Review

The endangered red panda (*Ailurus fulgens*): Ecology and conservation approaches across the entire range

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ABSTRACT

The red panda (*Ailurus fulgens*), a vegetarian member of the order Carnivora, is distributed in Nepal, India, Bhutan, Myanmar, and China. Many populations occur at low densities in small fragmented forest patches and face pressure from habitat loss, degradation, and fragmentation, poaching, and developmental activities. Most studies have taken place in China and Nepal; few studies have been conducted in the other countries, creating a gap in documentation. Therefore, there is an urgent need to increase our knowledge regarding the ecology of the red panda and its threats. Based on literature regarding the red panda, we attempt to summarize the progress in research on its current distribution, ecology, and existing threats in the wild, highlight conservation approaches and recommend future directions. Recent studies have focused on wild populations; however, earlier studies emphasized captive. China and Nepal have a wider elevational range in red panda distribution (2000–3800 m) compared to other countries. Bamboo mixed subtropical and temperate forest and other associated variables, including a relatively high cover of bamboo, shrubs, and canopy, high densities of fallen logs, relatively steep slopes, and proximity to water sources, are ecologically important in the habitat. Due to differences in methodologies, prior estimates on population size and habitat area have varied. The genetic diversity of red pandas is high in China, but a lack of such data in other range countries makes subspecies classification unclear. Movement, microbiota, pathogens, and threats have been insufficiently documented; thus, we recommended extensive research in these areas. Furthermore, regional cooperation in research, data sharing, and policy implementation are urgently needed to protect wild panda populations.

1. Introduction

The red panda (*Ailurus fulgens*), a member of the order Carnivora, is an arboreal vegetarian mammal that depends almost mainly on a bamboo diet (Wei et al., 1999; Yonzon and Hunter, 1991). The red panda occupies a highly specialized niche, primarily inhabiting bamboo understories in temperate and conifer forest types and areas adjacent to broadleaf forests in Nepal, India, Bhutan, Myanmar and China (Choudhury, 2001; Dorji et al., 2012; Kandel et al., 2015; Pradhan et al., 2001; Reid et al., 1991; Sharma and Belan, 2009; Wei et al., 1999; Yonzon, 1989; Yonzon and Hunter, 1991), and a separate population may occur in Meghalaya, India (Choudhury, 2001). *Ailurus fulgens fulgens* (Himalayan subspecies) and *Ailurus fulgens styani* (Chinese subspecies) are believed to be two subspecies based on morphological evidence and the geographical barrier of the Nujiang River (Glatston, 1994; Wei et al., 1999). However, this classification and geographical

boundary are debated and have remained unclear due to insufficient genetic evidence from the westernmost biogeographical ranges (Hu et al., 2011). Relied on skull morphometric data and other secondary information (comparative photographs of specimen of known origin), Groves (2011) thought that these two subspecies should update as two distinct species: *Ailurus fulgens* from the Himalayan and *Ailurus styani* from Yunnan, Sichuan, southeastern Tibet and Myanmar (Groves, 2011). However, these pieces of evidence are premature to justify distinct species due to limited sample size and lack of genetic evidence. Especially, genetic study of the Himalayan red panda would be very critical to justify taxonomic classification.

Habitat loss, fragmentation, and degradation are major threats to wild red pandas (Pradhan et al., 2001; Wei et al., 1999; Yonzon and Hunter, 1991). These factors have accelerated declines in wild populations, and the species has been listed as Endangered by IUCN (Glatston et al., 2015). Red panda population has plausibly declined by

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50% over last three generations and this decline is continuing (Glatston et al., 2015). However, any estimate of the total red panda population is likely to be inaccurate, as the red panda inhabits five countries, and occurrence records are scant and patchy. Most studies to date have relied on the observation of indirect signs, such as feces, pugmarks and feeding (Pradhan et al., 2001; Wei et al., 1999; Yonzon and Hunter, 1991), and consultation with experts and local communities in small units (Jnawali et al., 2012; Wei et al., 2014). There is a spatial bias in terms of the areas where most studies have been conducted. Studies have mainly been concentrated in parts of Sichuan in China and in the eastern part of Nepal, so there remains a huge area of the species' range where a few or no studies have been performed so far, such as the western part of Nepal, part of Arunachal Pradesh, part of Tibet, part Yunnan and norther Myanmar. However, little empirical research has been carried out in limited areas in the landscape, which have been sparsely documented.

There are still many gaps in the current knowledge regarding red pandas, including in relation to several aspects of the species' ecology, population parameters (e.g., population size, density, mating system, and dispersal pattern), behavior, pathology, genetics, isotopes, gut microbiota diversity and geographic demarcation of subspecies. To provide a thorough summary of what is known to date, here we performed a comprehensive review of the existing literature relevant to red panda studies in the wild habitats of its range countries. Our aims in this paper are to summarize the current scientific progress on the distribution and ecology of this species, update the existing threat status of the wild population and clarify the recommendations for future conservation efforts. Additionally, this paper provides a synthesis of prior conservation approaches and future directions that would be beneficial to scientific communities focused on other species and protected area managers to implement effective conservation measures.

2. Status and species ecology

2.1. Distribution and population status

The published information regarding the red panda is limited in comparison to that pertaining to other high altitude-dwelling species, such as the giant panda (*Ailuropoda melanoleuca*), snow leopard (*Uncia uncia*), and Himalayan musk deer (*Moschus leucogaster*), which are the iconic species of pristine mountainous ecosystems. The distribution of the red panda is restricted to isolated habitat patches in the mountainous regions of five Asian countries: Nepal, India, Bhutan, Myanmar and China (Choudhury, 2001; Pradhan et al., 2001; Wei et al., 1999; Yonzon et al., 1991) (Fig. 1).

Mountainous protected areas, including Langtang National Park (LNP), Makalu Barun National Park (MBNP), Rara National Park (RNP), Sagarmatha National Park (SNP), Annapurna Conservation Area (ACA), Gaurishankar Conservation Area (GCA), Kanchenjunga Conservation Area (KCA), Manaslu Conservation Area (MCA), and Dhorpatan Hunting Reserve (DHR), are the major habitats of red panda in Nepal (Jnawali et al., 2011; Jnawali et al., 2012; Williams, 2003; Yonzon, 1989). However, > 77% of red panda habitats lie beyond protected areas (Jnawali et al., 2011) and are under increasing anthropogenic threats, which is a serious conservation challenge. Recent surveys recorded the occurrence of red pandas in the Bhojpur, Dolpa, Jumla, Jajarkot, Kalikot, Khotang, Lamjung, Rolpa, Ramechhap, and Sindhupalchowk districts, which represent habitats outside protected areas (Bhatta et al., 2014; Bista et al., 2017b; Thapa et al., 2013).

In India, red panda occurrence records have been confirmed in West Bengal, Sikkim, Arunachal Pradesh, and possibly Meghalaya (Choudhury, 2001). The Singalila and Neora Valley national parks are protected areas in West Bengal that harbor good red panda habitat, and detailed studies have been carried out in these areas (Pradhan et al., 2001). A prior study found a density of one panda per 3.9 km² distributed within a range of elevation of 2600–3600 m in Singalila

National Park (Pradhan et al., 2001). Records of red pandas are known from eight protected areas in the state of Sikkim (Ghose and Dutta, 2011). Red panda with cubs was captured in camera-trap that setup in different locations in Kyongnosla Alpine Sanctuary of East Sikkim (Khatiwara and Srivastava, 2014). Similarly, they have been recorded in the Twang district in Arunachal Pradesh (Chakraborty et al., 2015; Srivastava and Dutta, 2010). Noteworthy, a red panda carcass was found in the highest elevation 4325 m in Twang district (Dorjee et al., 2014). The carcass may be carried here by predators in higher elevation. Choudhury (2001) reported hide of red panda in the village closer to Nokrek and Balpakram national parks in Garo Hills in Meghalaya (Choudhury, 2001). Yet, there has been no recent authentic report of red panda sighting (indirect evidence of fecal pellets) or scientific study of red panda in that district (Ghose and Dutta, 2011). Except Choudhury's (2001) report, there is no any further scientific exploration on this issue. Duckworth (2011) elaborated that the red panda skins found could be the descendant of previous captive pandas released by tea planter when they had departed that area. Due to great difference in ecological conditions with current distribution range, it would be premature to accept the existence of wild pandas based on this information in Meghalaya (Duckworth, 2011). A ground based field survey in Meghalaya is urgently need for investigation the signs of wild pandas.

The occurrence of the red panda has been confirmed in 13 districts, including Haa, Thimphu, Paro, Punakha, Wangdiphodrang, Gasa, Trongsa, Zhemgang, Bumthang, Mongar, Lhuntse, Trashigang and Trashiyangtse, in Bhutan (Dorji et al., 2012). Field-based studies have confirmed the presence of red pandas in the Jigme Dorji, Jigme Singye Wangchuck and Thrumshingla national parks, the Bumdeling and Sakteng wildlife sanctuaries and the Toorsa Strict Nature Reserve and biological corridors connecting these reserves (Dorji et al., 2012).

In China, its distribution is confined to Sichuan, Yunnan, and Tibet (Wei et al., 1999; Wei et al., 2014). A Population and Habitat Viability Assessment (PHVA) document indicated that the red panda could be distributed in 88 counties in five provinces, Sichuan, Yunnan, Tibet, Qinghai and Gansu, with 43.8% of the habitat in Sichuan; however, populations in Qinghai and Gansu have not been recorded. The subspecies *A. f. styani* is confined to the Sichuan province and northeastern Yunnan, whereas *A. f. fulgens* occurs in both the Tibet and Yunnan provinces in China (Wei et al., 1999). The distribution status is poorly known in Myanmar, and red pandas have only been confirmed in Hkhakaboraz National Park, Hponkanrazi Wildlife Sanctuary, and other places including Emaw Burn, Nam Tamai, Taron valley in closer border of Yunnan (Rabinowitz and Khaing, 1998).

Globally, the estimated potential red panda habitat is approximately 142,400 km², with China alone accounting for more than half of the area (Choudhury, 2001), but recent modeling-based estimates indicate 47,000 km² (Kandel et al., 2015). Recent estimates of habitat in Sichuan, Yunnan and Tibet are 17,228.3 km², 10,634.1 km² and 9574.1 km², respectively (Wei et al., 2014). Due to inconsistent methodologies, the estimated potential red panda habitat area varies (Table 1). Earlier estimated population is approximately 16,000–20,000 red pandas in the wild; 5000–6000 occur in China, and the remaining 5000–7000 are distributed in other range countries (Choudhury, 2001). Recent assessment based on the IUCN Red List indicates that the red panda population may be as low as 10,000 individuals in the wild (Glatston et al., 2015).

2.2. Habitat ecology

Habitat ecology is a widely covered research area in panda studies and is a major component of species-specific conservation tools. Subtropical and temperate forests constitute a broad habitat range for red pandas (Yonzon et al., 1991; Yonzon, 1989), but survival of a distinct sole population may occur in a warm climate, i.e., in tropical forest in Meghalaya at elevations of 700–1400 m (Choudhury, 2001). Roberts and Gittleman (1984) recorded an altitudinal range for the