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Original research article

Increased stress in Asiatic black bears relates to food limitation, crop raiding, and foraging beyond nature reserve boundaries in China

Karl D. Malcolm [a,b,g,*], William J. McShea [b], David L. Garshelis [c], Shu-Jin Luo [d], Timothy R. Van Deelen [a], Fang Liu [e], Sheng Li [a,b,f], Lin Miao [d], Dajun Wang [f], Janine L. Brown [b]

[a] Department of Forest and Wildlife Ecology, University of Wisconsin-Madison, Madison, WI, USA
[b] Smithsonian Conservation Biology Institute, Front Royal, VA, USA
[c] Minnesota Department of Natural Resources, Grand Rapids, MN, USA
[d] College of Life Sciences, Peking-Tsinghua Center for Life Sciences, Peking University, Beijing, China
[e] Institute of Forest Ecology, Environment, and Protection, Chinese Academy of Forestry, Haidian, Beijing, China
[f] School of Life Sciences, Peking University, Beijing, China
[g] United States Department of Agriculture, Forest Service, Southwestern Regional Office, Albuquerque, NM, USA

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ABSTRACT

Asiatic black bears (*Ursus thibetanus*) are declining throughout much of their range. In China they are partially protected by a nature reserve system and rely heavily on hard mast as a food source prior to winter denning. Bears may compensate for mast shortages by raiding agricultural crops and killing livestock, mainly outside reserves where they are exposed to increased threats of poaching. We hypothesized that stress would vary with availability of high-quality refugia and fluctuations in mast abundance. We collected fecal samples from free-ranging bears in and around nature reserves in southwestern China, recorded habitat characteristics at each fecal sample location, and quantified abundance of hard mast. We used feces for genetic and endocrine analysis and identified 106 individuals. Feces collected outside reserves, or in agricultural fields within reserves, contained elevated concentrations of glucocorticoid metabolites compared to samples collected in intact, mast-producing forests within reserves. Relationships with habitat variables indicated that the hypothalamic–pituitary–adrenal (HPA) axis of the Asiatic black bear is responsive to human activity, abundance of hard mast, extent of forest cover, and quality of diet. Our findings demonstrate biological reactions of a large mammal to variable forest quality, human threats, and foraging relative to boundaries of protected areas.

1. Introduction

Asiatic black bears (*Ursus thibetanus*) are threatened by loss of habitat and killing for commercial trade in bear parts (Garshelis and Steinmetz, 2008), a pervasive problem for many large mammals across much of Asia (Corlett, 2007). Poaching

* Correspondence to: Southwestern Regional Wildlife Ecologist, United States Forest Service, 333 Broadway Boulevard SE, Albuquerque, NM 87102, USA. Tel.: +1 505 842 3262, +1 231 218 9464 (mobile).
E-mail addresses: karl.d.malcolm@gmail.com, kdmalcolm@fs.fed.us (K.D. Malcolm).

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of Asiatic black bears is facilitated by regular interaction with humans. Damage to crops and attacks on humans and livestock inspire retaliatory killing (Sathyakumar, 2001; Huygens et al., 2004) and foster negative attitudes toward bears (Liu et al., 2011).

In central Sichuan Province, the core of China's Asiatic black bear range, nature reserves established to protect giant pandas (*Ailuropoda melanoleuca*) also harbor robust populations of Asiatic black bears (Liu et al., 2009). Since the 1990s the number and total area of nature reserves in China increased rapidly (Li and Han, 2001), and anti-poaching patrols within reserves likely reduced illegal killing (Liu et al., 2011). However, a significant expanse of habitats occupied by Asiatic black bears remains outside protected areas. Moreover, many nature reserves may not be large enough to encompass the home ranges of resident bears, and poaching outside reserves can be intense (Hwang et al., 2010).

Asiatic black bears occupy a generalist ecological niche similar to that of American black bears (*Ursus americanus*, Reid et al., 1991; Steinmetz et al., 2011), but whereas American black bears are expanding in number and range (Garshelis et al., 2008) the opposite is true for the Asiatic species (Garshelis and Steinmetz, 2008). Both rely heavily on hard mast crops for food (Vaughan, 2002; Hashimoto et al., 2003); mast crop failures have been linked to increased use of anthropogenic foods (Noyce and Garshelis, 1997; Oka et al., 2004; Baruch-Mordo et al., 2014). Fluctuating abundance of natural food is an important source of variation in vulnerability of Asiatic black bears to human-induced mortality (Oi and Yamazaki, 2006).

Because Asiatic black bears hibernate in some parts of their range, including Sichuan Province (Schaller et al., 1989; Trent, 2010), acquiring sufficient energy stores during autumn is an important determinant of individual fitness and hence a strong driver of their behavior. In Japan, black bears traveled greater distances in autumns with poor mast (Kozakai et al., 2011) and experienced more conflicts with humans when searching for alternate foods.

Known threats to Asiatic black bears (i.e., habitat degradation and exposure to humans) and food abundance correlate with circulating levels of glucocorticoid hormones in other wildlife species (Busch and Hayward, 2009). While glucocorticoid hormones have increasingly been used as an indicator of physiological stress in wildlife species (Baker et al., 2013), they exhibit complex relationships with nutrition and stress. For example, they are variable at low to moderate stress levels, but increase at higher stress (Busch and Hayward, 2009). Glucocorticoids ensure that normal metabolic function is maintained by promoting appropriate levels of glucose and fatty acids in circulation (Harlow et al., 1990; Landys et al., 2006), but when an otherwise healthy individual cannot maintain energetic homeostasis or is exposed to noxious and unpredictable stimuli, circulating glucocorticoids rise above the stress threshold and trigger adaptive physiological and behavioral changes that may promote survival at a short-term cost (Wingfield and Kitaysky, 2002). For example, concentrations of glucocorticoids were elevated in Asiatic black bears farmed for bile (Malcolm et al., 2013).

We explored relationships between glucocorticoid production in free-ranging Asiatic black bears inside and outside Chinese nature reserves. We hypothesized that concentrations of glucocorticoids would increase with certain physical states (e.g., food limitation), behaviors (e.g., crop raiding), and habitats (e.g., less forested, unprotected, near roads), all of which relate to potentially higher risks of persecution by humans. We tested this hypothesis by comparing glucocorticoid concentrations in feces from bears that occupied areas with varying human activity, forest cover, availability of hard mast, and levels of protection.

2. Materials and methods

2.1. Study design

We quantified concentrations of glucocorticoid metabolites in fecal samples collected from free-ranging Asiatic black bears in Sichuan, Shaanxi, and Yunnan Provinces, China (Fig. 1). Given the link between energetic state and stress condition (in general: Wingfield and Kitaysky, 2002; and bears specifically: Bryan et al., 2013) and the predisposition of Asiatic black bears to experience conflict with humans during mast crop failures (Oka et al., 2004), we monitored spatial and temporal fluctuations in abundance of hard mast during each field season. Because primary dietary constituents were shown to influence fecal glucocorticoid concentrations in brown bears (*Ursus arctos*, von der Ohe et al., 2004), we examined and classified each fecal sample based on identifiable content to account for variation in glucocorticoids attributable to types of food consumed. We also genetically analyzed fecal samples that provided endocrine data to assess which samples were repeats of the same individual, to determine the minimum number of individuals sampled at each study site, and to test for sex-related differences in fecal glucocorticoid concentrations (Malcolm et al., 2013). We used the resulting data to model fecal glucocorticoid concentration as a function of landscape metrics (e.g., inside versus outside reserve boundaries, habitat type, etc.), hard mast abundance, diet, and season.

2.2. Study area

We collected fecal samples from Asiatic black bears in 8 nature reserves located in southwestern China (98°11′-107°42′ E, 24°47′-33°41′ N, Fig. 1). We also collected feces beyond reserve boundaries. We focused much of our sampling in and around 6 reserves (Meigu Dafengding [Meigu], Yele, Tangjiahe, Wanglang, Xiaohegou, and Xuebaoding) in the Liangshan–Xiangling–Minshan Mountain region of Sichuan Province. Additional sampling was conducted in Changqing Nature Reserve in Shaanxi Province and Gaoligongshan Nature Reserve in Yunnan Province. We collected fecal samples in six broad habitat categories: broadleaf deciduous, conifer, mixed broadleaf and conifer, agricultural (planted primarily