitats. However, varying levels of insecurity associated with individual property rights and contracts under collective forest tenure has restrained households from pursuing more intensive uses of forests, and the contracting of harvesting activities to outsiders was prohibited.

On June 8th, 2008, the Chinese government published *The State Council's Decision on Promoting the Collective Forest Tenure Reform*, which officially launched the reform processes for privately owned collective forests nationwide (Central Government of the People's Republic of China 2008). The purpose of the reform is to clarify property rights for individual farming households, thereby enabling farmers to invest in new means of production to increase their economic returns. More flexible forest management under the reform allows operation rights to be transferred or leased to outside enterprises, which may pursue more intensive uses of forest that were previously not possible for local households. Previously restrained activities would be allowed to occur, including commercial logging, logging for construction, unmanaged tourism, and increased collection of firewood and other nontimber forest products (Xiao *et al.* 2008; He & Zhu 2010) .

The confirmation of the collective forest ownership has been completed nationwide; however, implementation is starting only through pilot programs in selected provinces. Collective forest tenure exchanges are already occurring in some areas in Zhejiang, Beijing, Chongqing, and Sichuan. In one recent transaction, a timber company purchased 150 km^2 of collective forest in Shizhu County in eastern Chongqing province at a reported price of $2.3 million USD (Chongqing Forestry Bureau 2010). The reform has not yet been implemented in provinces with giant pandas, but it soon could be. For example, forest tenure reform would allow the owners of collective forests in eastern Tumen District, Mao County in Sichuan province to sell their land for the development of a proposed industrial park and a 10-line 50 kV high-voltage transmission line through three planned corridors of panda habitat at Tudiling, Huangtuliang, and Gonggangling.

The reform would allow collective forest households to lease their forests for habitat conservation as an alternative to commercial exploitation. Collective forest could be leased for habitat conservation by private conservation organizations or by the Chinese government. One possible mechanism by which such forest could be leased for conservation would be an extension of China's ecological compensation ("eco-compensation") program. The eco-compensation program buys back development rights from local communities to secure the continued provision of ecosystem services. As part of eco-compensation agreements, communities establish contractual management systems that emphasize participatory decision-making and co-management of natural resources (wild animal and plant protection and Nature Reserve Management Division, State Forestry Administration 2002). By restoring native forests, eco-compensation projects have controlled sandstorms in the Beijing and Tianjin regions, lessened desertification in the lava area in Southwest China, and protected the water supply of Gansu (Xiong and Shao 2011). A single eco-compensation project, "Grain for Green," invested \$16 billion USD and restored 23,000 km^2 of farmland to forest from 1999 to 2005. This project benefited approximately 60 million households in more than 1800 counties (State Forestry Administration 2005). In the last 10 years, the Chinese Government has spent over \$100 billion USD on eco-compensation (Bennett 2009; Xinhua News Agency 2009) . The payments involved mainly watershed ecosystem services, carbon, timber, landscape amenities, biodiversity conservation, and antidesertification services (Bennett 2009). Specially, eco-compensation in mitigating the conflicts between wildlife protection and development has been more emphasized by the government in recent several years. Good examples occurred in northwestern Tibet and Yunnan province, where wildlife-human conflicts have been mitigated to a degree (Central Government of the People's Republic of China 2014; Yunnan.cn 2014). The Yunnan provincial government increased the annual budget from \$0.03 million USD in 1993 to \$4.4 million USD in 2013. In addition, the government is seeking the development of commercial compensation or insurance indemnity (Yunnan.cn 2014). In the case of the giant panda, communities would sign long-term binding forest preservation agreements to protect giant panda habitat outside of existing reserves. In exchange, these communities would be compensated monetarily by county departments.

We seek to understand the potential impacts of collective forest tenure reform on the giant panda and their habitats, as well as the potential for eco-compensation to mitigate negative impacts. On the one hand, the reform can be expected to have detrimental impacts on the giant panda by opening up a significant portion of its remaining habitats to destruction, degradation, or disturbance. The restoration of corridors among subpopulations of the giant panda would be made more difficult as well because many of the habitat corridors are in collective forest areas. On the other hand, a large-scale eco-compensation program applied to the panda habitat could reduce the threat to the survival of the giant panda while fulfilling the intention of the forest reform to increase local economic benefits.

We consider the costs and benefits of four future policy scenarios. In the first scenario, collective forest tenure reform is applied across all panda habitats in collective forest areas without a counterbalancing eco-compensation program. In the second scenario, collective forest tenure reform is applied across all panda habitats in collective forest areas and an eco-compensation program is put in place throughout all current panda habitats in collective forest areas. In the third scenario, collective forest tenure reform is applied across all panda habitats and eco-compensation is applied throughout the current and potentially restorable panda habitat in collective forest areas. In the fourth scenario, eco-compensation is conducted in key areas. We examine how forest tenure reform and eco-compensation might impact four indicators of panda survival—the current habitat, the potential habitat, the key habitat areas, and populations.

Methods

Data

Data were compiled on giant panda habitat range and population distribution (State Forestry Administration 2006), forest distribution, state and collective forest tenure (data provided by the Sichuan Provincial Institute of Forestry Survey and Planning 2010), and protected area status (Data provided by the Sichuan Wildlife Resource Survey and Conservation Management Station 2011). For two other potential factors that are critical to giant panda survival, bamboo die-off and earthquakes, data were not available.

Four indicators of giant panda survival

We examined four indicators of giant panda survival: the current habitat, the potentially restorable habitat, the key habitat areas, and populations. The current (existing) habitat was determined by overlaying the spatial layers of the giant panda occupancy and the distribution of bamboo and natural forests with four steps. First, mapping the distribution layers of bamboo and old-growth forest based on field survey and remote sensing images. Second, adding all panda occupancy sites into vegetation layers. Third, expanding 3 km with panda occupancy site as the center, based on panda behaviors and home range size. And fourth, figuring out habitat range combining ecological factors with panda behaviors. This included choosing the highest and lowest distribution altitude of bamboo and old-growth forests as the upper and lower boundary of panda habitat, respectively. This panda distribution and habitat model was adopted by various panda studies as well as the 3rd national survey (Hu 1990; Ran *et al.* 2005, 2009; State Forestry Administration 2006).

Potentially restorable habitat was determined by overlaying spatial layers of bamboo and old-growth forest surrounding the current panda habitat in which no pandas were found during the previous surveys and which could be suitable panda habitats in the future. Current and potentially restorable habitats were overlaid with maps showing areas where forest tenure, including forestland and wood reform, may apply (see Table 1). For the Minshan area in Gansu, which contains 117 giant pandas (7.3% of the total wild panda population), data on forest

Table 1 Panda habitat area, panda population, and cost under four scenarios: without eco-compensation, eco-compensation in current habitat, eco-compensation in current, and potential habitat plus restoration, and eco-compensation in key area

Scenario	Item	Num
Scenario 1: Without eco-compensation	Total habitat area (km^2)	18,123
	Panda population	1,357
	Total cost for Scenario1	0
Scenario 2: With eco-compensation in current collective habitat	Total habitat area (km^2)	22,747
	-Collective forest (km^2)	4,624
	Panda population	1,596
	-Panda population in collective habitat	165
	Cost for Scenario2	$1,228,794,980
Scenario 3: With eco-compensation in current and potential collective habitat plus restoration	Total habitat area (km^2)	31,874
	-Current and potential collective forest (km^2)	6,676
	-Potential forest (km^2)	9,127
	Panda population	2,234
	Eco-compensation cost	$1,775,743,064
	Reforestation cost	$1,931,366,304
	Cost for Scenario3	$3,707,109,368
Scenario 4: With eco-compensation in key area	Total habitat area in key area (km^2)	2,437
	-Current collective forest (km^2)	1,819
	-Potential collective forest (km^2)	618
	Panda population	78
	Eco-compensation cost	$648,242,000
	Reforestation cost	$130,768,800
	Cost for Scenario 4	$779,010,800

tenure were not available. For our analyses, we assumed that collective and state forests in this Minshan area of Gansu comprise the same portion as in the neighboring Minshan area of Sichuan.

Key areas were defined as specific habitat tracts (current and potential) in unprotected collective forests that serve roles to secure and enhance the survival of isolated and vulnerable giant panda populations. These key areas were identified based on two principles. First, these areas occupy critical sites, including habitat corridors, linking and/or augmenting gene exchange, and long-term viability of panda populations that are in danger of becoming increasingly isolated (in the present study, these areas were simply determined to be the connections between two or more larger blocks of panda habitat). Second, these key areas are located mainly in collective forests, often in unprotected collective forests, where they are at greater risk of being degraded or lost under the new forest tenure reform (Figure 1). These key areas were identified using a spatial overlay of the known giant panda habitat range (State Forestry Administration 2006), and state-owned and collective forests.

Panda population was surveyed by a fixed width line-transect technique by which feces were collected in panda distribution range, and subsequently the population size was estimated by a method distinguishing the bamboo

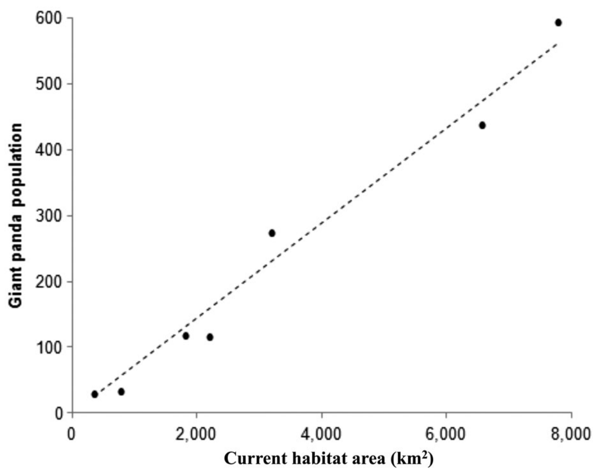

Figure 2 Linear relationship between the giant panda population and the current panda habitat area within the panda's seven mountain areas.

stem fragments in feces [see more details in Ran *et al.* (2005) and State Forestry Administration (2006)]. We estimated the potential change in the giant panda population using a power model in which changes in populations within each mountain range are proportional to changes in the habitat areas within the same mountain range. That is, $P_i' = P_i(A_i'/A_i)^z$, where P_i and P_i' represent population size before and after intervention within mountain range *i*, and A_i and A_i' represent habitat area before and after intervention within mountain range *i*. We estimated parameter *z* using the model $P = A^z$, calibrated using population and habitat data from the seven mountain ranges where giant pandas live, obtaining values of = 0.043015 and $z = 1.0534$ ($n = 7$; $R^2 = 0.95$; see Figure 2). We explored alternative population-area models, e.g., linear ($P = 0.0720 * A$; $n = 7$; $R^2 = 0.98$) and quadratic ($P = 0.00000125 * A\,\hat{}2 + 0.0638 * A$; $n = 7$; $R^2 = 0.98$); however, these added little additional explanatory power. While the explanatory power of all of these models appears high, we caution that predictive relationships based on a single explanatory variable, a small sample size, and uncertain population numbers must be regarded as speculative and highly uncertain.

Other factors affecting panda habitat, such as bamboo flowering and earthquake refuges, are also likely to be important considerations for panda habitat conservation (Ouyang *et al.* 2008; Wang *et al.* 2008; Wang *et al.* 2009). However, we did not include these factors in this initial stage of our research. We also focus on key areas in the collective forest, that provide habitat corridors needed to ensure or augment the links between fragmented panda populations to prevent them from becoming more isolated and thus reducing the overall viability of the panda wild populations as a whole.

Four policy scenarios

We considered the costs and benefits of four future policy scenarios. In the first scenario, the collective forest tenure reform was applied across all panda habitats without a counterbalancing eco-compensation program. With China's Property Law, the private owners could sell their owned collective forest outside protected areas to anyone for future development. For those private owned collective forests inside protected areas, they were protected under the Regulation of Nature Reserve. However, such an administrative regulation could not sit on equal footing with the Property Law. So that we assumed that in the absence of policy intervention, all collective forest habitat would ultimately become unsuitable as giant panda habitat.

In the second scenario, an eco-compensation program was put in place throughout all collective panda habitat. We assumed that the giant panda habitat in the collective forest could successfully be safeguarded by eco-compensation payments (Scenario II: "Eco-compensation in current habitat"). We studied 28 collective forest tenure trade cases that occurred in Sichuan Province in the past 3 years. The average price was approximately \$5,540 USD per km^2 per year, and we assumed that this is a reasonable price for eco-compensation payments. We also considered that eco-compensation would pay for collective forests both inside and outside protected areas.

Table 2 Estimated cost for potential panda habitat restoration

Item	Cost (US\$/Ha)
Land preparation	581
Initial tree planting	266
Labor cost of land preparation and initial planting	290
Supplemental tree planting	27
Labor cost of supplemental planting	48
Miscellaneous (transportation, watering, etc.)	327
Daily care and maintenance*	
(\$194/yr. for three years; 10% discount rate)	526
Management*	
(\$19/yr. for three years; 10% discount rate)	51
Total	2,116

*Three-year management cost after restoration

In the third scenario, eco-compensation was applied throughout current and potential collective forest panda habitats. We assumed that all habitats in collective forest can be successfully safeguarded by eco-compensation payments; that the price is as in Scenario II; and that potential giant panda habitats in state and collective forest areas can be successfully restored at a net present restoration cost of \$211,600 USD per km^2 (Sichuan Provincial Institute of Forestry Survey and Planning, 2010) (see Table 2 for details). We again considered that eco-compensation would be conducted both inside protected areas and outside protected areas.

In the fourth scenario, eco-compensation is conducted in key areas. We assumed that all key areas could be successfully safeguarded and all potential habitats could be successfully restored, and that the price is as in Scenario III.

Results

Forest tenure structure of habitats in different panda population habitats

Giant panda habitat covers an area of 22,747 km^2 of which approximately 79.7% or 18,123 km^2 is state owned and 20.3% or 4,624 km^2 is in collective forest owned by local communities. It is estimated that these collective forests, except for the Minshan area in Gansu where panda population were not available, contain 165 pandas (approximately 10.3% of the total panda population). Of the collective forest, 1,167 km^2 (5.1% of total panda habitat area) is protected and 3,457 km^2 (15.2% of total panda habitat) is outside protected areas.

Forest tenure structure in various mountainous areas

The distribution of collective forest in current panda habitat and potential panda habitat based on the proposed eco-compensation model was analyzed. The proportion (45.2%, 237/524) of potential habitat in the Qionglai Mountains, which exists under collective forest tenure, is considerably larger than in the other mountain areas. The amount (1890 km^2) and proportion (24.3%, 1890/7785) of current habitat under collective forest tenure in the Minshan Mountains (Sichuan area) is considerably larger than in the other mountain areas.

Key areas of panda habitat influenced by collective forest tenure reform

We identified 14 key areas of collective forests with a total of 2,437 km^2 where 78 pandas live. These areas include 1,306 km^2 of unprotected habitat (i.e., habitat outside of protected areas) (Table 3). These key areas are critical for the long-term survival of the giant panda. Most serve as corridors for connecting and consolidating fragmented habitats and associated isolated or vulnerable panda populations. It is these key areas of panda habitat that are likely to be influenced by the collective forest tenure reform. Without legal protection, all of these key areas of current habitat with pandas living inside will be under threat if local collective forest owners sell their forest land use rights to timber companies. Logging activity will likely make the current panda habitat more fragmented and isolated and is also likely to reduce the habitat quality of the remaining fragments due to the negative impact of the noise and disturbance caused by felling, cutting, and removing logs (see details in Figure 1 and Table 2).

Eco-compensation under four scenarios

In the absence of any actions to prevent increased logging in collective forests that harbor current panda habitats, we estimate an overall 15.0% decline in giant panda populations, from 1,596 to 1,357, based on simple calculations (Scenario I, Table 1). In Scenario II, where eco-compensation would be applied to the current habitat in collective forest, we estimate that eco-compensation payments in total of $1,229 million USD, including $247 million USD inside protected areas and $982 million USD outside protected areas, could prevent a predicted 15.0% decline in the population of giant pandas. In Scenario III, which includes eco-compensation for current and potential habitat in collective forest along with the restoration of potential habitat areas in collective and state forests, we estimate that eco-compensation payments totaling $1,776 million USD matched with an additional investment of $1,931 million USD, a total of $3,707 million USD for the restoration of native forest habitat, would not only prevent the predicted 15.0% decline in the panda populations, but could potentially stimulate a 40.0% increase in the panda population. In this scenario the panda population would increase from the current total of 1,596 to 2,234, which is more than double the threshold of 1,000 individuals below which a stable population is classified as vulnerable (The IUCN Red List of Threatened Species 2012). A total of $1,290 million USD would be used inside protected areas and $2,417 million USD would be used outside protected areas. In Scenario IV, key areas could be successfully safeguarded with $648 million USD, matched with an additional investment of $131 million USD for the restoration of native forest habitat.

Discussion

Pandas need old-growth forest (Zhang *et al.* 2011), and locals also need forest to improve their lives (Ran *et al.* 2009). Protected areas in China are limited in their coverage and effectiveness (Zhang *et al.* 2006), and thus eco-compensation may play an important role in balancing the needs for both conservation and development (Yang *et al.* 2013). Especially important for the survival of pandas are the Minshan and Qionglai Mountains, which together contain 71.9% (1147/1596) of the wild panda population and where 18.6% (3004/16194) of panda habitat is in unprotected collective forests. Based on our estimates, a total of $1.229 billion in effective eco-compensation payments could prevent an estimated 15.0% decline in the giant panda population, from 1,596 to 1,357. Furthermore, an additional $3.707 billion payment for effective eco-compensation and restoration of potential habitat could restore the giant panda population to an estimated 40.0% above current levels. These prices look high, but indeed, they would represent small percentages of the $100 billion USD that China has already spent on ecological compensation (Yang *et al.*, 2013) and would be a small price to pay to ensure the viability of a national and global icon. The giant panda serves as a conservation flagship or umbrella species (Zhang *et al.* 2011), and by conserving the giant panda and its habitat, many other species from the same habitat would also be conserved—as will the old-growth forest ecosystems that filter freshwater for hundreds of millions of people living downstream in the Minjiang and Yangtze River basins.

To ensure success, revenue from eco-compensation would need to be shared equitably between local forest owners and forest rangers. A community-oriented

Table 3 Fourteen key areas for the survival of giant pandas in the collective forests and the estimated funding needed to conserve them, including those collective forests inside and outside current protected areas

Area code	Key area name	Panda population may get impacted in the region	Mountains	Panda population living in the area	Total collective forest (km^2)	Current collective forest (km^2)	Potential collective forest (km^2)	With eco-compensation in current collective habitat ($)	With eco-compensation in potential collective habitat ($)	The estimate costs of habitat restoration ($)	Total estimated costs ($)
1	Xushuihe	The corridor links 22 pandas in the west and 244 pandas in the east part of Qinling Mountains	Qinling Mountains	7	716	193	523	$51,338,000	$139,118,000	$110,666,800	$301,122,800
2	Baozuo-Baxi	The area would link the Minshan C population, about 13 panda individuals, with 193 pandas of Minshan A population	Minshan Mountains	0	9	0	9	$0	$2,394,000	$1,904,400	$4,298,400
3	Huoxihe	Important to 193 pandas of Minshan A population	Minshan Mountains	4	62	62	0	$16,492,000	$0	$0	$16,492,000
4	Sier	Important to 193 pandas of Minshan A population	Minshan Mountains	12	278	277	1	$73,682,000	$266,000	$211,600	$74,159,600
5	Huya-Shijiabao	Important to 193 pandas of Minshan A population, and to link the north and south meta population	Minshan Mountains	20	487	481	6	$127,946,000	$1,596,000	$1,269,600	$130,811,600
6	Mupi	Important to 193 pandas of Minshan A population	Minshan Mountains	6	44	43	1	$11,438,000	$266,000	$211,600	$11,915,600
7	Tudiling	Important to 193 pandas of Minshan A population and link to 32 pandas of Minshan B population	Minshan Mountains	5	114	105	9	$27,930,000	$2,394,000	$1,904,400	$32,228,400
8	Qiaoqi	Important to 319 pandas in Qionglai Mountains	Qionglai Mountains	7	126	124	2	$32,984,000	$532,000	$423,200	$33,939,200

Continued

Table 3 Continued

Area code	Key area name	Panda population may get impacted in the region	Mountains	Panda population living in the area	Total collective forest (km^2)	Current collective forest (km^2)	Potential collective forest (km^2)	With eco-compensation in current collective habitat ($)	With eco-compensation in potential collective habitat ($)	The estimate costs of habitat restoration ($)	Total estimated costs ($)
9	Zhonggang	Important to 319 pandas in Qionglai Mountains	Qionglai Mountains	4	50	50	0	$13,300,000	$0	$0	$13,300,000
10	Yongfu-Mingli-Mingzhi	Important to 319 pandas in Qionglai Mountains	Qionglai Mountains	8	302	298	4	$79,268,000	$1,064,000	$846,400	$81,178,400
11	Hongba-Hekanshang	Important to link 1 panda in the northern to the southern habitat	Xiaoxiangling Mountains	0	61	40	21	$10,640,000	$5,586,000	$4,443,600	$20,669,600
12	Tuowushan	Important to link 17 pandas in Xiaoxiangling population A and 13 pandas in population B	Xiaoxiangling Mountains	1	56	55	1	$14,630,000	$266,000	$211,600	$15,107,600
13	Yiziya	Important to link the panda populations in the northern and southern Liangshan Mountains	Liangshan Mountains	4	91	89	2	$23,674,000	$532,000	$423,200	$24,629,200
14	Shanlenggang-Lanbazi	Important to the survival of 21 pandas living in the southern Liangshan Mountains	Liangshan Mountains	0	41	2	39	$532,000	$10,374,000	$8,252,400	$19,158,400
	Total			78	2437	1819	618	$483,854,000	$164,388,000	$130,768,800	$779,010,800

eco-compensation system for monitoring and evaluation institutions should be established as well (Xiong and Shao 2011). As good examples, keeping revenues locally from compensation for damages done by elephants and wild boars has made the managers see benefits for conservation in Yunnan province, China (Yunnan.cn 2014). In Nepal, such a scheme has also ensured the coexistence of park and people in Chitwan National Park (Nakarmi 2009). In addition, it needs to ensure that eco-compensation of collective forests is competitive to the company investment for development (such as logging, etc.).

We have identified 14 key areas of collective forests that provide habitats for small populations or are corridors facilitating gene exchanges (see Figure 1 and Table 3 for details). We estimate that protecting these key areas could be achieved by approximately $648 million for eco-compensation, with an additional investment of $131 million for habitat restoration. For the 14 key areas, eco-compensation should be immediately put in force to prevent the loss of those privately owned panda habitats outside protected areas. For those key areas inside the protected areas, governmental funding needs to invest to support local communities' alternative livelihoods with long-term eco-compensation measures. The forest tenure reform policy provides an opportunity for governmental agencies or civil society to purchase these collective forests from their private owners and secure them under the currently protected area system.

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