Biological Conservation 184 (2015) 251–258

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Snow leopard predation in a livestock dominated landscape in Mongolia

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ARTICLE INFO

Article history:
Received 11 September 2014
Received in revised form 29 January 2015
Accepted 1 February 2015

Keywords:
Gobi desert
GPS collar
Kill rate
Panthera uncia
Prey choice
Wildlife conflict

ABSTRACT

Livestock predation is an important cause of endangerment of the snow leopard (*Panthera uncia*) across its range. Yet, detailed information on individual and spatio-temporal variation in predation patterns of snow leopards and their kill rates of livestock and wild ungulates are lacking.

We collared 19 snow leopards in the Tost Mountains, Mongolia, and searched clusters of GPS positions to identify prey remains and estimate kill rate and prey choice.

Snow leopards killed, on average, one ungulate every 8 days, which included more wild prey (73%) than livestock (27%), despite livestock abundance being at least one order of magnitude higher. Predation on herded livestock occurred mainly on stragglers and in rugged areas where animals are out of sight of herders. The two wild ungulates, ibex (*Capra ibex*) and argali (*Ovis ammon*), were killed in proportion to their relative abundance. Predation patterns changed with spatial (wild ungulates) and seasonal (livestock) changes in prey abundance. Adult male snow leopards killed larger prey and 2–6 times more livestock compared to females and young males. Kill rates were considerably higher than previous scat-based estimates, and kill rates of females were higher than kill rates of males. We suggest that (i) snow leopards prey largely on wild ungulates and kill livestock opportunistically, (ii) retaliatory killing by livestock herders is likely to cause greater mortality of adult male snow leopards compared to females and young males, and (iii) total off-take of prey by a snow leopard population is likely to be much higher than previous estimates suggest.

1. Introduction

Carnivore-caused damage to human interests and welfare is a major obstacle to conservation (Woodroffe et al., 2005). Negative attitudes of local people towards large carnivores are associated with actual or perceived losses such as livestock predation, competition for game animals, or attacks on humans, and can lead to retaliatory killing (Linnell et al., 2001). Thus, one of the key components of carnivore management and conservation is to mitigate losses to local communities through efforts such as better livestock protection (Jackson and Wangchuk, 2004), damage compensation (Maclennan et al., 2009), and creating greater awareness and tolerance (Marker et al., 2003).

Effective management and conservation planning for large carnivores in habitats used for livestock grazing is dependent on reliable estimates of predation pressure on livestock and wild prey. The two key factors to estimate a predators' impact on its prey are kill rate and prey choice. These parameters need to be interpreted in relation to the underlying drivers of predation events (Suryawanshi et al., 2013). These drivers may include: (1) prey profitability and vulnerability: a given prey may be avoided depending on its size or density because the cost of searching or killing outweighs the benefits (Sunquist and Sunquist, 1989), or it may be unavailable for killing (e.g. fenced or housed during particular periods; (Jackson and Wangchuk, 2004); (2) availability of alternative prey: predators may shift the extent of predation if 'easier' or more profitable prey becomes available and some predators may kill

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http://dx.doi.org/10.1016/j.biocon.2015.02.003
0006-3207/

livestock because their natural prey are depleted (Woodroffe et al., 2005); (3) demography: male and female predators may target different prey species or age/sex categories due to sexual size dimorphism, differences in life history strategies (Knopff et al., 2010; Mattisson et al., 2013), or different energetic needs (especially females rearing offspring; Anderson and Lindzey, 2003); (4) seasonality: prey choice and kill rate may show seasonal patterns, for example, when prey exhibits birth pulses the predator could intensify predation on neonates (Sand et al., 2008) or when migration alters prey availability (Sunquist and Sunquist, 1989). Knowledge of how these factors influence predation on natural prey or livestock can allow for more efficient mitigation efforts by directing them to the time periods and areas where predation is most likely to occur.

GPS locations of radio-collared animals can be used to identify possible kill sites, usually represented by spatially aggregated clusters of locations (Anderson and Lindzey, 2003). The snow leopard (*Panthera uncia*) is an endangered apex predator of the high mountains of central Asia that are extensively used for livestock production (Mishra et al., 2003). As with many other threatened large carnivores, livestock predation is a major conservation issue throughout the snow leopard's range (Kyrgyzstan, Jumabay-Uulu et al., 2013; China, Li et al., 2013; India, Mishra, 1997; Mongolia, Shehzad et al., 2012; Nepal, Wegge et al., 2012), often resulting in retaliatory killings (Li and Lu, 2014), and in some areas, possibly exacerbated by wild prey depletion (Bagchi and Mishra, 2006; Jackson et al., 2010). Correlative evidence suggests that livestock predation is primarily determined by the local abundance of snow leopards and their wild prey (Suryawanshi et al., 2013). Previously, attempts to search for kills from VHF-radio-collared snow leopards were deemed too difficult (Jackson, 1996), and consequently, predation patterns were inferred from faecal analyses (e.g. Jumabay-Uulu et al., 2013; Shehzad et al., 2012; Wegge et al., 2012) which does not allow for an understanding of the temporal, spatial or individual variation in prey choice. Thus, reliable individual based estimates of snow leopard kill rates or the understanding of individual variation in prey choice have been lacking.

We present robust information on kill rates and prey choice of individual snow leopards of various age–sex categories (adult males, young males, single females and females with cubs). We radio-collared 19 snow leopards and by examining their prey-choice, we try to understand if livestock predation is opportunistic or whether snow leopards actively seek out livestock. We compare predation patterns of various age–sex categories, given that in large carnivores, males and sub-adults are considered to be more predisposed to killing livestock due to their wide-ranging movement or tendency to take greater risks (Linnell et al., 1999). We specifically seek to answer the following questions:

(1) How often do snow leopards kill wild ungulates and livestock?
(2) Are there seasonal variations in livestock predation?
(3) Are there differences in predation patterns on livestock and wild ungulates among snow leopard sexes and age/physiological classes?
(4) Do individual snow leopards maintain their diet composition or do they change their diet in response to spatial variation in prey abundance?

2. Materials and methods

2.1. Study area

This study was conducted over an area of c. 1700 km^2 in the Tost Mountains in South Gobi, Mongolia (43°N, 100°E), from September 2008 to November 2013. Tost consists of several rugged mountain massifs traversed by valleys and steep canyons (elevation ranges 1800–2500 m). Annual precipitation is <130 mm/year and temperatures range from −35 °C to 38 °C with strong winds year around.

Approximately 90 herder families live in the study area. The herders are semi-nomadic and move several times during the year; living in flatter areas in summer and in mountainous areas in winter to shelter from the cold winds (Traditional knowledge, B. Agvantseeren Pers. Communication). Their livestock are comprised of ∼32,000 goats (*Capra aegagrus*) and sheep (*Ovis aries*), ∼1100 camels (*Camelus bactrianus*), and ∼120 horses (*Equus ferus caballus*). Horses and camels were largely free-ranging in small herds, predominantly in the plains or the lower, less rugged parts, whereas goats and sheep were actively herded and penned close to campsites at night.

Among wild ungulates, Siberian ibex (*Capra sibirica*) were common throughout the rugged parts of the mountains and argali (*Ovis ammon*) occurred mainly in the rolling hills in the northern and western parts of the study area (Tumursukh, 2013). A preliminary survey found 429 ibex and 11 argali or ∼59 ibex/argali in the Southern range and 221 ibex and 74 argali or ∼3 ibex/argali in the Northern range (K. Suryawanshi, unpublished data). Horses and camels mainly occurred in the Northern range whereas goat and sheep were evenly distributed. Smaller potential prey species included Tolai hare (*Lepus tolai*), chukar partridge (*Alectoris chukar*) and various rodents. Sympatric predators and scavengers included wolf (*Canis lupus*), lynx (*Lynx lynx*), red fox (*Vulpes vulpes*), marten (*Martes* spp.), bearded vulture (*Gypaetus barbatus*), golden eagle (*Aquila chrysaetos*), black vulture (*Aegypius monachus*) and raven (*Corvus corax*).

We used Vector Ruggedness Measures to capture and describe the spatial variation in topography within the study area. This estimates terrain ruggedness based on variation in three-dimensional orientation between neighbouring cells in a grid, where values can range from 0 (no variation) to 1 (complete variation). We used eight neighbouring grid cells to estimate ruggedness, each with the size of 250 m^2.

To understand how snow leopards responded in their prey choice with changes in local prey abundance, we divided our study area into Southern (556 km^2) and Northern (807 km^2) ranges. The Southern range (mean ruggedness 0.089 (±0.0001 SE)) was more rugged and mountainous than the Northern (mean ruggedness 0.058 (±0.0001 SE), Fig. 1).

2.2. Snow leopard captures and cluster visits

Snow leopards were captured in foot-snares, chemically immobilized and equipped with GPS collars (North Star, King George, USA) in 2008–2009 and GPS-Plus collars (Vectronic Aerospace, Berlin, Germany) in 2010–2013 (Johansson et al., 2013). Collars were programmed to take one GPS fix every seven and five hours for the North Star and the Vectronic collars, respectively, and immediately uplinked data via satellite communication (Globalstar). GPS position clusters were investigated for 16 snow leopards (eight males, and eight females, of which two males transitioned from young to adult and three females transitioned between single to females with cubs during the study). Age was estimated by body size, coloration and wear of teeth and presence of facial scars where all adult males were severely scarred (Johansson et al., 2013). Snow leopards younger than 3.5 years were categorized as young.

We assumed that a kill site of a large prey will result in a cluster of GPS locations close to each other given the propensity of large carnivores to stay for extended periods at their kills (Anderson and Lindzey, 2003; Sand et al., 2008). However, all clusters of GPS locations are not necessarily kill sites, e.g. they can be