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OPINION ARTICLE

Giant panda habitat restoration requires more than just planting bamboo and trees

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Planting bamboo and trees is of great importance in giant panda (*Ailuropoda melanoleuca*) habitat restoration. In practice, however, simply planting bamboo and trees cannot effectively and rapidly restore lost, degraded, and fragmented habitats. Based on present restoration work in the Qinling Mountains, China, we argue that: (1) Planting should be done on open and suitable forest lands, but the area that could be afforested is relatively small. (2) Forests that have regrown naturally on cut-over lands are mostly middle-aged and early secondary stands, which need to be managed, not replanted. (3) Plantations of non-native larch (*Larix* spp.) urgently need to be replaced and replanted with native trees and bamboos, but new policies are needed that allow these plantations to be thinned or cut. (4) Bamboo forests in the mid-high mountain zones need to be assessed to determine if they are disclimaxes of degraded forests. Pilot studies are needed to determine the best need and practices to rehabilitate and restore them. We conclude that the restoration of panda habitat cannot be accomplished simply through tree and bamboo plantings.

Key words: habitat restoration, larch plantation thinning, logging, secondary forest tending, tree and bamboo planting

Implications for Practice

- Large scale of tree and bamboo planting is no longer needed in giant panda habitat restoration because of the previous reforestation projects and a favorable climate condition.
- Furthermore, tree and bamboo planting does not reliably result in functional panda habitat. The restoration practices should depend on the current vegetation status: (1) secondary forest needs tending; (2) non-native larch plantation needs thinning; and (3) pilot studies are needed for bamboo forests.
- The restoration of emblematic species (like giant panda) habitat provides a great chance to achieve and improve ecosystem functions and services.

Introduction

The size, connectivity, and quality of giant panda (*Ailuropoda melanoleuca*) habitat are critical for maintaining and increasing wild populations, and support reintroduction efforts of captive individuals (Li & Shen 2012). Although there are no specific, quantitative measures of ideal giant panda habitat, there are two general principles that have been used when setting goals for its conservation and restoration. First, bamboo (For example, *Bashania fargesii* and *Fargesia qinlingensis*) is the staple food resource for giant pandas. Only high-quality bamboo can meet pandas' dietary requirements. Second, trees that form a closed canopy provide shelter for giant pandas and a microenvironment for growth of bamboo and shrubs in the understory (Li & Shen 2012). However, giant panda habitat is threatened by logging, grazing, herb collection, road development, and tourism, which together have resulted in increased habitat fragmentation and a decrease in habitat size and quality (Kang 2020).

In the past few decades, the Chinese government has implemented a series of ecological restoration projects to protect the natural environment, including the Natural Forest Protection Project (China's logging ban), the Wildlife Protection and Nature Reserve Development Program (establishing nature reserves), and Returning Farmland to Forest Program. These projects have led, either directly or indirectly, to the protection of giant pandas and their habitat through reducing human disturbances like logging, hunting, and farming (Jin et al. 2012; Zhou 2017). Currently, the protection and restoration of natural ecosystems is a priority and projects focus on enhancing ecological stability, quality, and service value (National Development and Reform Commission of China 2020). In 2021, China formally established a national park system that emphasizes the

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integrity and authenticity of ecosystems. With such efforts, the protection and restoration of giant panda habitat is well underway and will continue to be pushed forward into the future.

Timber demands and infrastructure construction have led to vast areas of forests being cut down and damaged. The revegetation of these areas, through planting of trees and bamboo, has become one of the most common ways to restore giant panda habitat. This practice is emphasized in the forestry industry and local standards (State Forestry Administration of China 2014; Bureau of Quality and Technical Supervision of Sichuan Province 2015). These revegetation projects, however, do not reliably result in functional panda habitat. In this paper we use the habitat of the giant panda subspecies (*A. melanoleuca qinlingensis*) in the Qinling Mountains as an example to argue why functional habitat restoration cannot be simply achieved by tree and bamboo plantings. We also discuss what research and practical work is needed to guide and support the restoration of giant panda habitat.

Open and Suitable Forest Land Does Need Replanting

The role that tree and bamboo plantings play in giant panda habitat restoration cannot be ignored. The implementation of ecological restoration projects and the regional warmer and wetter climate accompanying global climatic change has led to an expansion of forest canopy cover and bamboo density in the Qinling Mountains (Sun 2007; Jin et al. 2012). The area of forested land increased by 25,456 hm^2 from 2000 to 2015, and the ecological quality of the vegetation has significantly improved (Ji et al. 2021). There are very few open and suitable areas around local communities that need reforestation (Zhou 2017).

Middle-Aged and Young Secondary Forests Need Tending

Currently, giant panda habitat in the Qinling Mountains is comprised mainly of middle-aged and young secondary forests resulting from large-scale timber harvests and construction of roads and other infrastructure prior to the implementation of the Natural Forest Protection Project (China's logging ban). From 1960 to 2000, approximately equal to 818,000 ha of giant panda habitat in the Qinling Mountains was lost, approximately equal to 399,000 ha was logged by six main state-owned forest enterprises and approximately equal to 419,000 ha by local forest farms (Sun 2007).

Intensive studies have shown that pandas prefer old-growth natural forest, and secondary forests are very different from old-growth natural forests (Zhang et al. 2011; Hong et al. 2012; Duan et al. 2014; Qin 2020). Compared to old-growth natural forests, naturally regenerated secondary forests have more shrubs and smaller trees (Hong et al. 2012; Duan et al. 2014). Such dense shrubs can inhibit panda movement (Hong et al. 2012), whereas larger trees provide more shade and holes in which pandas can rest and breed (Hu 2001). Stratified bamboo groves with varying height, density, base diameter, and age structure can be found within secondary forests (Hong et al. 2012; Qin 2020), but the overall structure and composition of these groves depends on whether bamboo was present within or near to the land at the time of logging, and competition with other shrubs.

Secondary forests that have regrown after logging can, in some conditions, be suitable habitat for pandas (Ouyang et al. 2002; Bearer et al. 2008; Duan et al. 2014). In the Sichuan Wolong Nature Reserve, it takes approximately equal to 50 years for the secondary forest to become suitable habitat for pandas and approximately equal to 70–80 years for the vegetation community structure to resemble that of the native forest (Ouyang et al. 2002). Another study at the same reserve indicated that at least 37 years of natural recovery time was needed for pandas to begin to reuse the land (Bearer et al. 2008). Although apparent panda habitat in secondary forest is significantly different from that in old-growth forests, pandas did use the 50-year-old secondary forest in the Sichuan Wanglang Nature Reserve (Duan et al. 2014).

Bamboo grows faster than the time it takes for vegetation structure to recover after logging (Ouyang et al. 2002). Thus, by planting bamboo within secondary forests and allowing for some years of natural recovery, restoration of adequate bamboo foods may be achieved. However, for middle-aged and young secondary forests impacted by logging, planting trees and bamboo is insufficient by itself to re-establish panda habitat. In addition, more intensive management, including clearing and cutting of shrubs and ramets to release them from competition, or sanitation cutting, increment felling, and replanting if necessary, should be adopted for middle-aged and young secondary forests to accelerate the habitat restoration process.

Non-Native Larch Plantation Need Thinning

Most of the nature reserves for pandas in the Qinling Mountains are state-owned forest enterprises. Local forestry officials have emphasized and prioritized the use of monoculture plantations of non-native larch (*Larix*) to restore panda habitat in these nature reserves. Two non-native species of larch (*Larix principis-rupprechtii* (Mayr) and *Larix kaempferi* (Lamb.) Carr.), which grow fast and have high yields, have been introduced successively into clear-cut areas since the 1970s. Although larch planting has now been stopped, a recent study showed that larch plantations currently cover approximately equal to 21,000 ha in the Qinling Mountains, of which just over 8,500 ha are in nature reserves (Nan et al. 2021). These larch plantations, mainly distributed on hillsides and river valleys and set into native vegetation, have caused the loss and fragmentation of panda habitat (Zhao et al. 2008).

After decades of growth, the canopy closure of these larch monocultures is nearly 90%. Their understory has no bamboo and, at most, a few shrubs or herbs (Zhao et al. 2008), and there is scant (0.5–1 cm) litter (Luo 2017). These plantations are not suitable habitat for pandas. The most recent surveys (early 2000s: Sun 2007; early 2010s: Zhou 2017) found no panda activity in larch plantations in the Qinling Mountains. Similarly, larch plantations are rarely utilized by other sympatric species (such as *Budorcas taxicolor* and *Rhinopithecus roxellanae*) (Zhao et al. 2008).

Although larch plantations are no longer used for restoration of panda habitat by foresters and conservation biologists, the felling of standing trees is restricted by ecological and environmental protection polices, and is unpopular with the public and in the media. Instead of felling, an attempt to plant an understory of bamboo (*B. fargesii)* within larch plantations has been conducted by the Shaanxi Changqing Nature Reserve. Although *B. fargesii* survives and grows in these larch plantations, they had still not branched into clumps 3 years after planting and the understory was still poor with few herbs, even in forest gaps (Fig. 1). In Sichuan's Wolong Nature Reserve, stand thinning of larch achieved some positive results: understory shrubs and herbs species increased in abundance (He et al. 2020). In this same study, bamboo and native mid-successional trees had lower survival rates and growth than native pioneer tree species after being planted into highly-thinned larch plantations (He et al. 2020).

Although more studies are needed, thinning and clear-cutting of larch plantations is necessary, whether to restore panda habitat or increase ecological security. Therefore, it is imperative to have the support of the government to pursue restoration efforts through thinning of larch plantations followed by native tree and bamboo plantings (Luo 2017; Li 2020). At present most larch plantations have reached maturity or near-maturity with years of growth and larch seedlings are not naturally regenerating in forest gaps (Zhao et al. 2008; He et al. 2020). This is an ideal time to thin the larch plantations as a means to recover and restore panda habitat. However, this work must be supervised effectively to prevent extensive cutting of other natural and secondary forests while thinning the larch stands.

Pilot Studies Are Needed before Restoring Bamboo Forests

Restoration of bamboo (*F. qinlingensis*) forests in the mid-high mountain zones of the Qinling Mountains (Fig. 2) for panda habitat frequently has been proposed. There are only a few studies on the vegetation characteristics, driving factors, wildlife habitat selection, and restoration practices of this region. A survey conducted on giant panda habitat of the Qinling Mountains

Figure 1. Panda habitat restoration status from larch plantation through understory planting of bamboo *Bashania fargesii* after 3 years of planting. Photos taken in November 2021, by D. Chen.

Figure 2. Examples of bamboo (*Fargesia qinlingensis*) forests in the mid-high mountain zone of Qinling Mountains. Photos taken in April 2020, by Q.F. Zhu.

states that these bamboo forests are generally characterized by a near monoculture of bamboo of uniform growth, high density, approximately equal to 90% canopy closure, a height of 1.5–3 m, and low herbaceous cover (Zhou 2017). It has been suggested that this vegetation structure is a result of the relatively high altitude and poor site conditions (soil, water, and strong wind). Another possible interpretation is that this is a degraded forest ecosystem following clear-cutting that succeeded into a climax community of bamboo. These bamboo forests are rarely used by giant pandas because there are no or few tree stands and the dense bamboo poles that inhibit panda movement (Zhou 2017).

To understand the origins of this bamboo forest requires the collection and review of historic documents, interviews with long-term farmers and foresters, analysis of satellite images, and field studies. If this is found to be a degraded forest ecosystem, pilot studies of restoration can be planned. Experimental designs involving patterns and intensities of thinning with a combination of native tree introductions could be tested to determine if this is a suitable and effective method for habitat restoration (e.g. a restoration patent by Mo et al. 2021). Additional studies and data are also needed to support policies or practices of bamboo thinning and large-scale restoration efforts. Hasty restoration efforts may lead to further degradation of the habitat.

Conclusions

Planting trees and bamboo is vital to giant panda habitat restoration, but practical work is more complicated than it seems to be for at least four reasons. First, there are few sites needing afforestation as vegetation has recovered on cut-over land and farmland because of ecological forestry projects in a warm and humid climate. Second, naturally regenerating forests are mostly middle-aged or young secondary forests, which need tending rather than planting. Third, non-native larch plantations urgently need to be replaced and replanted with native trees and bamboos; this will require new policies that allowing them to be cut. Finally, it needs to be determined if bamboo forests in the mid-high mountain zones are degraded forests, and if so, pilot restoration practices should be implemented. Hasty planting may lead to a low survival rate and poor growth of bamboo and other species, leading to adverse consequences for the ecosystem. In conclusion, the restoration of giant panda habitat requires moving from simply planting trees and bamboos to recovering a native and diversified forest ecosystem with higher stability, functions, and service values. Giant panda habitat restoration needs long-term exploration to accompany its practice, support from scientific, financial and policy sectors, and will not be accomplished at one stroke through tree and bamboo plantings.

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