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Cover: Himalayan Gray Langur *Semnopithecus ajax* (adult female) © Rupali Thakur.



Kleptoparasitic interaction between Snow Leopard *Panthera uncia* and Red Fox *Vulpes vulpes* suggested by circumstantial evidence in Pin Valley National Park, India

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Abstract: In the present study, we describe an interspecific kleptoparasitic interaction between two sympatric mammalian carnivores in the high altitudinal Trans-Himalaya region of Himachal Pradesh, India. The study was based on the inferences drawn from the circumstantial evidence (direct and indirect) noticed in the study area in Pin Valley National Park. The inferences from the analysis of the evidence suggested the interaction between a Snow Leopard *Panthera uncia*, a Red Fox *Vulpes vulpes*, and a donkey. The arrangement of evidence in a sequential manner suggested that a donkey was killed by a Snow Leopard and a Red Fox stole the food from the carrion of the Snow Leopard's prey. The Red Fox was killed by the Snow Leopard, which was caught while stealing. The present study represents an example of kleptoparasitic interaction between the Snow Leopard and the Red Fox. This study also proves that such interactions may cost the life of a kleptoparasite and supports the retaliation behaviour of Snow Leopards.

Keywords: Animal interaction, carnivore, mammals, prey, Trans-Himalaya.

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Author details: VIPIN was working as a research associate II in the Snow Leopard project at LaCONES, Centre for Cellular and Molecular Biology, Hyderabad, Telangana. TIRUPATHI RAO GOLLA was a senior research fellow in the Snow Leopard project at LaCONES. VINITA SHARMA is an assistant professor in the Department of Zoology, Central University of Jammu, Jammu and Kashmir. Her area of research is related to animal taxonomy, systematics and behavior, wildlife and conservation biology, human-wildlife conflict, wildlife forensics, comparative anatomy and geometric morphometrics. BHEEMAVARAPU KESAV KUMAR was working as a Junior Research Fellow in the Snow Leopard project at LaCONES. AJAY GAUR is a senior principal scientist and was the principle investigator of the Snow Leopard project at LaCONES, CSIR-CCMB, Hyderabad. The main area of his research is conservation genetics of Indian endangered species. His research focuses on the development and application of DNA markers in population genetics, evolutionary genetics, conservation breeding and wildlife forensics.

Author contributions: V, VS, AG designed the study; V, VS, TRG collected the data; V, VS, AG analysed the data and wrote the paper; TRG, BKK did the proofreading; and AG supervised the study.

Ethics statement: All data and samples were collected with due permissions of the state forest department. All ethical conditions implemented by the project running institute have been followed.

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INTRODUCTION

Species interaction is an important component of an ecological community, which also works as a balancing force in it (Purves et al. 1992). Species interactions are direct (predation and interference competition) and indirect (trophic cascades and exploitative competition) (Case & Gilpin 1974; Estes & Palmisano 1974; Menge & Sutherland 1987; Paine et al. 1990; Bengtsson et al. 1994; Wootton 1994; Menge 1995). Kleptoparasitism is a form of indirect exploitative competition that refers to the stealing of any kind of resources by intra- or inter-specific members of a community (Webster & Hart 2006; Iyengar 2008). The member that steals the resource is called a kleptoparasite, and the other is the host. Kleptoparasitic interactions can influence the evolution of behavior and morphological traits of host and kleptoparasite (Iyengar 2008). The interspecific kleptoparasitic interactions may affect the entire ecosystem if the host, which also happens to be the apex predator, has a depleted prey base. Despite many studies carried out on species interactions, very little information on their effects, direct or indirect, on food webs involving terrestrial mammalian carnivores, particularly on keystone species, is available (Terborgh & Winter 1980; Pianka 1988; Pimm 1991; Strauss 1991; Terborgh 1992; McLaren & Peterson 1994; Palomares & Caro 1999). Therefore, studies throwing light on such interactions, more particularly involving apex predators, need to be carried out. Kleptoparasitism is a type of competition that may occur (intra- or inter-specific) between unrelated individuals (Iyengar 2008). The present study documents one such example of inter-specific kleptoparasitic interaction between two sympatric mammalian carnivore species. The two species are Snow Leopard and the Red Fox. The former is a keystone species of the high mountain ecosystem in the western Himalaya of India as it has a disproportionately larger impact on its ecosystem relative to its abundance (Bhatnagar et al. 2001; The Snow Leopard Conservancy 2007). The study was part of a larger study carried out by us on the genetic diversity and conservation status of Snow Leopards *Panthera uncia* in India from 2011 to 2013. Based on inferences drawn from the observations, we tried to show how interspecific kleptoparasitic interactions may affect the lives and behaviour of participants.

MATERIAL AND METHODS

The Pin Valley National Park (31.11°–32.03°N & 77.70°–78.10°E), Himachal Pradesh, India was the study site (Image 1). The National Park is situated in the Spiti Subdivision of Lahaul and Spiti district, a Trans-Himalayan cold desert mostly occurring above 3,200 m and a stronghold of Snow Leopards and Himalayan Ibex (Anonymous 2008). The kill sites were carefully marked for incidents, measured, and ad libitum information on the carcasses and spoor was recorded. Along with that, the data in the form of opportunistic evidence (direct and indirect) of suspected animal interactions were also recorded with details of time, date, and location. All evidence was photographed with the help of a DSLR camera (Sony alpha 35) and georeferenced with GPS (eTrex 10, Garmin). The evidence found in the study is denoted here by the numbers in brackets. The area between the entry point of the National Park and Thango (7.6 km) was walked on foot for three days from 1 to 3 May 2012 (Image 1). The natural animal trails were walked on foot for a total length of 15.68 km in 15.59 days hours, the details of which are as follows: May 1: 2.38 km from Ka Dogri to Gechang Base Camp (2.45 hours), May 2: 09.25 km to the west and back (8.05 hours), May 3: 4.05 km to the east and back (5.09 hours). It is to be noted that while returning to the base camp, the track followed was always 30–100 m apart from the track covered in the reverse direction. The scrapes and pugmarks were identified as per the 'Snow Leopard Survey and Conservation Handbook' (Jackson & Hunter 1995). The scats were identified as per the 'Scat Survey Methodology for Snow Leopards' (Janecka et al. 2008). The flies were identified using morphological identification keys by Szpila (2009). The beetle identification was carried out using the Encyclopaedia of Life' (<https://eol.org/pages/3383922/media>).

RESULTS

On May 2, 2012, after walking around 3.4 km from the base camp at Gechang, a strong smell of something rotting attracted us to the carrion of a donkey (1) (Image 2A, 3A). A scat, possibly of Red Fox *Vulpes vulpes* or a Snow Leopard (2), was lying nearby (approx. 6 m) (Image 2A, 3B). About 30m away from the donkey carrion, a Red Fox was lying dead on the bank of the Pin River (3) (Image 2A, 3C). We labelled the area between the dead donkey and the Red Fox as an "incident site" near (approx. 2 m) the dead Red Fox was a scapula bone from the same dead

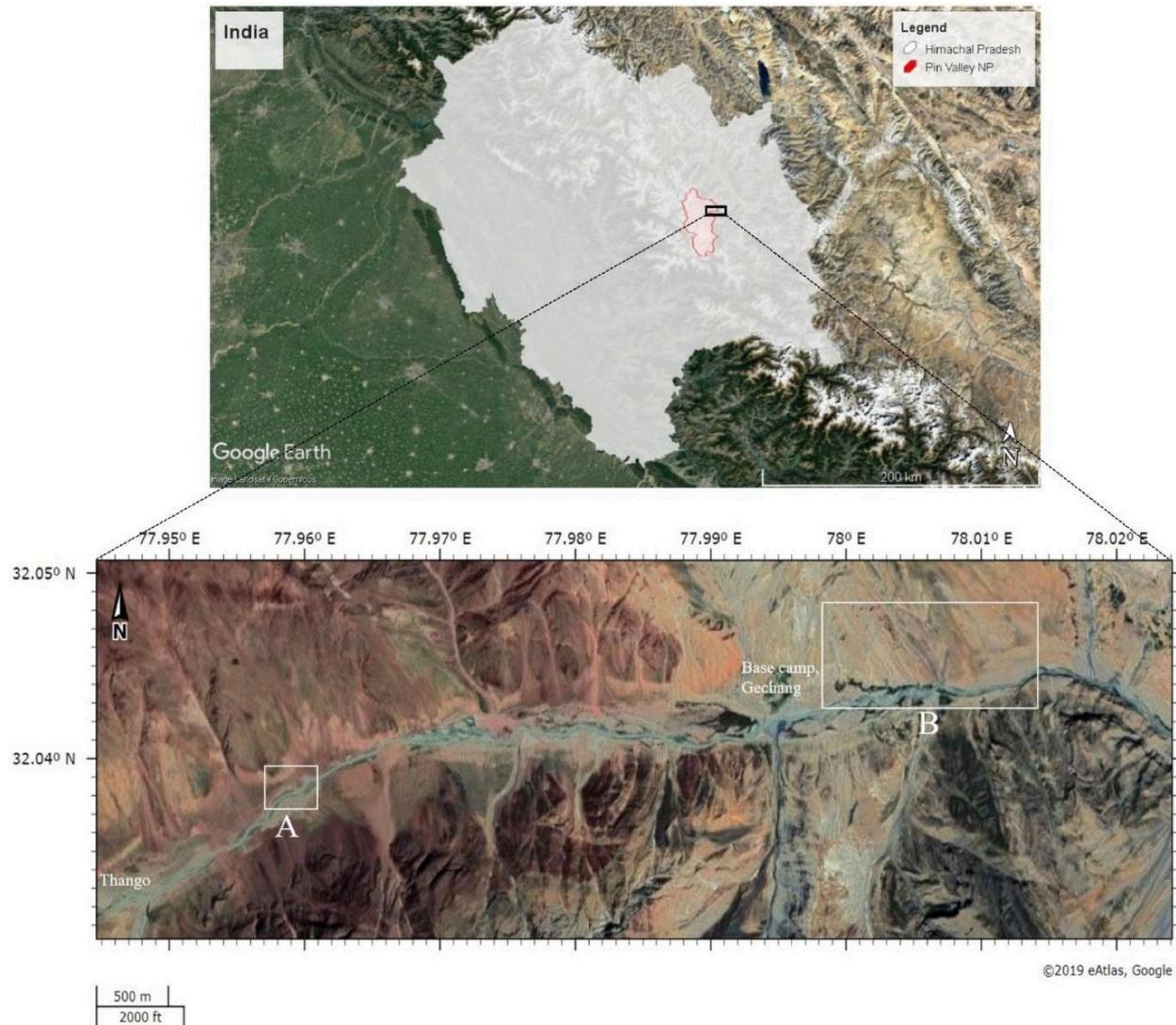


Image 1. The inset shows study area in Pin Valley National Park (Pink colour polygon with red boundary) in the state of Himachal Pradesh (White colour polygon). The areas marked as 'A' and 'B' with white boundaries shows the data collection sites.

donkey (4) and a scat (5) suspected of a Snow Leopard (Image 2A, 3D). The pugmarks of Snow Leopards were found about 120 m before the incident site (6) (Image 2A, 3E). There were wounds on the left lateral side of the Red Fox, from the neck to the mid-body, and flies were also found sitting on and around its body (Image 3F). On close observation of the fox's body, pale-yellow maggots and beetles were found on the left side of the mouth (Image 3G). Some relevant observations made about the presence of Snow Leopards in Pin Valley National Park are as follows: On May 1, many pugmarks of suspected Snow Leopards were found on the bank of the Pin River about 1 km east of the base camp (7) (Image 2B, 4A). On May 3, scrapes and urine (8) (Image 4B) of a suspected Snow Leopard were found on the slope near the base

camp. Further investigation led us to an overhang resting site (9) where pugmarks of a suspected Snow Leopard (10) and exposed bone (11) were found inside it (Image 4C). Further tracing the pugmarks (12, 13, 14) (Image 4D), a freshly killed Blue Sheep (15) (Image 4E) (without any larvae and smell) was found over the den on a ridge (approx. 300 m above the Pin River). Nearby (approx. 6 m away), we found a scat, suspected to be of a Snow Leopard (16) (Image 4F). The inferences drawn from the above evidence, if connected in the correct order, may help draw a sequence of events that might have taken place between the animals involved. Flies of blue metallic color were found on and around the Red Fox's body. These were identified as blowflies. The blowflies feed on carrion and belong to the family Calliphoridae of

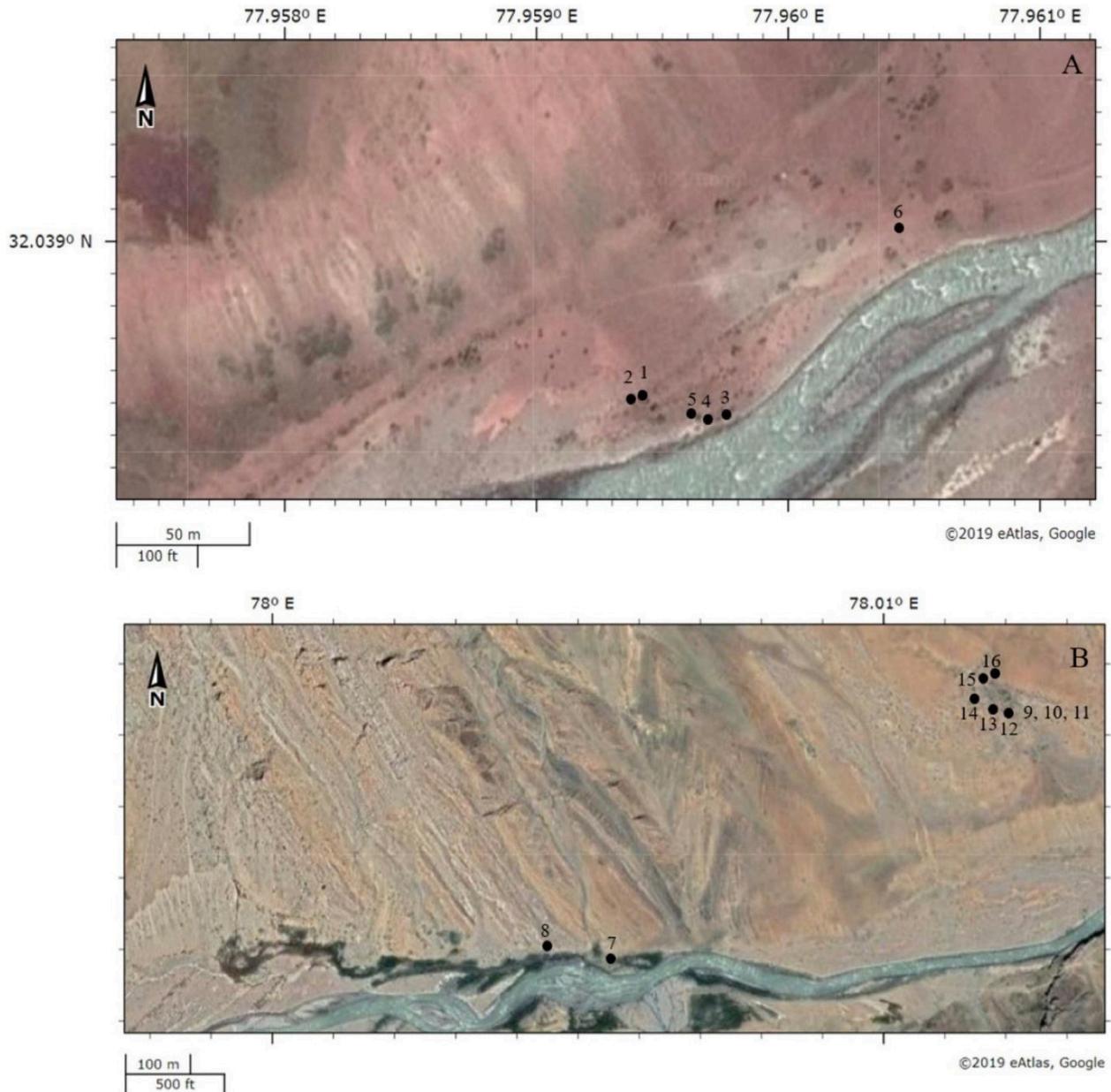


Image 2. A—evidence (1–6) recorded from the incident site on May 02 | B—evidence recorded before the base camp on 01 May (7) and 03 May (8–16).

class Insecta (ITIS 2008). A large number of larvae were present on the body of the Red Fox and no smell was coming out of it, indicating it was in the bloated stage of decomposition (Matuszewski et al. 2008). The blowflies lay eggs on carrion and, after that, the development of larval (pale yellow) stages, from the first instar to the third instar, generally takes place between 23 to 72 hours (Jordan et al. 2018). The beetle on the Red Fox's body identified, on morphological resemblance, as *Thanatophilus minutus*. *Thanatophilus minutus* is also a carrion beetle having distribution in Himachal Pradesh

and is known to arrive on carrion after the blowflies (Ruzicka et al. 2011; Tariq 2020). *Thanatophilus* species larvae are darker in colour (Diaz-Aranda 2013) and did not match, in morphology, to the larvae found on the Red Fox. The donkey's carrion had a foul odor, no insect larvae were found on it, and the meat was dried. This indicated that it might either be in the active or the advanced stage of decomposition (Matuszewski et al. 2008). All this evidence proved that the donkey was killed earlier than the Red Fox. The incidents that happened, point towards the involvement of three



Image 3. A—Donkey carrion | B—Scat of either a Snow Leopard or Red fox | C—Carrion of a Red fox | D—Scapula of dead donkey and scat of suspected Snow Leopard | E—Pugmarks of suspected Snow Leopard | F—Wounds on Red fox's body and flies sitting around it | G—Maggots (in dotted circle) and beetles. © Vinita Sharma & Vipin.

species, i.e., a donkey, a Red Fox, and a Snow Leopard. There is no doubt about the donkey and Red Fox, as their carcasses were present. The pugmarks (6) (Image 2A; near the incident site), scat (5) of uniform diameter of 2.0 cm, segmented, with blunt ends, and having the presence of hairs in it point towards the involvement of a Snow Leopard. A Snow Leopard scat has an average diameter of 1.8 cm, which is uniform along its length, having constrictions and blunt ends (Janecka et al. 2008). The pugmarks (6) were identified as those of a Snow

Leopard according to Jackson & Hunter (1995), which is the only large cat present in that habitat (Anonymous 2008). The shape and size of the scat (5) confirm the presence of Snow Leopard in and around the incident site. The Snow Leopard pugmarks were found frequently throughout the Pin Valley National Park on 1 & 3 May 2011. The pugmarks found near the bank of the Pin River on May 1 were found to be of Snow Leopard (Figur 4A). All the pugmarks and scrapes found on May 03 were from Snow Leopard. The scat '16' was confirmed



Image 4. A—Pugmarks of suspected Snow Leopard | B—Scrap and urine | C—Den and pugmarks of a suspected Snow Leopard and a bone | D—Pugmarks of suspected Snow Leopard | E—Carriion of a freshly killed blue sheep | F—Scat of a suspected Snow Leopard. © Vinita Sharma & Vipin.

to be of a Snow Leopard through the genetic analysis done at our laboratory (study unpublished). The Grey Wolves and Brown Bears are known as kleptoparasites of the Snow Leopard (Hunter 2015). But no signs of Wolf or Brown Bear pugmarks were found on the tracks we covered between 1 & 3 May in the valley. A full-grown Snow Leopard hunts a large prey every 10–15 days and remains near it for about 3–7 days until it is finished (McCarthy & Chapron 2003; Hunter 2015). The presence of scat (5), which only could be of a Snow Leopard, as per its shape and measurements, in the vicinity of the dead donkey and the Red Fox, points out that, most probably, both were killed by the Snow Leopard at different times. The presence of donkey scapula (4) near the body of the dead Red Fox indicates that it was stealing the meat from the dead donkey during which it was killed by the Snow Leopard. On arranging all the above findings, the inferences can be drawn from the circumstantial

evidence that a donkey was killed by a Snow Leopard. Since a Snow Leopard takes 3–7 days to consume its prey, the Red Fox was stealing the food from the Snow Leopard's kill. At some time, the Red Fox was caught stealing food by the Snow Leopard and was killed. There are records of a Red Fox being accidentally killed by a Snow Leopard (Hunter 2015). The present findings point toward the first incident of kleptoparasitism by a Red Fox on a Snow Leopard in Pin Valley National Park, Himachal Pradesh. This incident of kleptoparasitic interactions between two sympatric mammalian carnivores also reveals the retaliatory behaviour of the Snow Leopard. The retaliatory behavior may be advocated as the Red Fox's body remained uneaten even after 23–72 hours of being killed as suggested by the presence of blowflies larval stages.

DISCUSSION

The evolution of the morphology and behaviour of participants may be influenced by kleptoparasitism (Iyengar 2008). Among the varied types of responses of a host towards a kleptoparasite, the host may retaliate if the kleptoparasite is large and can consume a substantial part of its kill (Iyengar 2008). In such conditions, a host can injure or kill the kleptoparasite (Iyengar 2008). There are many examples of it. The food of predatory birds is stolen by smaller birds (Meinertzhagen 1959), stealing of sea star's food by whelks (Rochette et al. 1995), and many spiders are killed by larger hosts while stealing their food (Whitehouse 1997). The present case suggests an example of retaliatory behaviour in Snow Leopards in Pin Valley National Park. A survey on interspecific killings among mammalian carnivores revealed that the Red Fox was the most affected victim as a kleptoparasite than other species of canids, mustelids, and felids to the killer species belonging to the families of felids and canids (Palomares & Caro 1999). There is one report of kleptoparasitism by Snow Leopards from Hemis National Park, India (Hunter 2015). The accessibility of alternative prey may be a decisive factor for interspecific mammalian carnivore killing and consumption (Macdonald 1977; Polis 1981; Ackerman et al. 1984; Stephenson et al. 1991; Palomares & Caro 1999) because the diets of sympatric carnivores often overlap (Kruuk 1972; Delibes 1980; Major & Sherburne 1987; Lindstrom 1989; Smits et al. 1989; Theberge & Wedeles 1989; Paquet 1992; Mills & Biggs 1993; Palomares 1993; Okarma 1995; Okarma et al. 1997; Palomares & Caro 1999). It has been reported that a killer species eats its prey completely, partially, does not eat, or never eats (Palomares & Caro 1999). However, the victim's characteristics have been found to make no difference in the consumption by a killer species (Palomares & Caro 1999). The other records of a Red Fox as a kleptoparasite are from central and southeastern Europe (Krofel et al. 2019). Therefore, the partially eaten-up blue sheep's body by the Snow Leopard and the presence of its alternative prey (the donkey carrion), other than the natural prey (Thiele 2003), in a sympatric habitat might also have been the reasons for the uneaten Red Fox's body which is further indicative of retaliatory behaviour in Snow Leopards. The differentiation between different larval stages of blowflies was not done here, so we gave the general time range (23–72 hours) for development from the first instar to the third instar larvae. If we compare the blowfly's larval development between the average temperature range 16°–22°C, then the time

taken for the appearance of the first instar to the third instar comes in the range of 52–96 hours (Zhang et al. 2019). Therefore, the larvae found on the body of the red fox might be 2–4 days old. The insect's development varies at different temperatures and so at different habitats. Hence, it is very difficult to estimate the precise death time of an animal through forensic entomology until specific studies on blowfly development are available from that area. Comprehensive knowledge of kleptoparasitic interaction between Snow Leopard and Red Fox as well as among other sympatric carnivores is very important in Pin Valley National Park and similar habitats across the country. Because any future decline of an apex predator may jeopardize the animals at lower trophic levels through the release of mesopredators (Castle et al. 2021).

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