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Original investigation

Seasonal habitat use in three species of wild ungulates in Sikkim Himalaya

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ABSTRACT

Ungulates face increasing seasonal fluctuations in climate and forage availability with increasing latitude. While ungulates in the temperate regions address this by migrating across latitude and elevation, the strategies used by ungulates in the sub-tropical mountains is very little studied. We examined the influence of season, elevation, aspect and slope on the use of habitat by three species of ungulates in the Himalaya. The study area, Kyongnosla Alpine Sanctuary in Sikkim in India, covered 31 km^2. We deployed camera traps in 16 trails in an elevation range of 3000 m to 4200 m and used photo-captures in week-long sessions as indicator of habitat use during the winter and post-winter during 2011–12. We used zero-inflated negative binomial regression in a model selection approach and model averaged parameter estimates to examine the relative influence of covariates on photo-captures. Zero captures or species absence was closely associated with winter and more northern aspects in the Himalayan musk deer (*Moschus chrysogaster*), higher elevation in the Himalayan goral (*Naemorhedus goral*) and both winter and more northern aspects in the Himalayan serow (*Capricornis thar*). The non-zero photo-captures increased with elevation and decreased with northerly aspects in musk deer, decreased with increasing elevation in goral, while no pattern was evident in serow. Thus, the three species have different strategies to deal with drastic seasonal changes: goral is a resident at low elevations, musk deer is a commuter between aspects at higher elevations, and serow is probably a migrant between high and low elevations. The lack of sampling ≪3000 m, might have been the reason for low photo-captures of serow, especially in winter. Overall, we had few captures for all species due to the use of a limited number of cameras. This probably accounts for large standard errors of parameter estimates in the count models.

Introduction

Ungulates living in the higher latitudes face increasingly greater seasonal fluctuations in temperature, precipitation and forage availability. Many species migrate long distances to warmer lower latitudes during winter and *vice versa* during summer. Pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*) and woodland caribou (*Rangifer tarandus*) migrate long distances, across latitudes, between summer and winter (Sawyer et al., 2005; Terry and Wood, 1999). On the other hand, species that live in mountain ranges in the temperate migrate to summer feeding grounds in the higher elevations and to winter feeding grounds in lower elevations. Mule deer in British Columbia (Poole and Mowat, 2005), the mountain goat (*Oreamnos americanus*) in southern Alaska (White, 2006), female Alpine Ibex (*Capra ibex*) (Grignolio et al., 2004) in Italy and the golden takin (*Budorcas taxicolor bedfordi*) in Qinling mountains in China (Zeng et al., 2010) show very clear elevational separation between their summer and winter ranges. These latitudinal and elevational migrations are often closely linked to snow cover, solar radiation, phenological changes and resource availability, with animals often following a green gradient (Mysterud et al., 1997, 2001). In the red deer in north-eastern Italian Alps, the males migrated, but only half of the females showed elevational migration, the other half shifting to different areas within their winter range (Bocci et al., 2012).

Topographically complex mountains in temperate and subtropics show sharp changes in microclimates over short distances due to changes in aspect and slope and, therefore, the vegetation composition can change substantially across small changes in

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elevation (Parmesan, 1996). Aspect becomes a major influence at higher elevations; for example, in Lassen Volcanic National Park in northern California at ~2350 m the southern slopes can receive six times more solar radiation than the north facing slopes (Auslander et al., 2003). The south-facing slopes also remain snow-free for the longest in the central Rocky Mountains in north-central Utah (Newmark and Rickart, 2012). Delayed snow melt due to this in the northern aspects delays plant maturation and leads to higher forage quality compared to southern aspects (Hay and Heide, 1984). Thus, varying combinations of elevation, aspect and slope in topographically complex mountains provide resource patches among which animals can 'commute' from one season to another. While the summer and winter ranges of the 'migrants' are non-overlapping and separated by long-distances, that of the 'commuters' are within their home range (Dingle and Drake, 2007) and seasonal migrations may be absent in them (Cagnacci et al., 2011). While factors such as latitude, elevation, aspect and precipitation influence the abundance and quality of forage, the ungulates' responses are often mediated by body size, with larger species having greater energy requirements and mobility moving over longer distances (Teitelbaum et al., 2015; Hein et al., 2012).

While ungulates in the temperate regions seem to be latitudinal and elevational migrants (see references cited above), the seasonal use of habitat by ungulates in the sub-tropical mountains has been very little studied. What are the patterns of seasonal habitat use by sympatric ungulates inhabiting the sub-tropical mountains, where seasonal changes in temperature and precipitation can be very high although not as extreme as in the more northern latitudes and what topographical features influence these? We address this question with reference to three ungulate species in an elevation range of 3000 m to 4200 m in Himalaya in the Indian state of Sikkim. The smallest of these, the Himalayan musk deer (*Moschus chrysogaster*, 11–18 kg), occurs within an elevational range of 2400 m to 4750 m; the Himalayan goral (*Naemorhedus goral*, 35–42 kg) has a far greater elevational distribution from 200 m to about 4000 m (Mishra and Johnsingh, 1996). Although goral and musk deer are sympatric, competition between them is avoided because of the differences in their feeding habits (Green, 1985). Himalayan serow (*Capricornis thar*, 85–140 kg) occurs within a wider lower elevational range across the southern slopes of Himalaya from Kashmir to Tripura (Menon, 2014) and is known to be a generalist feeder (Giri et al., 2011). Himalaya is the largest sub-tropical mountain range in the world with the highest diversity of mountain ungulates (Bhatnagar, 1993). Here the bharal (*Pseudois nayaur*) (Oli, 1996), musk deer (*Moschus chrysogaster*) (Green, 1985) and Himalayan goral (*Naemorhedus goral*) (Mishra and Johnsingh, 1996) do not seem to show any elevational migration. The Himalayan ibex (*Capra ibex sibirica*), on the other hand, not only migrate to the higher elevations in summer and to lower elevations in spring (Manjrekar, 1997), but also show preferences for northern and eastern aspects during summer (Bhatnagar, 1997).

Material and methods

Study area

We conducted this study in and around Kyongnosla Alpine Sanctuary (KAS) situated in the East district of Sikkim (27°N 88°E), India (Fig. 1), between April 2011 and March 2012. The Sanctuary encompasses an area of 31 km^2 with an elevational range of 3000 m to 4200 m. The mountain ranges in the area generally follow an east-west direction. In winter (November-March) the temperature goes down to − 9 °C, with nearly 300 mm of snowfall, while in post-winter (April-October) the temperature reaches up to 20 °C, with 2200–2500 mm of rainfall. The elevation gradient in the study area was classified into four different zones (Table 1). Other than the study species, large mammals in the area include bharal, snow leopard (*Panthera uncia*), Himalayan black bear (*Ursus thibetanus*), red fox (*Vulpes vulpes*), leopard cat (*Prionailurus bengalensis*), golden cat (*Pardofelis temminckii*), Himalayan yellow-throated marten (*Martes flavigula*) and red panda (*Ailurus fulgens*). There were no human settlements inside the Sanctuary. There were many army colonies along the boundary of the Sanctuary and a few small settlements. However, cattle grazing had been banned in all protected areas in Sikkim state, and only low intensity grazing by yak occurred close to the boundary. Therefore, only few trails had signs of grazing by them.

For about half of the year, most of the Sanctuary is covered with snow. In an average year, the snowpack begins to accumulate in November through most of the higher elevations from 3600 to 4200 m. Heavy snowfall typically occurs between December and February and melting of most of the snowpack occurs from March end till April end at the lower elevations ($\ll$ 3600 m) and till early June at higher elevations ($\gg$> 3600). Thus, the total snowpack season ranges between four to seven months at all the elevations.

Methods

In order to estimate habitat use, we deployed 16 camera traps (Bushnell, Trophy Cam), one each on 16 trails selected after overlaying a map of the study area with grids of 1 km × 1 km. Number of cameras in an elevation zone depended on its area as well as the accessibility to the grids (Table 2). The cameras were set about 30 cm above the ground, with one-minute delay between successive activations and were operational during entire study period. All photographs of the same species within an hour at a trap were considered a single record (Bowkett et al., 2007). We divided the study duration into one-week sessions and used the number of photo-captures per week in a camera trap as the indicator of habitat use. For every camera trap, we recorded the geographic location and elevation with a Garmin 60Cx GPS instrument (Datum WGS84). We extracted the aspect and slope for each location at 30 m × 30 m pixel resolution from a 30-m ASTER Digital Elevation Model (GDEM) (METI and NASA, 2011) of the study area.

Data analysis

An excess number of zeros is fairly common in count data in ecology (Martin et al., 2005). This is often generated by two processes. The first process generates zero values because non-zero values are not possible, for example the absence of a species from low or high elevation, with other covariates having no influence. The second process generates count data where zero and non-zero values are expected as a function of different covariates. In such situations, variance in the count part is often greater than mean, showing over-dispersion with reference to Poisson distribution. Therefore, we chose zero inflated negative binomial (ZINB) regression to model the photo-capture data, with a logit model for excess zeros and negative binomial model for the counts (see Martin et al., 2005 for application of zero-inflated models in ecology). These two processes can have separate predictors. Failure to account for zero inflation can reduce the chances of detection of other ecological relations in the data. For each species, we set up five alternate models, each with a logit part which modelled the excess zeros or zero inflation and negative binomial part which modelled the counts (Table 3). These combinations were based on the published literature on the species (see introduction) and exploratory analysis of data collected in this study. The models and results of model selection are described in the results section.

Among the covariates, we treated elevation (Zones I, II, III & IV) and season (winter and post-winter) as categorical variables. How-