

Short report

Predation may counteract climatic change as a driving force for movements of mountain ungulates



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ABSTRACT

Temperature variations are expected to influence altitudinal movements of mountain herbivores and, in turn, those of their predators, but relevant information is scarce. We evaluated monthly relationships between temperature and altitude used by a large mountain-dwelling herbivore, the Himalayan tahr *Hemitragus jemlahicus*, and its main predator, the snow leopard *Panthera uncia*, in an area of central Himalaya for five consecutive years (2006–2010). In contrast to expectations, there was no significant direct relationship between altitude of tahr sightings and temperature. The mean altitude of tahr sightings decreased by c. 200 m throughout our study. As expected, snow leopard movements tracked those of tahr, although the core area of the snow leopard did not move downwards. Tahr remained the staple of the snow leopard diet: we suggest that the former did not move upwards in reaction to higher temperature to avoid encounters with the latter. Avoidance of competition with the larger common leopard *Panthera pardus* at lower altitudes could explain why snow leopards did not shift their core area downwards. Apparently, interspecific interactions (predation; competition) influenced movements of Himalayan tahr and snow leopards more than climatic variations.

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1. Introduction

Current climatic changes are influencing the distribution of organisms (e.g. Walther et al., 2002; Parmesan and Yohe, 2003). Plant and animal species living in cold or strongly seasonal ecosystems, e.g. in mountain habitats, should be amongst the first ones to be affected (e.g. Gottfried et al., 2012; Telwala et al., 2013). Effects on plants, herbivores and carnivores can potentially generate cascading consequences across trophic levels (e.g. Walther et al., 2002). In mountainous areas, numbers and movements of large herbivores and carnivores should be greatly influenced by climatic changes because of thermoregulation (e.g. searching for cooler places in the warm season), snow cover and/or altitudinal shifts of respective food resources, but relevant evidence is scarce (e.g. Georgii and Schroeder, 1983; Grignolio et al., 2004; Lovari et al., 2006; Mason et al., 2014). Mountain ungulates need to increase their body reserves throughout the warm season to enhance their chance of survival during the following winter (e.g. Festa-Bianchet,

1988; Côté and Festa-Bianchet, 2001; Pettorelli et al., 2007). In the long-term, climatic variability should affect plant distribution (e.g. Gottfried et al., 2012) and phenology, in turn influencing movements and survival of herbivores (e.g. Pettorelli et al., 2007). Accordingly, movements of carnivores should be expected to track those of their prey.

We conducted a 5-year study (2006–2010) to assess relationships between variation in ambient temperature and altitudinal movements of Himalayan tahr *Hemitragus jemlahicus* (Artiodactyla: Bovidae) and its main predator, the snow leopard *Panthera uncia*, in a high altitude mountainous habitat in Central Himalaya, the Sagarmatha (Mt. Everest) National Park (SNP, Nepal). Numbers of predator and prey were shown to be linked, in the same area (Lovari et al., 2009a; Ferretti et al., 2014; Lovari and Mishra, in press). Snow leopards prey mainly upon meso-large wild mammals (e.g. Anwar et al., 2011; Shehzad et al., 2012; for reviews: Lovari et al., 2013b; Lyngdoh et al., 2014), i.e. the Himalayan tahr in our study area (Lovari et al., 2013a), and should be particularly vulnerable to climatic changes (Forrest et al., 2012; Lovari et al., 2013b). As 2009 was exceptionally warm in respect to the other years (Fig. 1a), we collected data to test whether a shift in altitudinal movements of tahr and, in turn, snow leopards occurred. For SNP, Lovari (1992) and Ale (2007) reported the core area of tahr distribution at almost 4000 m a.s.l. in 1989 and 2004–06, respectively.

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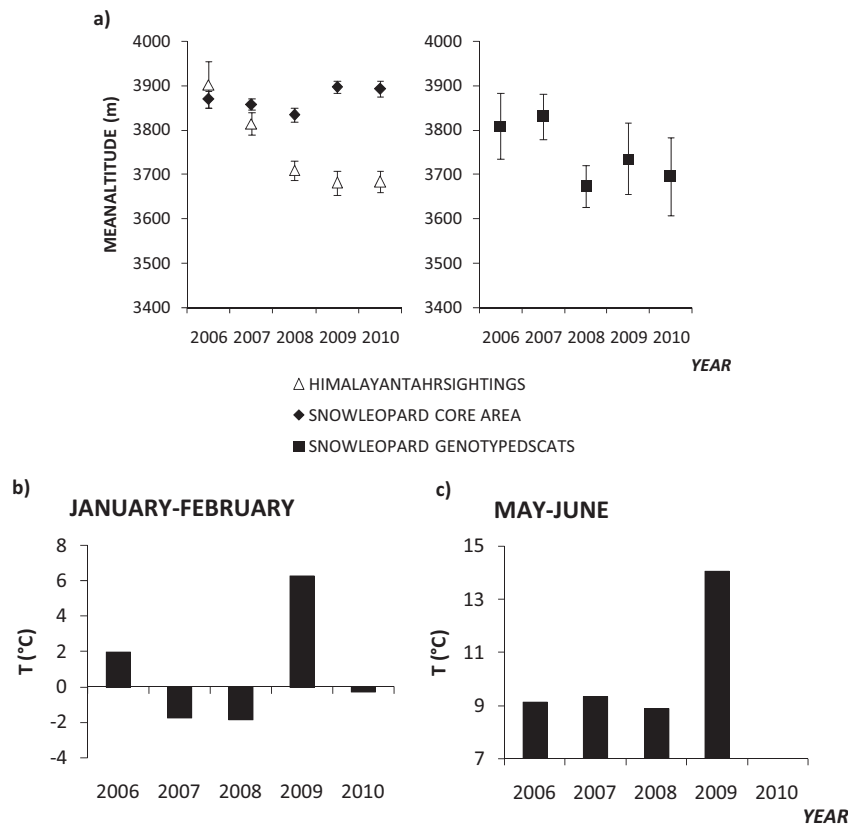


Fig. 1. (a) Altitude (mean \pm standard error) of genotyped scats ($N=72$) and core area (N of snow leopard scats and scrapes, $N=1019$), as well as sightings of Himalayan tahr ($N=593$) and mean temperature in (b) January–February and (c) May–June, in Sagarmatha National Park, in 2006–2010. Temperature data for 2010 were not available.

We wished to test the following predictions: (i) there should be a positive relationship between temperature and altitude of sightings of tahr, expected to use sites at higher altitudes in the warmest year, i.e. 2009, than in the other years, to search for cooler places; (ii) snow leopards should follow tahr and use areas at higher altitudes in the warmest year.

2. Materials and methods

2.1. Study area

Our study area (Sagarmatha National Park, 1148 km², 27°20'N, 86°45'E) lay mainly between the villages of Namche, Phortse and Gokyo Lake (3440–4750 m a.s.l., cf. Lovari et al., 2013a). Vegetation included mixed *Betula-Rhododendron-Abies* spp. forest (below 4000 m); *Juniperus-Rhododendron* spp. (4000–5000 m); mosses, lichens, Alpine grasslands (above 5000 m). Beside the Himalayan tahr, c. 300–350 individuals in 2003 and c. 100 individuals in 2010 (e.g. Lovari et al., 2009a, b; Ferretti et al., 2014) and the relatively abundant forest/shrubland dwelling musk deer (c. 300 individuals/1000 km²; Aryal et al., 2010), only the Himalayan serow *Capricornis sumatraensis* was present, but with a sparse, localised distribution in the forest (Lovari et al., 2005). Himalayan tahr was the staple prey of snow leopards (>55% of diet, Lovari et al., 2013a), which returned as a breeding species to SNP on 2003 (Lovari et al., 2009a, 2013a: 2–5 individuals/year). Intense predation by snow leopards on tahr, especially on kids, led to the heavy decline of the latter (see Lovari et al., 2009a for the discussion of potential alternative factors limiting the tahr population). Domestic yak *Bos grunniens* and their hybrids with zebu cattle *Bos indicus* (c. 2000 individuals) also occurred (cf. Lovari et al., 2013a). The common leopard *Panthera pardus* was the only other large predator living

permanently in SNP (Brower, 1991; Lovari et al., 2013a: 1–2 individuals/year) below the upper treeline, c. 3500–4000 m a.s.l., where it preyed mainly on musk deer, whereas the snow leopard occurred mainly above it, up to c. 5000 m a.s.l. (Lovari et al., 2013a). Himalayan tahr was the third prey of the common leopard (c. 20% of diet), which showed a substantial dietary overlap with the snow leopard (c. 70% of diet), suggesting a potential competition between these large cats (Lovari et al., 2013a).

2.2. Data collection and analyses

Our study was conducted from May 2006 to October 2010. Mean daily temperatures were obtained from a weather station located in Namche Bazaar (c. 3300 a.s.l.). Sightings of Himalayan tahr were made through 10 \times 40 binoculars and a spotting scope 15 \times 45 and georeferenced by a GPS, from fixed trails crossing the study area, for a total length of c. 140 km, repeated monthly (see Lovari et al., 2013a). We also recorded and georeferenced scrapes, which are distinctive signs widely used to confirm leopard presence (e.g. Schaller et al., 1988; McCarthy et al., 2005). Locations of scrapes found along the trails (within the snow leopard core area, Lovari et al., 2013a; cf. below) and that of genotyped scats in and out of the snow leopard core area were georeferenced and used as a measure of snow leopard altitudinal movements; scats were also used to assess species identity, distribution and minimum number of individual leopards (Lovari et al., 2013a). The core area of snow leopards (i.e. the area used exclusively by them and not by common leopards) was assessed by Lovari et al. (2013a) and coincided with the kernel 25% area determined according to the locations of genotyped scats. See Lovari et al. (2009a, b, 2013a) and Ferretti et al. (2014) for further details on study area and data collection techniques.

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