Impact of Earthquakes on Giant Panda (*Ailuropoda melanoleuca*) Activities in the Qionglai Mountains

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Abstract As an endemic and critically-endangered wildlife species in China, the giant panda (*Ailuropoda melanoleuca*) has attracted widespread attention from all sectors of society regarding its survival status. In this study, the impact of earthquake-dameged areas on the distribution and activities of giant pandas in the Qionglai Mountains was analyzed by comparing data from two giant panda surveys conducted in the Qionglai Mountains of Sichuan Province and combining with remote sensing (RS) data from relevant regions. The results indicated that there was only a small area of overlap between the earthquake-damaged areas and giant panda activity trace points. The main earthquake-damaged areas were distributed at elevations (3,500-4,100 m) higher than the primary elevation range of giant panda distribution (1,700-3,100 m). In the Wolong Nature Reserve, no major earthquake damage was observed in the central section east of Provincial Highway 303 with relatively more giant panda activities. Within the Caopo Nature Reserve, the earthquake-damaged areas were mostly concentrated in the northeastern corner and along the border with the Wolong Nature Reserve. However, no large-scale giant panda activity traces were detected in these areas during either of the two surveys. Overall, the range of giant panda activities showed no signs of decline. Therefore, the impact of earthquakes on giant panda activities remains limited.

Keywords Earthquake, Qionglai Mountains, Giant panda activity, Impact

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The giant panda (*Ailuropoda melanoleuca*) belongs to the pleistocene *Ailuropoda*–Stegodon fauna[1]. Among the fossils of its ancestors discovered so far, the earliest can be traced back to the late Miocene epoch, 8 million years ago, when humans were still in the evolutionary stage of *Dryopithecus*. At that time, the ancestor of the giant panda, *Ailurarctos lufengensis*, had already appeared on Earth. As an endemic and endangered species in China, the giant panda is renowned as a "national treasure" and a "living fossil". It is listed as an endangered species by the International Union for Conservation of Nature (IUCN) and was classified as a first-level protected animal in China in 1988[2]. Meanwhile, the giant panda is also the emblem and logo of the World Wide Fund for Nature (WWF)[3]. As a flagship species for global biodiversity, the giant panda, despite retaining the digestive traits of a carnivore, has gradually evolved into a herbivore that primarily feeds on bamboo due to environmental changes over a long evolutionary process[3]. In the diet of wild giant pandas, bamboo accounts for more than 99%. This dietary speciali-zation has led to adaptive changes in their morphology, behavior, and physiology.

At 14:28 on May 12, 2008, an 8.0 Ms major earthquake struck Wenchuan County, Sichuan Province. The epicenter was located at the junction of Yingxiu Town and Xuankou Town in the southeastern part of Wenchuan County, within the Aba Tibetan and Qiang Autonomous Prefecture of Sichuan Province. Public data from the China Earthquake Administration shows that the surface wave magnitude of this earthquake reached 8.0 Ms, while the moment magnitude was as high as 8.3 Mw, with the intensity at the central region reaching level 11. The earthquake affected a vast area, with tremors felt across most of China and in multiple countries and regions in Asia.

The area severely affected by the earthquake exceeded 100,000 km^2, making it the most destructive earthquake since the founding of the People's Republic of China. According to the Fourth Giant Panda Survey Report of Sichuan Province, the Wenchuan earthquake damaged 52,100 hm^2 of panda habitat across 20 nature reserves in Sichuan Province, including Baishuihe, Longxi-Hongkou, Jiudingshan, Wolong, and Caopo. In some reserves, the proportion of damaged habitat reached 54.45%, posing significant challenges to giant pandas' survival environment[4].

The primary impact zone of the Wenchuan 8.0 Ms earthquake was located along the front mountains of the Longmen Mountains and the Central Fault Belt on the western margin of the Sichuan Basin, which is a densely distributed area for giant pandas. Meanwhile, the strong aftershocks associated with the Wenchuan earthquake occurred multiple times within giant panda reserves, causing repeated and cumulative damage to their habitats. Among these, one aftershock of magnitude 5 or higher occurred in the Wolong Nature Reserve, and three occurred in the Caopo Nature Reserve. This study explored the impact of the Wenchuan earthquake on giant pandas' activities in the Qionglai Mountains by combining data from two giant panda surveys.

1 Study area

The Qionglai Mountains are situated in central Sichuan Province, west of the Sichuan Basin, and stretches approximately 250 km in a north-south direction (Fig.1). It serves as the watershed between the Dadu River and the Minjiang River, as well as the physiographic boundary between the Sichuan Basin and the Tibetan Plateau. Its highest peak, Yaomei Peak of Siguniang Mountain, lies at the border of Xiaojin County and Wenchuan County, with an elevation of 6,250 m. Major peaks also include Jiajin Mountain, Balang Mountain, and Erlang Mountain. It serves as a natural geographical barrier in the transition zone between the Sichuan Basin and the Tibetan Plateau[5]. The unique geographical location and climatic conditions provide an ideal living environment for diverse flora and fauna, resulting in exceptionally rich biological resources. The region is rich in precious tree species such as *Larix potaninii* Batalin

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and *Taxus wallichiana* var. *chinensis* (Pilger) Florin, and produces renowned medicinal herbs including *Fritillaria* spp., *Gastrodia elata* Bl., and *Cordyceps sinensis* (BerK.) Sacc. It is also home to rare and endangered plants such as *Tetracentron sinense* Oliv., *Cercidiphyllum japonicum* Siebold & Zucc., *Kingdonia uniflora*, and *Davidia involucrata* Baill. The Qionglai Mountains harbor a variety of rare mammals, such as giant pandas (*Ailuropoda melanoleuca*), golden snub-nosed monkeys (*Rhinopithecus roxellana*), and takins (*Budorcas taxicolor*), as well as approximately 2,300 species of birds[5].

2 Research methods

2.1 Remote sensing image classification

The remote sensing data used were Landsat 4–5 TM satellite data, sourced from the Geospatial Data Cloud website (http://www.gscloud.cn) of the Computer Network Information Center, Chinese Academy of Sciences. The analysis was conducted using Landsat5 TM remote sensing images with the following data identifiers: LT51300382007261IKR00 and LT51300392007261IKR00 for September 18, 2007, and LT51300382008200BKT00 and LT51300392008200BKT00 for July 18, 2008. Since the acquisition of original remote sensing images can be affected by atmospheric reflection, varying sensing media, water vapor, and other factors, which may impact classification results, preprocessing was performed on the original images before classification. Preprocessing primarily included steps such as radiometric calibration, atmospheric correction, seamless image mosaicking, and cropping of the study area. Subsequently, ground control points were used for precise topographic correction, and the data were projected into the UTM/WGS 84 coordinate system. After correction and resampling, a spatial resolution of 30 m ×30 m was achieved. This study primarily employed unsupervised classification to categorize the preprocessed remote sensing images.

2.2 Extraction of earthquake-demaged areas and spatial distribution characteristics

The classification results before and after the earthquake were vectorized. Using the Change Detection Statistics tool and the Thematic Change tool in ENVI, the classification results were analyzed to obtain the seismic damage area layer. SRTMSLOPE 90M resolution slope data and GDEMDEM 30M resolution digital elevation data for the study area were downloaded from the Geospatial Data Cloud website (http://www.gscloud.cn). The elevation raster and slope raster were extracted using GIS to obtain the elevation and slope vector layers of the study area. The spatial overlay of the earthquake-demaged areas with elevation and slope vector data was conducted to obtain the spatial distribution characteristics of the earthquake-demaged areas in terms of elevation and slope. These operations were performed using ENVI 5.1 and ArcGIS 10.2 software.

2.3 Spatial distribution relationship between giant panda trace points and seismic information

Seismic ground motion parameter data (including vector data such as PGA, PGV, and PSA) for the Wenchuan earthquake were obtained from the USGS website (https://earthquake.usgs.gov). The PGA values and seismic intensities in various areas of the Wolong and Caopo Nature Reserves were determined. In Gis, the giant panda trace points from two surveys were spatially overlaid with the seismic intensity PGA layer to obtain and compare the number of giant panda activity points in different intensity zones in the two surveys. The earthquake-demaged areas were spatially overlaid with the giant panda activity points to determine the spatial relationship between giant panda activity points and the earthquake-demaged areas. All these operations were performed using ArcGIS 10.2 software.

3 Research results

3.1 Extraction of Wenchuan earthquake-damaged areas

The TM images of the study area were classified using the unsupervised ISODATA method. Both pre-earthquake and post-earthquake TM images were categorized into five classes: broadleaf forest, coniferous forest, shrub grassland, bare land, and others (including snow cover, mountain shadows, and clouds) (Fig.2). The earthquake-induced damage to surface features primarily involved vegetation destruction and mountain collapse. The damage areas caused by the earthquake exhibited surface characteristics consistent with bare land. Therefore, the post-earthquake bare land includes both the pre-earthquake bare land and the earthquake-damaged areas. Therefore, relevant information such as the approximate distribution and area of the earthquake-damaged areas can be obtained by calculating the changes in bare land before and after the earthquake. Meanwhile, through the comparison before and after the earthquake, general information about the damage caused by the earthquake to different types of surface features, such as broadleaf forests, coniferous forests, and shrub grasslands, could be acquired.

3.2 Distribution range of earthquake-damaged areas

Spatial operations were performed on the pre-earthquake and post-earthquake bare land to obtain the spatial distribution of the earthquake-damaged areas (Fig.3). The figure shows that the damage caused by the Wenchuan earthquake to the Caopo and Wolong Nature Reserves mostly appeared in a regionally concentrated mode. In the Caopo Nature Reserve, the main damaged areas were concentrated along both sides of Huangnibaping–Changheba in the northeast, north of Cutou Gully, and along the border adjacent to the Wolong Nature Reserve, and scattered distribution was found in other parts of the reserve. In the Wolong Nature Reserve, the major earthquake-damaged areas were concentrated at the entrance of National Highway 303 into the reserve (from Muping Tunnel to Qicenglou Gully) and north of Zhenghe River.

The damaged areas were sporadically distributed in other areas. Within the Wolong Nature Reserve, the damage was concentrated at the entrance area of National Highway 303 into the reserve (from Muping Tunnel to Qicenglou Gully). The bare land area in the Zhenghe–Huoba Gully region significantly increased, and there was also widespread scattered distribution within the reserve area east of Provincial Highway 303. The earthquake and its secondary disasters, such as debris flows and landslides, caused a total damage area of 24,625.08 hm^2 to various ecosystems in the Caopo and Wolong Nature Reserves in Wenchuan County. In specific, the damage to the forest ecosystem reached 9,660.96 hm^2, accounting for 39.23% of the total damaged area. The ecosystem damage area in the Wolong Nature Reserve reached 19,198.41 hm^2, while the damage area in various ecosystems in the Caopo Nature Reserve was 5,426.67 hm^2.

3.3 Spatial positions between giant panda activity areas and earthquake-damaged areas

Overlay analysis of giant panda trace points from two surveys and the Wenchuan earthquake-damaged area layer revealed that the earthquake-damaged areas partially overlapped with the distribution of trace points from the third survey (Fig.4). These overlaps primarily occurred at the entrance of Provincial Highway 303 into the Wolong Nature Reserve, and along both sides of the section from Shaotanghekou to Tangfang on National Highway 303, and near Tiechanggou in the northwest of the reserve. During the fourth giant panda survey, no traces of giant panda activities were detected in the aforementioned areas. The range of giant panda activities was retreated, as the surface damage caused by the earthquake led to the abandonment of these areas by giant pandas.

Secondly, in the area east of Provincial Highway 303 where giant pandas are densely distributed, remote sensing interpretation did not identify large-scale surface damage in this region. Furthermore, the distribution range of giant pandas in these areas did not show significant retreat. Similarly, within the Caopo Nature Reserve, there was limited overlap between the earthquake-damaged areas and the giant panda activity areas identified in the survey. Instead, the distribution range of giant panda activities showed a slight expansion, with more giant panda traces recorded in areas closer to the Miyaluo Nature Reserve.

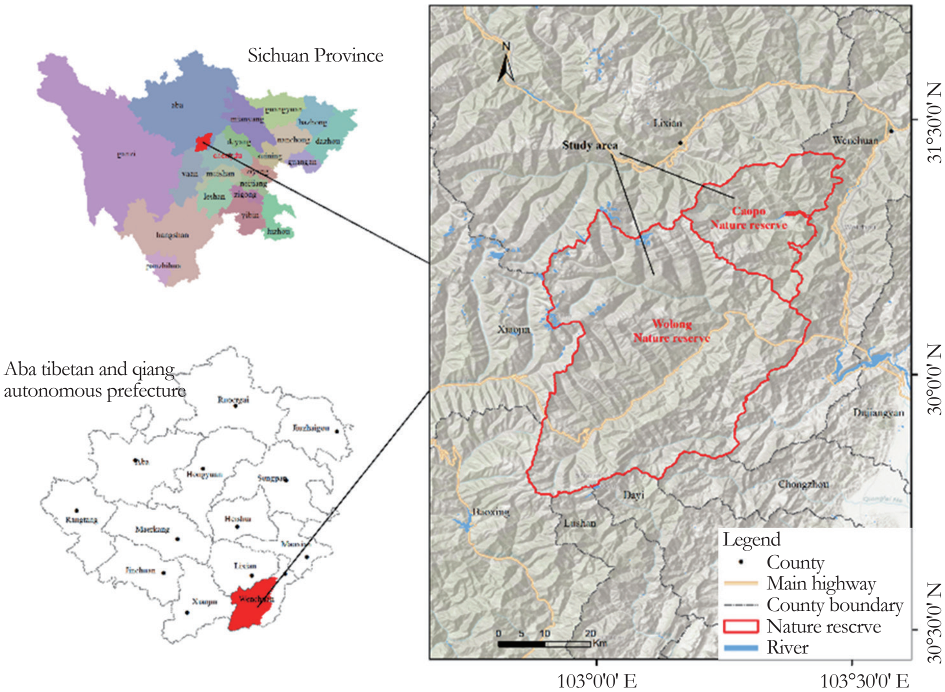

Fig.1 Location of the Qionghlai Mountains in Sichuan Province

4 Discussion

Following the Wenchuan earthquake, many experts and scholars conducted analyses on the impact of seismic destruction on giant panda habitats in multiple nature reserves. For example, Wang et al.[6] combined remote sensing interpretation with GIS modeling to study the Longxi-Hongkou Nature Reserve in Dujiangyan City. Their results indicated that the earthquake caused a loss of 21.63% of giant panda habitat in the Dujiangyan area.

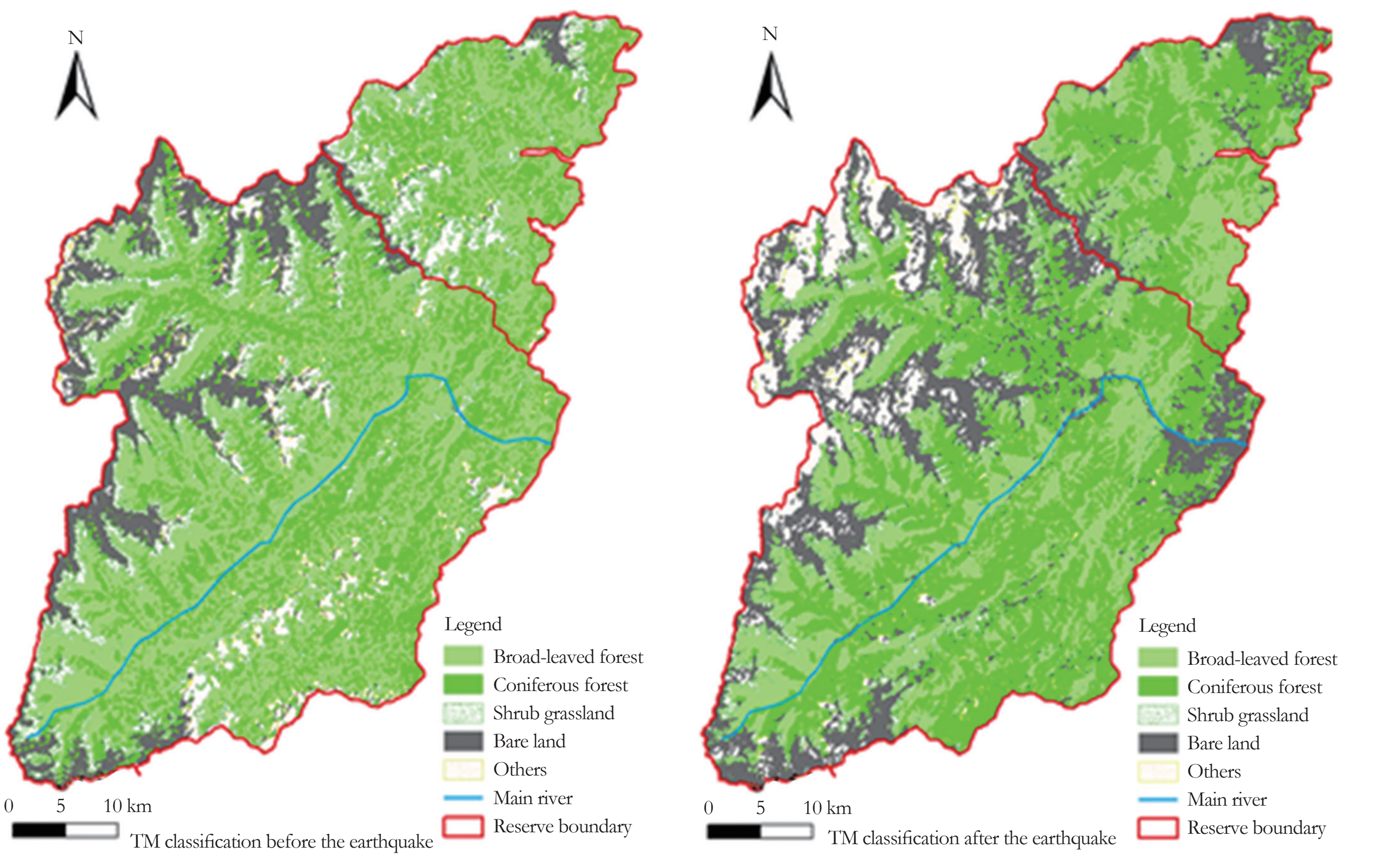

Fig.2 The TM images before and after the earthquake by non-supervised classification

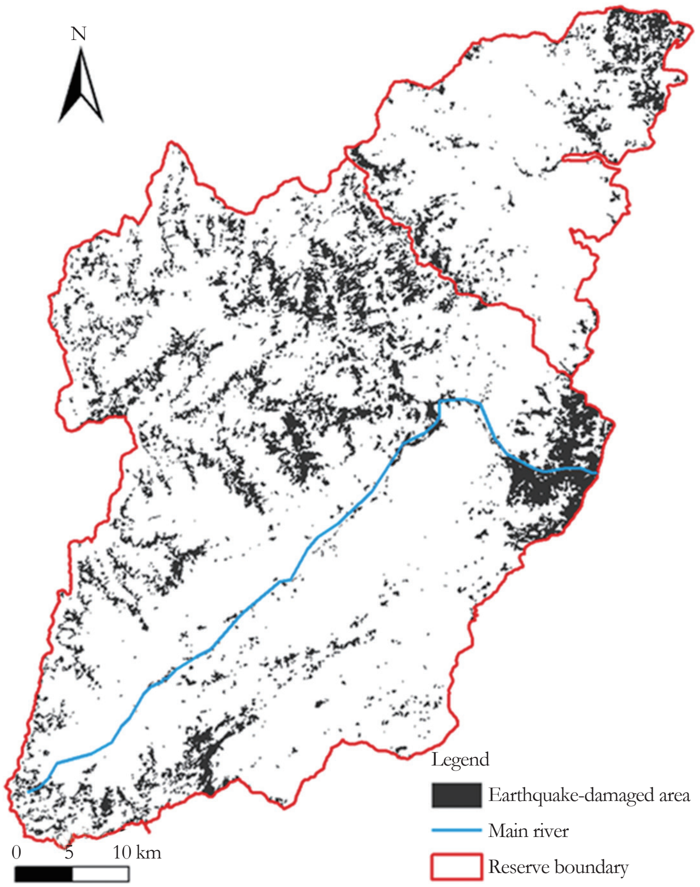

Fig.3 Spatial distribution of earthquake-damaged areas

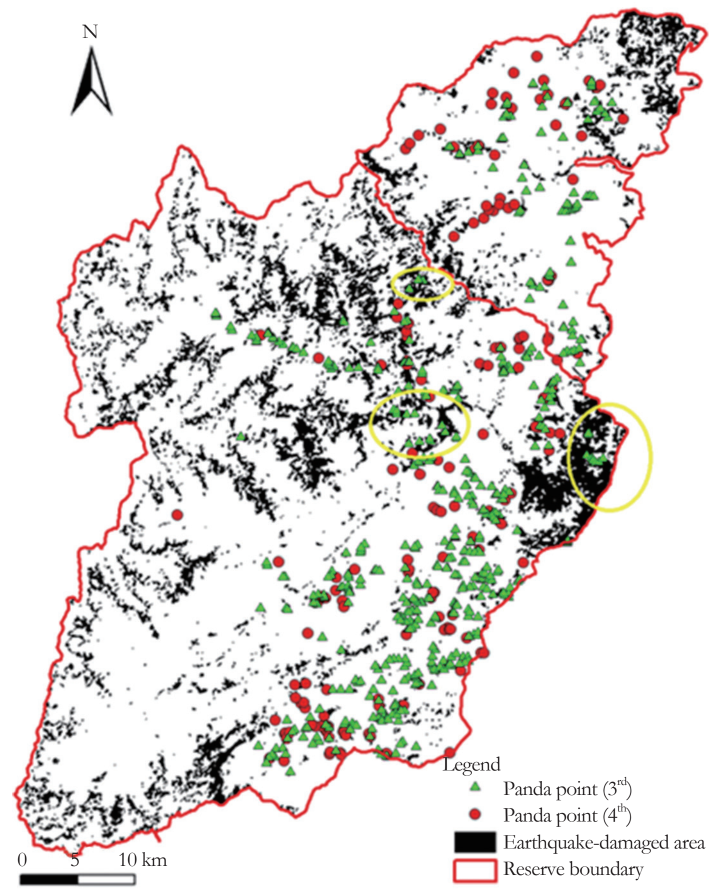

Fig.4 Distribution map of Wenchuan earthquake-demaged areas and giant panda activity points

Zheng et al.[7] studied the impact of Wenchuan earthquake on the utilization pattern of giant panda habitats in the Longxi-Hongkou Nature Reserve and the Tangjiahe Nature Reserve. They found that over the seven-year period spanning before and after the earthquake, there were no significant annual changes in the utilization pattern of giant panda habitats. Han[8] used remote sensing interpretation to analyze the impact of earthquake damage on giant panda habitats in the Wolong Nature Reserve, but the study lacked data on giant panda habitat selection and utilization recorded during actual field investigations. Through extraction of earthquake-damaged areas in the Wolong and Caopo Nature Reserves by remote sensing interpretation, combining with comprehensive field data from two giant panda surveys in these reserves, this study analyzed the impact of Wenchuan earthquake-damaged areas on giant panda distribution.

The Wenchuan earthquake caused significant surface vegetation damage in the Caopo and Wolong Nature Reserves, leading to partial loss of giant panda habitats. However, based on data from two giant panda surveys, changes in giant panda activities did not show a consistent correlation with the intensity of the Wenchuan earthquake, and the overlap between the earthquake-damaged areas and the areas with giant panda activity traces identified in the two surveys was relatively small. The earthquake-damaged areas were primarily distributed at higher elevations than the main activity areas of giant pandas, resulting in limited impact on them. The effects of the Wenchuan earthquake on giant panda distribution and activity were confined to relatively small areas. In the core frequent activity areas within the reserves, no decline in the range of giant panda activities was observed, indicating that the earthquake's impact on giant pandas is far less significant than initially anticipated.

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