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The use of camera traps for estimating tiger and leopard populations in the high altitude mountains of Bhutan

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ABSTRACT

We used camera traps in combination with capture–recapture data analysis to provide the first reliable density estimates for tigers and leopards from the high altitude and rugged terrain in Bhutan's Jigme Singye Wangchuck National Park. Fifty days of camera trapping in each of five study zones collapsed into two trapping blocks, resulted in a sampling effort of 4050 trap days. Camera trapping yielded 17 tiger photos (14 left flanked and 3 right flanked) and 48 leopard photos (25 left flanked and 23 right flanked). Using photos of these left flank, the closed heterogeneous Jackknife Model M_h was the best fit for the capture history data. A capture probability ($\hat{P}$) of 0.04 was obtained for both tigers and leopards, thus generating population size (N) of 8 tigers ($SE = 2.12$) and 16 leopards ($SE = 2.91$) with densities of 0.52 tiger 100 km^{-2} and 1.04 leopard 100 km^{-2}. Photographic evidence indicated that tigers and leopards did not overlap in their spatial use of space. Tigers preferred less disturbed areas located further away from settlements, while leopards appeared to be more resilient to disturbances in so far as they were found nearer to human settlements. Camera trapping using a capture–recapture framework was an effective tool for assessing population sizes for tiger and leopard in low density areas such as Bhutan.

1. Introduction

Conservation of large carnivores such as tigers (*Panthera tigris tigris*) along with other predators like leopards (*Panthera pardus fusca*) is a global priority, because they may serve as umbrella species across a wide range of habitats, and are functionally important components of the ecosystems of which they are part. Socio-culturally, in Bhutan and many other parts of their ranges, despite the tensions of human-predator conflict, these felids are revered as protector deities and symbols of power and beauty (Wang, 2008). Thus conservation strategies targeted at these felids can garner both local and global support for conservation, and foster the protection of all the attributes of a healthy ecosystem (Steneck, 2005). However, loss of habitat, poaching for trade, declining prey populations and conflicts with humans primarily provoked by predation on livestock has driven three tiger subspecies to extinction (*P.t. balica; P.t. virgat and P.t. sondaica*), and has endangered tiger and threatened leopard populations overall (Nowell and Jackson, 1996; Sunquist, 1981). Human induced changes in the landscape have reduced the tiger's historical range to about 7% (of which only 1% is used by breeding females; Wang, 2008) and is continuing to threaten the survival of existing populations of tigers and leopards. This problem is further exacerbated by the fact that a large portion of the tiger's remaining habitat is situated in developing countries

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characterized by high human population and with livestock rearing a major foundation of livelihoods. Not only do humans and their livestock compete with these large cats for food, shelter and space, but humans also persecute them in retaliation for livestock losses (Wang and Macdonald, 2006). Given these circumstances, management and protection of the remaining tiger populations and their habitats, together with mitigating conflicts with farmers and enhancing co-existence, is an urgent conservation priority (Johnsingh and Negi, 2003). However, rigorous information on the population ecology of tigers and leopards, which forms the basis for effective management, is still lacking for many range countries (Karanth et al., 2001; Wang, 2008).

Bhutan is one of the 10 priority hotspots for tiger conservation (Wang, 2004). Tigers in Bhutan are a global priority because the tiger population there is thought to have the highest probability of persistence of any worldwide (Dinersten et al., 2006). Tigers in Bhutan, along with eleven felid species including leopard, snow leopard (*Uncia uncia*) and clouded leopard (*Neofelis nebulosa*) enjoy large tracts of undisturbed habitat (about 70% of the country is under forest cover) with rich flora and fauna (RGoB, 2002) and political and religious support. Both tigers and leopards are listed in Schedule I of the 1995 Forest and Nature Conservation Act of Bhutan, a designation that affords them special protection (Wang and Macdonald, 2006). Culturally, tigers are one of the four 'protector' animals symbolizing potency as lords of the mountains and they, like leopards, feature conspicuously in local culture and religion, emphasizing the cultural as well as biological importance of their conservation in Bhutan.

Despite their place in Bhutanese culture, tigers and leopards have been threatened in Bhutan through habitat loss, disturbance, conflict with humans and poaching. Wang and Macdonald (2006) reported that tigers and leopards were thought to be responsible for 82% of the total annual predation on livestock by wild carnivores in Jigme Singye Wangchuck National Park (tigers, leopards, dholes [*Cuon alpinus*] and Himalayan black bears [*Ursus thibetanus*] together killed a total of 76 livestock amounting to a total monetary loss of US$ 12,252), sparking retaliatory mortality by angry farmers. Livestock losses together with crop damage (Wang et al., 2006a) are major causes of negative attitudes towards wildlife and to conservation policy around the park (Wang et al., 2006b). These conflicts can be resolved only by understanding both their ecological and human dimensions, but progress is thwarted because little is known of the behaviour or population ecology of these big cats in Bhutan, and even simple estimates of their numbers have been unavailable.

This paucity reflects the technical difficulty of estimating population size for cryptic carnivores at low population densities, and highlights the need for an accurate, reliable and user-friendly tool to estimate populations of these cats. Use of Traditional pugmark based expert systems was found to be error prone and lacked statistical rigor (e.g., Choudary 1970, 1971; Sawakar, 1987; Sharma, 2001). Following Karanth's (1995) demonstration that tiger population size can be estimated using photographic capture–recapture analysis, this method has been used to estimate populations of diverse range of wild felids (e.g., Karanth and Nichols, 1998, 2000, 2002; Khorozyang and Malkhasyangg, 2002; O'Brien et al., 2003; Trolle and Kerry, 2003; Kawanishi and Sunquist, 2004; Karanth et al., 2004a; Jackson et al., 2006; Soisalo and Cavalcanti, 2006; Harmsen, 2006).

For the first time in Bhutan, we use camera traps to: (i) estimate abundance and density of tigers and leopards; (ii) provide baseline data from which to begin long term population monitoring programs; and (iii) apply our findings as a basis for conservation planning and in particular produce recommendations to reduce livestock losses to tigers and leopards.

2. Study area

The study was conducted in the five warden jurisdictions (zones) of Bhutan's Jigme Singye Wangchuck National Park (JSWNP), located in central Bhutan and joined in the south by Royal Manas National Park (Fig. 1). The park is bordered to the east and west, respectively, by the rivers Mangde chu and Sunkosh chu. The park's diverse physical features, temperature and rainfall have created climatic zones ranging from wet sub-tropical in the south to permanent alpine pastures and glaciers in the north (Wang, 2001). Elevation rises sharply from 150 m above mean sea level (amsl) from Tingtibi (south) to over 4900 m amsl at the peak of Mt. Jo-Durshing la. This ruggedness renders approximately 15–20% of the park inaccessible for sampling especially during summer and winter (Fig. 1).

This park, together with Royal Manas National Park and Indian Manas Tiger Reserve, form the largest tiger conservation area in South Asia, representing the full range of habitats from the sub-tropical plains to the alpine zone with high species diversity. These diverse habitats host important populations of predators (e.g., tiger, leopard, dhole, etc.) and prey (e.g., guar *Bos gaurus*, sambar *Cervus unicolor*, wild pig *Sus scrofa*, serow *Carpicornis sumatraensi*, langur *Trachypithecus geei*, macaque *Macaca Mulatta* [Wang, 2001]). The park, including part of the Manas-JSWNP link areas, is thought to support up to 10% of Bhutan's tiger population (Wang, 2001).

Almost 6000 farmers inhabit 34 villages spread throughout the park. Most of the farmers are either settled in the rich river valleys, or on the gentle shoulders of the hills or in the glacial valleys. Agriculture and livestock-rearing are the major sources of livelihood (Wang et al., 2006a). All farmers from lower altitudes keep cattle, while farmers who live in alpine regions favor yak.

3. Methods

3.1. *Preliminary survey*

A preliminary survey for tiger and leopard signs was carried out in each of the study zones by walking all available trails. All tiger and leopard signs were then plotted in a Geographic Information System (GIS) along with associated details of elevation, aspect and substrate. Sections of trails characterized by high concentrations of tiger and leopard activity (inferred from signs such as pugmarks, scats, scrapes, etc.), narrow trails below ridgelines near waterholes or passages between hills, or where movement was basically constrained by relief