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Sacred forests are keystone structures for forest bird conservation in southwest China's Himalayan Mountains

Jodi S. Brandt [a,b,*], Eric M. Wood [a], Anna M. Pidgeon [a], Lian-Xian Han [c], Zhendong Fang [d], Volker C. Radeloff [a]

[a] Department of Forest and Wildlife Ecology, University of Wisconsin-Madison, 1630 Linden Drive, Madison, WI 53706, United States
[b] School of Natural Resources and Environment, University of Michigan, Ann Arbor, MI, United States
[c] Department of Conservation Biology, Southwest Forestry University, Kunming, Yunnan, PR China
[d] Shangri-La Alpine Botanical Garden, 118 Mailbox, Xianggelila County, Yunnan 674400, PR China

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ABSTRACT

Identifying and protecting "keystone structures" is essential to maintain biodiversity in an increasingly human-dominated world. Sacred forests, i.e. natural areas protected by local people for cultural or religious regions, may be keystone structures for forest birds in the Greater Himalayas, but there is limited understanding of their use by bird communities. We surveyed birds and their habitat in and adjacent to six Tibetan sacred forests in northwest Yunnan China, a biodiversity hotspot. Our goal was to understand the ecological and conservation role of these remnant forest patches for forest birds. We found that sacred forests supported a different bird community than the surrounding matrix, and had higher bird species richness at plot, patch, and landscape scales. While we encountered a homogeneous matrix bird community outside the scared forests, the sacred forests themselves exhibited high heterogeneity, and supported at least two distinct bird communities. While bird community composition was primarily driven by the vegetation vertical structure, plots with the largest-diameter trees and native bamboo groves had the highest bird diversity, indicating that protecting forest ecosystems with old-growth characteristics is important for Himalayan forest birds. Finally, we found an increased bird use of the sacred forests and their edges during 2010, a severe drought year in Yunnan, indicating that sacred forests may serve as refuges during extreme weather years. Our results strongly indicate that sacred forests represent an important opportunity for Himalayan bird conservation because they protect a variety of habitat niches and increase bird diversity at multiple spatial scales.

1. Introduction

As humans consume an ever-increasing proportion of the Earth's resources, biodiversity declines at an accelerating rate (Chapin et al., 2000; Foley et al., 2005), making the protection of "keystone structures", i.e., discrete spatial features that maintain biodiversity at multiple spatial scales, ever more important (Belsky and Canham, 1994; Manning et al., 2006; Stagoll et al., 2012; Tews et al., 2004). For example, forest gaps, large trees, and temporary wetlands are keystone structures whose presence adds heterogeneity to the resources available in landscapes, facilitating greater species richness. The question is how to identify such keystone structures, and how to protect them.

Sacred forests, i.e., natural areas protected by local people for cultural or religious reasons (Dudley et al., 2009), may be keystone structures for biodiversity in traditional landscapes around the world. Sacred forests are numerous, dispersed across a broad range of topographic and micro-climatic conditions, and range in size from a single hectare to thousands of square kilometers (Ormsby, 2011). As such, they likely serve multiple ecological functions, including as corridors, refugia, and source habitats (Bhagwat and Rutte, 2006; Dudley et al., 2010). Sacred forests may be critical components of protected area networks (Verschuren et al., 2010), but we have little understanding of their potential role for biodiversity conservation, especially in the less-studied biodiversity hotspots.

The traditional land management systems that sustain sacred forests may create optimum conditions for species diversity at multiple spatial scales. For example, sacred forests are typically managed by communities (Dudley et al., 2009) and often experience a gradient of human disturbance (UNESCO-MAB, 2003), where a variety of organisms can utilize variable resource

* Corresponding author at: School of Natural Resources and Environment, University of Michigan, Ann Arbor, MI, United States. Tel.: +1 (734) 764 9542.
E-mail addresses: jsbrandt@umich.edu (J.S. Brandt), emwood@wisc.edu (E.M. Wood), pidgeon@wisc.edu (A.M. Pidgeon), lianxian.han@gmail.com (L.-X. Han), zhendong.fang@gmail.com (Z. Fang), radeloff@wisc.edu (V.C. Radeloff).

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conditions (Belsky and Canham, 1994). In addition, sacred forests are typically embedded in landscapes with matrix habitats that are hospitable to at least some species, and thus conventional assumptions of patch size and fragmentation effects (MacArthur and Wilson, 1967) may not apply (Prugh et al., 2008). Furthermore, the edges between sacred forests and their matrix are often not abrupt barriers, but a gradient of disturbance to levels characteristic of the surrounding matrix. These edges may serve as "ecotones", facilitating ecological interactions between the patch and the matrix, and offering supplementary resources not available in the core habitats (Ries et al., 2004). Despite their potential importance for species dispersal and persistence, we have little understanding of how sacred forests are influenced by patch size, edge effects, and interactions between patch and matrix habitats.

One region where sacred forests are relatively common are the Himalayan mountains (Barbhuiya et al., 2010; Luo et al., 2003; Mallarach, 2008; Salick et al., 2007; UNESCO-MAB, 2003; Xu et al., 2005). Several ethnic minority groups recognize sacred areas as part of their religion, including sacred beyuls (which protect entire valleys), sacred mountains (10s to 100s of km^2), and village-level sacred forests (1–1000 ha). The Himalayan mountains also contain three biodiversity hotspots (Myers et al., 2000) and forest birds are of special conservation concern (Renner, 2011). The region exhibits high levels of bird diversity and endemism and ranks highest in global assessments of threatened bird species richness (Grenyer et al., 2006). Many forest bird species in the Greater Himalayas follow a Sino-Himalayan distribution (Renner, 2011; Renner and Rappole, 2011), which includes the Himalayan range, the mountains of southwest China, and the Qinghai Tibetan plateau (Fig. 1a). Forest degradation has accelerated throughout this region in recent decades (Brandt et al., 2012; Renner et al., 2007; Spehn et al., 2010), destroying bird habitats (Dumbacher et al., 2011). Sacred areas may be critical for bird conservation throughout this rapidly changing region, but their importance for Himalayan forest bird communities across multiple spatial extents is not well understood.

Our overarching objective was to understand the role of sacred forests for the conservation of Himalayan forest birds. We studied bird communities within and outside of Tibetan sacred forests in northwest Yunnan, China, with the following specific objectives:

1. Determine whether bird community composition and diversity is different within sacred forests compared to the surrounding matrix.
2. Identify the critical habitat characteristics structuring bird diversity, abundance, and community composition.
3. Investigate how patch size and edge habitats influence bird community composition, diversity and abundance patterns.

2. Methods

2.1. Study area

Our study area is in Shangrila, northwest Yunnan Province, China (Fig. 1a). Northwest Yunnan is a biodiversity hotspot in the Hengduan Mountains of the southeastern sub-Himalayan mountains, bordering Myanmar, Tibet and Sichuan Province. Three major rivers (the Yangtze, Mekong, and Salween) create steep gorges, with elevations ranging from 1800 to 6740 m, creating a large array of ecological niches in a relatively small area.

Northwest Yunnan has great importance for local, regional, and global bird diversity. First, it is a center of bird endemism (Lei et al., 2003). Second, it is part of the East Asian migratory flyway, providing important stop-over habitat for long-distance migrants (Cheng, 1987). Third, it lies at the confluence of the Palearctic, Himalayan, and Indo-Malay zoogeographic regions, and thus provides habitat for birds with distinct ecological and evolutionary histories (Renner, 2011).

Northwest Yunnan's avifauna is one the poorest understood on Earth (Renner and Rappole, 2011), and it is likely that forest birds face serious threats. Large expanses of northwest Yunnan's forests were clear-cut by state logging companies from the 1960s through the 1990s to fuel China's national development. Despite a ban on commercial logging in 1998 and heavy investment in reforestation and protected areas (Liu et al., 2008), old-growth forests continue to be logged and the ecological integrity of the new forests is unclear (Brandt et al., 2012; Xu, 2011).

Northwest Yunnan is home to several ethnic minority groups that recognize sacred areas as part of their religion (Xu et al., 2005). In particular, Tibetans have a complex sacred site system that includes large Tibetan sacred mountains (tens to hundreds

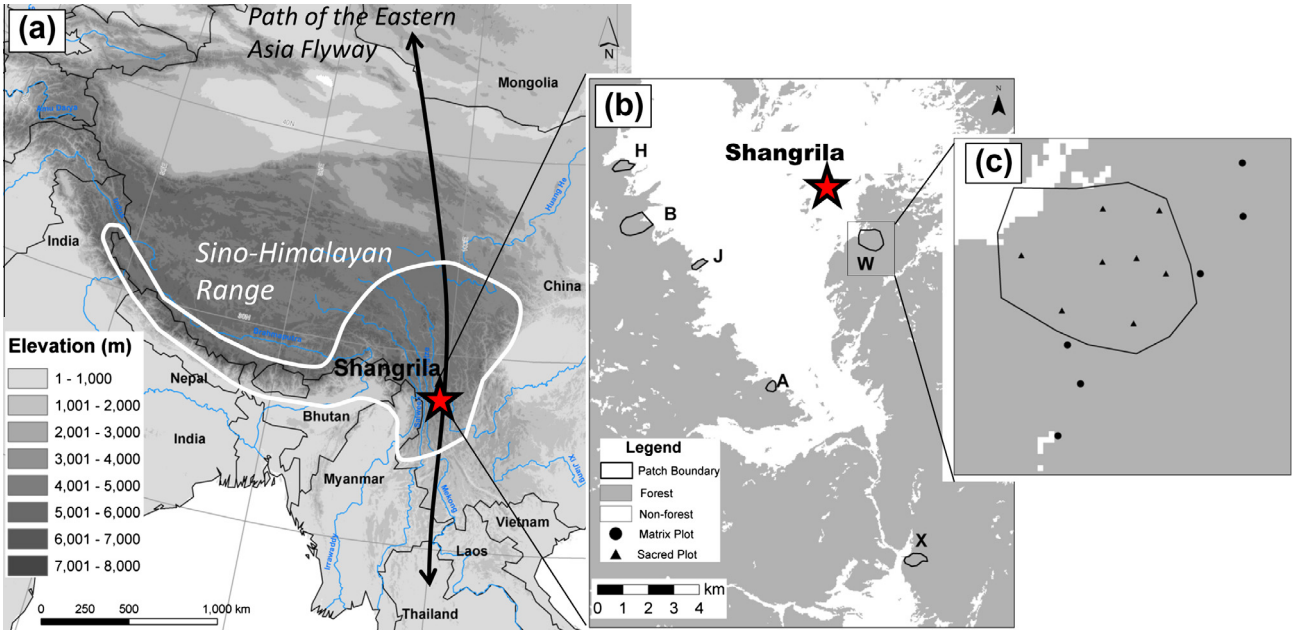

Fig. 1. (a) Location of Shangrila within the Greater Himalayan region, (b) the six sacred forest patches that were surveyed, and (c) sampling plots within and outside of sacred forests. Matrix plots were placed on transects at approximately 60, 260, and 510 m away from the edge of the sacred forest.