nature ecology & evolution

BRIEF COMMUNICATION

DOI: 10.1038/s41559-017-0317-1

Reassessing the conservation status of the giant panda using remote sensing

Weihua Xu[1], Andrés Viña[2,3], Lingqiao Kong[1,4], Stuart L. Pimm[5]*, Jingjing Zhang[1,4], Wu Yang[6], Yi Xiao[1], Lu Zhang[1], Xiaodong Chen[3], Jianguo Liu[2] and Zhiyun Ouyang[1]*

The conservation status of the iconic giant panda is a barometer of global conservation efforts. The IUCN Red List has downgraded the panda's extinction risk from "endangered" to "vulnerable". Newly obtained, detailed GIS and remotely sensed data applied consistently over the last four decades show that panda habitat covered less area and was more fragmented in 2013 than in 1988 when the species was listed as endangered.

The International Union for Conservation of Nature (IUCN) recently changed the status of the giant panda (*Ailuropoda melanoleuca*) from "endangered" to the less threatened "vulnerable"[1]. The justification was the observed increase in the adult population from the second national survey (1985–1988) to the fourth survey (2011–2014). Data collection methods, analyses, and sampling area were inconsistent, however, and this makes comparisons difficult. For instance, surveyed areas changed from 49 counties for the second survey[2], to 57 counties for the third survey[3], and to 62 counties for the fourth[4]. The increase to the fourth survey likely reflects there being more habitat and that the pandas are expanding their range.

To provide comparable estimates across surveys, we use consistent methods across the same geographical area in all years and include various measures of habitat extent and quality such as habitat patch size and fragmentation by roads. We also analyse the factors driving panda habitat changes. These are important for a complete conservation status assessment, but missing in IUCN's assessment, which is based almost solely on population numbers while ignoring emerging threats. Our results show a more complicated picture that warns against complacency while providing benchmarks against which to compare future surveys and assessments.

Using an integrated model that combines elevation, slope and forest cover derived from remotely sensed data[5], we evaluated the giant panda habitat across its entire geographic range from 1976 to 2013. Habitat decreased by 4.9% from 1976 to 2001, but increased by 0.4% from 2001 to 2013, despite the devastating 2008 Wenchuan earthquake. Mean patch size of the remaining habitats decreased by 24.0% from 1976 to 2001, but increased by 1.8% between 2001 and 2013. Habitat recovery has not offset previous habitat loss. For example, compared to 1988 when the panda was listed as endangered, the habitat area and mean habitat patch size in 2013 were 1.7% and 13.3% less than those in 1988, respectively (Figs. 1,2).

Multiple human and natural factors drive these changes. Commercial logging was the most harmful activity to pandas, directly causing habitat loss and fragmentation. Between 1950 and 1985, 27 state-owned logging companies were established within the panda's geographic range and logged >4,000 km^2 of forest[3] (Fig. 2a).

The establishment of nature reserves has significantly reduced habitat loss and promoted habitat restoration (Supplementary Tables 2, 3). The first were established in the early 1960s and 67 reserves were established by 2013 (Fig. 1c). Habitat within panda reserves increased from 3.7% in 1976 to 33.3% in 2013 (Fig. 1d). In recent years, investments in capacity building in nature reserves such as professional training and infrastructure development have increased. For instance, a nature reserve that upgrades from the provincial to national level receives approximately ¥15 million (US$2.2 million) for infrastructure development. Conservation measures including field monitoring and patrolling, improved management, and reduced human disturbances such as hunting inside the reserves. Other measures, such as switching from firewood to electricity[6] decreased fuelwood collection.

Commercial logging stopped in 1999 with the implementation of two large programmes — the Natural Forest Conservation Program (NFCP) and the Grain-to-Green Program (GTGP)[7]. These programmes substantially improved habitat across the entire panda range[8]. Moreover, in 2008, China instituted the key Ecosystems Function Conservation Areas (EFCAs), further promoting large-scale conservation[9]. Under the EFCAs, the counties involved receive annual compensation for conservation. From 2008 to 2014, ¥200.4 billion were transferred to 512 counties. Compensation was increased or reduced according to the results of county-based ecological evaluations, motivating local governments to improve the environmental status of their counties. Twenty-nine of 55 panda counties were within the EFCAs in 2008, increasing to 37 in 2016. Panda conservation efforts within these counties have benefited.

Between 1982 and 2000 the human population within the panda's range increased by 13.5%, while only 3.6% of the panda counties exhibited a decrease. In contrast, between 2000 and 2010 the human population increased by 0.5% while decreasing in 47.3% of the panda counties. In addition, between 1990 and 2000, the agricultural population decreased in 52.7% of the panda counties, while between 2000 and 2010, it decreased in 87.3%. While the increase in human population and activities enlarges resource consumption (e.g. bamboo harvesting, herb collection, and mining) and environmental degradation[10], the reduction in agricultural population likely reduces demand for local natural resources, lessening the pressures on panda habitat.

[1]State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, 100085 Beijing, China. [2]Center for Systems Integration and Sustainability, Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48823-5243, USA. [3]Department of Geography, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599, USA. [4]University of the Chinese Academy of Sciences, 100049 Beijing, China. [5]Nicholas School of the Environment, Duke University, Box 90328, Durham, NC 27708, USA. [6]College of Environmental and Resource Sciences, Zhejiang University, 310058 Hangzhou, China. *e-mail: stuartpimm@me.com; zyouyang@rcees.ac.cn

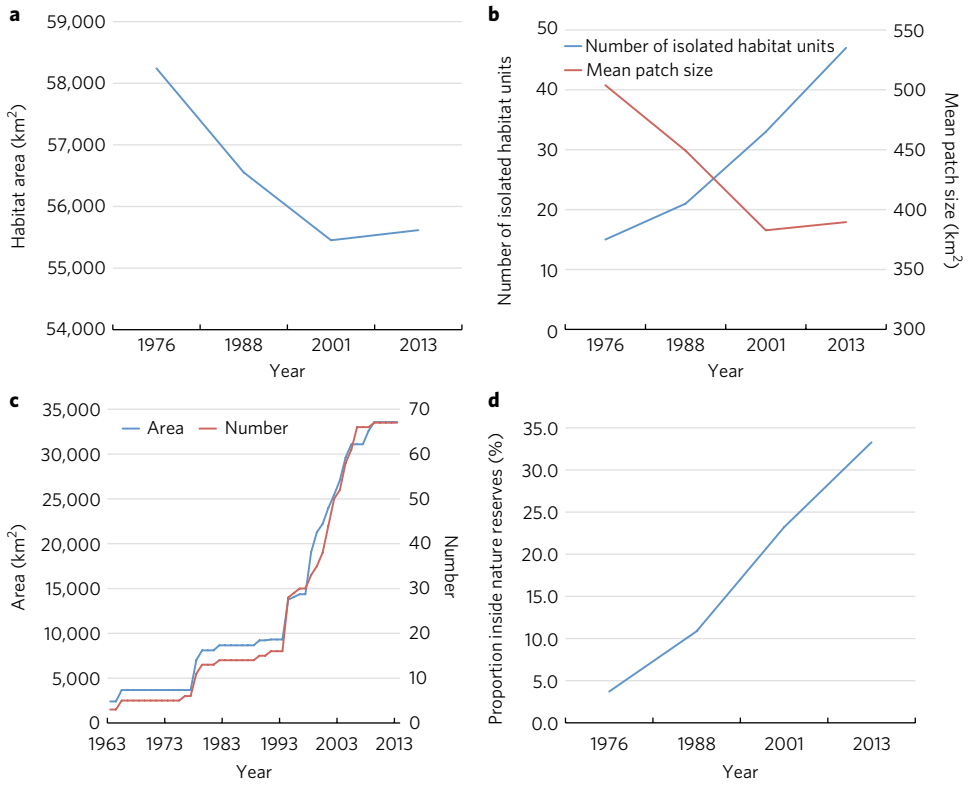

Fig. 1 | Area, isolation and protection status in nature reserves for giant panda habitat. a, Changes in panda habitat between 1976 and 2013 across its current geographic range. **b**, Changes in the number of isolated units and mean patch size of panda habitat between 1976 and 2013. Number of units isolated by major road and rivers increased throughout the entire period. Mean patch size decreased from 1976 to 2001, but increased from 2001 to 2013. **c**, Temporal trend in the establishment of panda nature reserves. **d**, Proportion of the giant panda habitat within nature reserves between 1976 and 2013.

Giant pandas currently live in one of the most tectonically active regions of China. (In the past, pandas had a much larger range across China, so while earthquakes are natural events, their impacts may now be disproportionately severe.) The region experienced three devastating earthquakes within 37 years: the Songpan Earthquake (magnitude 7.2 on the Richter scale) in 1976, the Wenchuan Earthquake (magnitude 8.0) in 2008[11] and the Ya'an Earthquake (magnitude 7.0) in 2013. Earthquakes and consequent landslides destroyed large areas of habitat. For instance, we attribute 71.1% of the habitat losses between 2001 and 2013 to the Wenchuan earthquake. However, earthquakes also reduced human activities within panda habitat, and wildlife populations increased in some areas devastated by the earthquake[11].

Road construction is a major factor driving habitat loss and fragmentation (Fig. 2b). Pandas avoid using habitat areas close to roads[12]. Road density in 2013 was 2.7 times larger than in 1976. The habitat impacted within 500 m from roads increased by 6.6 times and the number of habitat units isolated by major roads and rivers increased three times during this period (Fig. 1b). The construction of road tunnels, together with habitat restoration in some panda corridors have reduced the harm, however. For instance, recent panda signs such as faeces have been found around national road 108, which runs mainly through tunnels in the Qinling Mountains. Road construction also promoted rural-urban migration of the agricultural population, which lessened the pressure on panda habitat.

Habitat fragmentation and population isolation continue to be important threats. Currently, the panda population is divided into 30 isolated groups across the six mountain regions comprising their range, with 18 of these having ≤10 individuals[4]. They face a high risk of local extinction.

Given current levels of investment in panda conservation, together with the implementation of a new urbanization plan for 2014–2020, various pressures on pandas and their habitat will likely decrease. The new urbanization plan expects to increase the ratio of urban-to-total human population from 53.7% in 2014 to 60% by 2020, through rural-urban migration. Thus, both the total and agricultural population will likely decrease within the panda's range.

In contrast, the benefits of conservation efforts could also be diminished, due to the increase of infrastructure development (e.g. hydro-power stations and road construction) and other factors. In recent years, tourism has expanded across the panda's range. Tourists even visit the core zones (the areas of strict conservation) of nature reserves[13]. Tourism might also promote meat consumption and increase livestock grazing outside and inside some panda reserves causing substantial habitat losses[14]. More than one-third of the transects during the fourth national panda survey showed evidence of livestock grazing[4]. The newly proposed giant panda national parks in Sichuan, Shaanxi and Gansu provinces list tourism as one of their main objectives, indicating the potential to exacerbate the harmful effects of tourist traffic. Furthermore, the proposed collective forest tenure reform may allow timber extraction and fuelwood collection in forests where these activities were previously banned[15], further increasing habitat loss. The recent logging of a large tract of natural forest in the Sichuan Giant Panda Sanctuaries (a World Natural Heritage region) provides a worrisome example[16]. Finally, global climate change may alter the amount and distribution of many bamboo species (some of which are the panda's main food source), increasing habitat loss and fragmentation[17].

In summary, based on the analysis on panda habitat changes and their driving factors, we found panda habitat increased

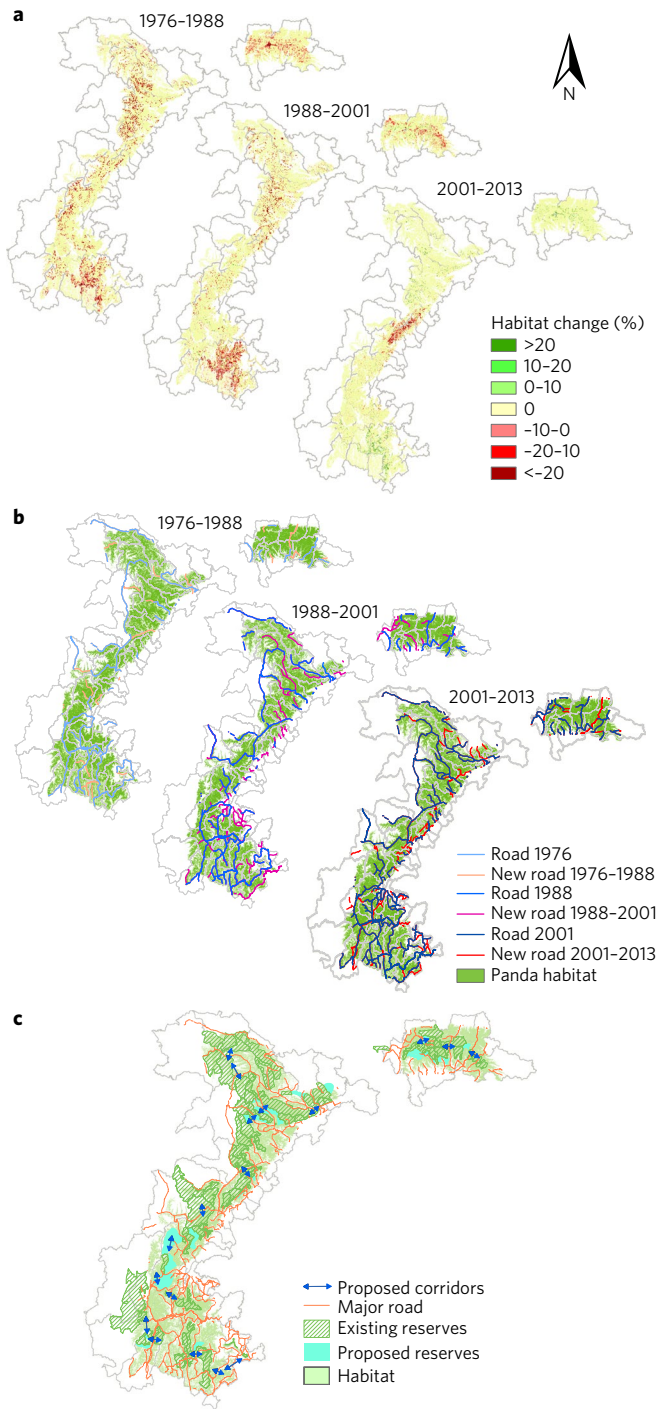

Fig. 2 | Giant panda habitat changes between 1976 and 2013, and proposed panda reserves and corridors. a, Proportion of habitat change within 500 m × 500 m grid cells. **b**, Road changes within panda habitat areas from 2001 to 2013. **c**, Proposed panda reserves and corridors.

between 2001 and 2013. This is consistent with the results from the 3rd and 4th surveys. Most of the factors including ecological conservation policies and human population trends benefited panda habitat restoration during the period. These trends supported changing the pandas' status from "endangered" to "vulnerable". In contrast, compared to panda habitat in 1988 when the panda was listed as endangered, there was less habitat in 2013 than in 1988 and major roads divided that habitat into more isolated fragments. Currently, pandas are facing great threats and challenges from habitat fragmentation, population isolation, infrastructure development, tourism, and climate change. These factors increase the uncertainties in making the status change. Simply, we need to realize the complexities of the panda's changing status and, for this, we need consistent information to provide comprehensive assessments of the panda's conservation status.

Additional measures could contribute to the long-term survival of the panda and prevent having to upgrade its conservation status to "endangered" again. First, new legislation should set "ecological red lines" — boundaries that delineate mandatory conservation of key habitats and corridors to prevent further habitat loss and human disturbance[18]. Collective forests located within them can be converted to state-owned to reduce the risk of their being deforested through collective forest tenure reform. Second, nature reserves should expand to include key panda habitat especially inside the "red lines" areas, given that two-thirds of panda habitat lies outside reserves (Fig. 2). Corridors should also be established to connect isolated populations. The development of road tunnels should be preferred over traditional roads in corridor areas. Third, through the new urbanization programme, more people in panda habitat should be encouraged to relocate to less ecologically sensitive areas. Fourth, panda conservation should also consider the requirements of other endangered species[19], and ecosystem services such as water supply. Such integrated conservation policy will get more support from not only the government but also from the public[20]. Finally, the new establishment of panda national parks should coordinate and balance conservation with tourism.

Methods

We evaluated giant panda habitat using a model that combines elevation, slope and forest cover[5]. Pandas live between 1100 and 3000 m in the Qinling Mountains, and between 1200 and 3800 m in the other mountains regions of their geographic range. The difference in the lower and upper values for the Qinling Mountains is due to differences in human habitation and the lower elevation of this mountain region. Pandas prefer gentler slopes below 50 degrees. Forest is the only suitable land cover type. We obtained data on elevation and slope from a Digital Elevation Model (DEM) with a 90 m/pixel resolution. For forest cover, we used 52 Landsat MSS/TM images from the scientific database of the Chinese Academy of Sciences (http://www.csdb.cn/) and the China Remote Sensing Satellite Ground Station, including 13 scenes per year for 1976, 1988, 2001, and 2013. Image acquisition years match those of the four national panda surveys. If cloud-free images were unavailable in these years, we selected images from adjacent ones. The supplementary materials provide further details.

The fragmentation of panda habitat in different years was evaluated using the number of isolated habitat units and mean patch size. The number of isolated habitat unit reflects the integrated effects of isolation factors by natural process and human activities. We calculated it by overlapping the panda habitat with isolation factors (i.e. major rivers, permanent snow cover, and major roads), since these factors are major barriers for panda movement. Major rivers include branches of the Yangtze River such as the Min and Jialing rivers. Major roads refer to roads at the county, provincial and national levels. We acquired data on these parameters from the National Geomatics Center of China, and a published atlas. The indicator of mean patch size reflects the habitat fragmentation at the local scale and was calculated using Fragstats 3.3.

To assess the effects of different biophysical and socioeconomic drivers, we used several metrics including wetness index, elevation, human population, road density, and proportion of nature reserves at county level. The wetness index was calculated based on the DEM data to indicate soil moisture, mean elevation was also calculated from DEM data. We obtained human population data from the national population censuses of the National Bureau of Statistics of the People's Republic of China. If the years of national census data did not match well with those of the panda habitat evaluation, we selected the closest year. The forestry administrations in Sichuan, Shannxi, and Gansu provinces provided the nature reserve boundaries. We obtained the proportion of nature reserves area to total habitat distribution area from them. Road density was calculated based on road maps in published atlases. Using these variables, we developed multiple general linear regression models, using panda habitat loss and habitat gain as dependent variables. Since panda habitat showed a declining trend from 1976 to 2001, and an increasing one from 2001 to 2013, we analysed the impacts of these factors in declining panda habitat from 1976 to 2001, and in improving panda habitat from 2001 to 2013.

Data availability. Remote sensing data were available from scientific database of the Chinese Academy of Sciences (http://www.csdb.cn/) and the China Remote Sensing Satellite Ground Station. Other data in this paper are publicly available or presented in this paper and supplementary information.

Received: 11 April 2017; Accepted: 16 August 2017;
Published online: 25 September 2017

References

1. Swaisgood, R., Wang, D. & Weif, F. *IUCN Redlist of Threatened Species: Ailuropoda melanoleuca* (IUCN, 2016); http://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T712A45033386.en.
2. State Forestry Administration & WWF *The 2nd National Survey Report on Giant Panda in China* (1989).
3. State Forestry Administration *The Third National Survey Report on the Giant Panda in China* (Science Publishing House, Beijing, 2006).
4. Tang, X. et al. *Forest Resour. Manage.* **1**, 11–16 (2015).
5. Liu, J. et al. *Science* **292**, 98–101 (2001).
6. An, L. et al. *Ecol. Econ.* **42**, 445–457 (2002).
7. Liu, J. et al. *Proc. Natl Acad. Sci. USA* **105**, 9477–9482 (2008).
8. Li, Y. et al. *Land Use Policy* **33**, 42–53 (2013).
9. Ehrlich, P. R. et al. *Nature* **486**, 68–73 (2012).
10. Liu, J. et al. *Nature* **421**, 530–533 (2003).
11. Xu, W. et al. *Front. Ecol. Environ.* **7**, 353–358 (2009).
12. Sichuan Forestry Department *Giant Pandas in Sichuan: Report of the Fourth Giant Panda Survey in Sichuan* (Sichuan Science and Techology Press, Beijing, 2015).
13. Liu, W. et al. *J. Sustain. Tour.* **24**, 203–226 (2016).
14. Hull, V. et al. *J. Nat. Conserv.* **22**, 256–264 (2014).
15. Yang, B. et al. *Conserv. Lett.* **8**, 251–261 (2015).
16. *Report: Logging Hurts Panda Habitat* (China Daily USA, 2015); http://usa.chinadaily.com.cn/china/2015-10/23/content_22262759.htm.
17. Tuanmu, M.-N. et al. *Nat. Clim. Change* **3**, 249–253 (2013).
18. Kong, L. et al. *Biol. Conserv.* **210**, 83–88 (2017).
19. Li, B. V. & Pimm, S. L. *Conserv. Biol.* **30**, 329–339 (2016).
20. Xu, W. et al. *Proc. Natl Acad. Sci. USA* **114**, 1601–1606 (2017).

Acknowledgements

This work was supported by the National Natural Science Foundation of China (Grant 41671534), Ministry of Science and Technology through the National Key Programme of Research and Development Project (2016YFC0503200), State Forestry Administration, Worldwide Fund for Nature, and U.S. National Science Foundation.

Author contributions

W.X., A.V., S.L.P., J.L., and Z.O. designed research; W.X., A.V., L.K., J.Z., Y. X., and L.Z., performed research; W.X., L.K., J.Z., W.Y., and L.Z. analysed data; and W.X., A.V., S.L.P., W.Y., X.C., J.L., and Z.O. wrote the paper.

Competing interests

The authors declare no competing financial interests.

Additional information

Supplementary information is available for this paper at doi:10.1038/s41559-017-0317-1.

Reprints and permissions information is available at www.nature.com/reprints.

Correspondence and requests for materials should be addressed to S.L.P. or Z.O.

Publisher's note: Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.