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Anthropogenic food subsidies change the pattern of red fox diet and occurrence across Trans-Himalayas, India

Hussain S. Reshamwala[a], Shivam Shrotriya[a], Bhaskar Bora[a], Salvador Lyngdoh[a], Rodolfo Dirzo[b], Bilal Habib[a,*]

[a] Wildlife Institute of India, Dehradun 248001, India
[b] Department of Biology, Stanford University, California 94305, USA

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ABSTRACT

The anthropogenic food subsidy in the diet of animal populations is known to have negative ecological and physiological impacts on wildlife. The red fox (*Vulpes vulpes*), a generalist species living close to human habitation, often has access to garbage dumps. We studied the dietary pattern of red fox in the cold desert of the Trans-Himalayas in India, where natural resources are limited. We analysed a total of 1264 scats across six representative sites and examined red fox occurrences as a response to the availability of anthropogenic subsidies. We found that human subsidies contribute substantially (maximum 55.87%) to red fox diet. Red fox occurrence significantly increased with the increase in consumption of the food items originating from human subsidies ($R^2 = 0.85$, $p = .008$). Red foxes consumed less wild prey (rodents and lagomorphs) where there was an abundant supply of human subsidies. We found that dog presence negatively affected the consumption of human subsidies by the foxes. We posit that local cultures and religious practices might have played an indirect role in determining the red fox diet and occurrence. Our study recommends that management of anthropogenic subsidies is crucial to keep the wild populations healthy.

1. Introduction

Human activities have taken central stage in global ecological change (Oro et al., 2013). Food resources originating from human activities, including agricultural products, unmanaged waste and kitchen offal, are getting increasing recognition in the diet of animal populations both within natural and in human-dominated settings, given that it is increasingly available to the animals globally (Gloor, 2002; Oro et al., 2013). Optimal foraging theory emphasises that animals promote their fitness by foraging in ways that maximise their net rate of energy gain (MacArthur and Pianka, 1966). Anthropogenic subsidies are one of the most easily procurable food sources and often exploited by species living in close quarters with human habitation. Subsidies impact the food web dynamics (Polis et al., 1997; Marczak et al., 2007) and species have responded with changes in fecundity (Beckmann and Lackey, 2008), territoriality (Newsome et al., 2013), tolerance of conspecifics (Herrero, 1983), weight gain (Rogers, 1976; Lunn and Stirling, 1985), survival (Bino et al., 2010), reduction in daily activity and increase in resting time (Altmann and Muruthi, 1988).

Red fox (*Vulpus vulpus*) is known for its generalist and opportunistic behaviour across its geographic distribution (Macdonald, 1983). It is one of the most extensively studied carnivore species found in a wide range of habitats, ranging from arctic to subtropical regions (Nowak, 1999). However, in the arid Trans-Himalayan cold mountainous landscape there have been very few studies pertaining to this animal. Despite living in human-dominated landscapes, red fox is rarely sighted owing to their highly elusive and secretive behaviour. Red fox of the Trans-Himalayan region belongs to the oldest lineage of the fox, the Holarctic clade (Statham et al., 2014). Aubry et al. (2009) found that mountain red foxes are unique both in size and habitat affinities and maybe threatened in portions of their historical range. Habitat alteration, invasion of dogs and increasing road traffic are cited as some of the major threats to their populations (Baker et al., 2004; Vanak and Gompper, 2009). However, foxes often occur in high densities near farmlands (Panek and Bresinski, 2002) and are known to feed upon human resources (Doncaster et al., 1990; Serafini and Lovari, 1993).

In a developing country like India with a large human population and improper garbage disposal mechanisms, animals encounter ample opportunities to feed on garbage dumps. However, the human population in the Trans-Himalayan region of India occurs at low density ($4.9/km^2$) and is highly clustered (Chandramouli, 2013). The Trans-Himalayan region is a highly inhospitable cold desert biotope with a

* Corresponding author. Department of Animal Ecology and Conservation Biology, Wildlife Institute of India, Dehradun 248001, India.
E-mail address: bh@wii.gov.in (B. Habib).

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short summer and Arctic-like winters (Mishra and Humbert-Droz, 1998). Arid ecosystems, including the Trans-Himalayas, are characterised by low ecosystem productivity and in turn low animal densities (Schweinfurth, 1984). Therefore, we assume that low availability of natural resources might lead foxes to seek for food resources close to human habitation. However, dogs too occur at higher densities in areas with a high human population (Odell and Knight, 2001) and could play an indispensable role in determining fox population via a number of negative impacts. Indeed they are often known to harass red foxes, compete with them for resources (Butler et al., 2004; Vanak and Gompper, 2009), spread diseases like rabies, canine distemper and parvovirus (Vanak et al., 2009) and thus, pose a distinct threat to wildlife (Doherty et al., 2017). Here, we studied the diet of red fox across the Trans-Himalayan landscape in India and examined red fox occurrences as a response to anthropogenic factors such as food subsidies and presence of dogs.

2. Materials and methods

2.1. Study area and sites

The Indian Trans-Himalayan landscape spreads across the northern border of the country along Tibet (China) and Nepal. The Trans-Himalaya is a high altitude dry rugged terrain having an annual precipitation of about 100 mm (Hartmann, 1983). Precipitation is in the form of snow, and the average altitude varies from 2800 to 7000 m above sea level. The climate is cold and arid with temperatures dropping down to -30 °C in winters, providing a short growth season for plants between May to August (Bagchi et al., 2012). The region is sparsely populated and patchy with a human density of only 4.9 individuals/km^2 and most of the people are locally engaged in traditional pastoralism and agro-pastoralism (Schaller, 1998; Chandramouli, 2013). The vegetation is very sparse with the alpine meadows dominated by *Kobresia* spp., *Carex* spp., *Potentilla* spp., and *Nepeta* spp. and shrublands dominated by *Hippophae* spp., *Salix* spp., and *Myricaria* spp. (Kachroo et al., 1977). There are no trees except for few isolated patches of *Juniperus indica*, *Juniperus macropoda* and *Betula utilis* in the wild and *Populus* spp. and *Salix* spp. in cultivation.

We conducted intensive sampling in six representative sites across the landscape-five within the Trans-Himalayas (Chiktan, Khalse, Leh, Spiti and Uttarakhand) and one in the Himalayas (Dachigam National Park). The sites varied from each other for the presence of human settlement, the presence of dogs and agricultural practices (Table 1).

Table 1
Description of study sites and sign encounter rate of red fox in the Trans-Himalayan landscape, India.

	Chiktan	Khalse	Leh	Spiti	Dachigam	Uttarakhand
Permanent settlements	+	+	+	+	–	–
Dog presence	–	*	+	+	–	*
Apricot plantation	–	+	+	–	–	–
Area (km^2)	58.54	21.66	65.27	137.74	76.37	227.02
Distance walked (km)	17	16.11	33.22	35.72	102.39	265.5
Number of fox sightings	11	5	4	0	0	2
Number of fox dens	4	1	4	0	0	0
Number of scats	334	115	356	129	183	147
Number of den scats	163	3	157	0	0	0
Sign encounter rate (SER sign/km)	10.94	7.32	6.23	3.61	1.78	0.56

+ Presence, − Absence, * Less than 5 dogs.

We included Dachigam National Park in Kashmir valley where red fox is present in non-arid habitat at tree-line.

2.2. Collection of samples

We collected and analysed a total of 1264 scats of red fox (Fig. 1, Table 1). While we collected scats at all other sites during February 2015 to August 2015, scats at Dachigam National Park were collected during January 2013 to December 2014. Scats were searched and picked on naturally occurring trails at the study sites. We tried to maximise the effort and the trails were never walked more than once. Trails were walked by a team of two to three researchers. Scats of red fox and dogs were identified and distinguished in the field based on shape, size, odour and quantity typical to that of the relative species, following a standard protocol (Vanak and Mukherjee, 2008). We searched for the burrows and rock crevices while walking the trails and wherever we could locate the fox dens, we collected additional fox scats.

2.3. Laboratory analysis

The scats were first weighed and then washed in running water through a fine sieve of BSS 120 having a pore aperture width of 125 µm so that the digested material could pass through the sieve. Indigestible items including hair, feathers, bones, claws, teeth, chitin remnants of insects, seeds, grasses and other plant material and human-derived materials (HDM) such as cloth, paper, plastic and rubber were collected for further identification. After drying the derived mammalian hair and avian feather samples in an oven at 40 °C for 48 h, sampled pieces were mounted on a slide and observed under a microscope, taking care of placing all different hair types when more than one prey was consumed. The medullary hair pattern was compared with reference to hair samples collected from the field as well as with a reference guide (Bahuguna et al., 2010). Samples showing ambiguity or too little indigestible content were excluded from further analysis (N = 96). Diet was analysed both for occurrence of food items and prey biomass consumed.

2.4. Statistical analysis

Percent occurrence of a food item (scats with food item i/number of scats) × 100, was calculated to compare consumption. Prey biomass consumed was calculated using digestibility coefficients calculated by Goszczynski (1974) and Lockie (1959) for most of the prey items except large mammals. Top-predators such as wolf, snow leopard or dog usually consume most of the flesh and soft organs of large prey, and red fox is left only to scavenge the bones and hides with very little flesh. Therefore, we kept the digestibility coefficient at 15 (Jedrzejewski and Jedrzejewska, 1992) instead of 118 (Lockie, 1959) in case of calculating biomass consumption for large prey. We calculated percent biomass as (dry weight of remains of prey item i × digestibility coefficient/total biomass) × 100. We did not calculate biomass consumption in Dachigam National park because the dry weight of the scats was not available.

2.5. Sign encounter rate (SER)

In areas with low rainfall, the faecal count could be a reliable approach towards estimating the fox abundance (Cavallini, 1994). Indirect methods like faecal count are cost effective and are potentially more practical for large-scale surveys especially when direct sightings are poor. Faecal counts have been used as a relative index of density for canids (Cavallini, 1994). Webbon et al. (2004) suggest that faecal density counts have the potential to be used to estimate fox density over large spatial scales. In this study, we utilised faecal count along with other signs like direct sightings and den sites to estimate relative fox