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Acute cold stress: a potential threat to Royle's pika (*Ochotona roylii*) survival at Central Himalayas of Nepal

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Climate change and its threat to human life and biodiversity are under discussion as the major issue of this century. In this study, pika (*Ochotona roylii*) was taken as a model animal to study the effect of changing climatic parameters in the Central Himalayas of Nepal. The study was carried out for three consecutive years (2011−2013) in the Kyanjing Valley situated at 3900 m asl, Langtang National Park, Nepal. The study focused on the population density of pika, its lowest elevation distribution, and temperature patterns of the pika-burrows and their immediate surroundings. An iButtons Temperature Recorder was installed inside a pika-burrow for acquiring burrow temperature while the ambient temperature data were obtained from the nearby metrological station. The population density of pika decreased compared to those based on the previous studies. Over the last 25 years, there was a significant increase in the minimum temperature (R^2=0.77) that decreased the snow cover which might have reduced the insulation effect and colder winter to animals living inside the burrow. The temperature inside the burrow was recorded below −5°C for nearly 50% time during January alone and 25% time during total winter days. The environment with a temperature below −5°C could be a threat to the survival of pikas suffering from acute cold stress. Neither there was any record of heat stress (above 25°C) recorded nor there was an increasing trend of the ambient maximum temperature within the LNP during the study period. The lowest elevation of the pika's habitat was found to have shifted 200 m upwards over the last 46 years, indicating that the animals had either migrated upwards or facing extinction locally at lower elevations. However, this short-term study is not sufficient to reflect the effects of climate change on the population of pika in the Central Himalayas. Therefore, a long-term study is required to explore the relation between pikas and their vulnerability to the changing climate.

Keywords: Extinction, hyperthermia, hypothermia, iButtons, Langtang National Park

Climate change is one of the contemporary threats to biodiversity worldwide both individuals and population in animal communities (Isaac, 2009). Climate change and its effect on the species might be one of the more difficult challenges faced by any natural resource manager. It is expected that the global temperature could rise by as much as 6.4°C by the end of the twenty-first century (IPCC, 2007). Many taxa response to inter-annual fluctuations in precipitation, temperature, and extreme climatic events over ecological and evolutionary timescales (Post & Forchhammer, 2002). The abundance, distribution, and demography of

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animals are known to track climate-related variables over a wide range of spatial and temporal scales (Post & Stenseth, 1999). Organisms especially distributed and restricted to narrow fragmented habitats are particularly threatened by climate change (Peters, 1985). Species adapted to cold climatic environments are more vulnerable to global warming (Hughes, 2000) since the rate of climate change is higher in alpine areas (Naftz *et al.*, 2002).

Figure 1: A Royle's pika in its natural habitat (photo: NPK)

Pikas are saxicolous (rock-dwelling) groups inhabiting a diverse range of environments, from mid-elevation forests and steppes to high alpine talus, specific to microhabitat and microclimate on higher peaks in the Himalayas (Hoffmann & Smith, 2005; Reese & Roles, 2014; Smith *et al.*, 1990). Royle's pika also called "Himalayan mouse hare" (*Ochotona roylii,* previously *Ochotona roylei*) is a small, mountain-dwelling mammal that inhabits the Himalayas and Tibetan Plateau (Figure 1). It has been listed under "least concern" in the IUCN Red List (IUCN, 2016) Pikas have short limbs, a round body, and even coat fur (Smith *et al.*, 1990). The thin abdominal skin, high metabolic rate, poor heat dissipation and high body temperature of 40.1°C (MacArthur & Wang, 1973; Kawamichi, 1998) force them to adapt to cold and high altitude environments (Primack, 1998). They are supposed to be extremely temperature-sensitive and are non-hibernating species. Therefore, pikas are supposed to be vulnerable to global climate change (Rodhouse *et al*., 2010). Pikas are living in sky islands (Koju *et al*., 2017) which cannot easily move to higher altitudes or northward latitude for cold as their habitat is usually fragmented and restricted to small areas (Deo *et al*., 2008). They may suffer from hyperthermia or death after brief exposure to an ambient temperature above 25°C (Smith, 1974) and hypothermia causing acute cold stress below −5°C temperature (Beever *et al*., 2010). Therefore, we aimed to explore the pika's survival threat due to acute cold stress in the Kyanjing Valley of the Langtang National Park (LNP).

Materials and methods

Study area

Langtang National Park is located in the central Himalayas of Nepal between 85°15'− 86°0' E longitudes and 28°20'−28°32' N latitudes. Langtang Lirung (7,245 m) is the highest peak in the Park (DNPWC, 2020). The LNP encompasses over three districts of Nepal, *viz*., Rasuwa, Nuwakot, and Sindhupalchowk. The Park experiences distinct summer and winter seasons. From mid-April to mid-June, it is warm but often cloudy with occasional rain. Summer monsoon lasts until the end of September. The climate varies with altitude. Average daily temperature decreases after the onset of December and continues up to February (DNPWC, 2020). The snowline in the LNP lies at 5000 m above mean sea level (asl) while the tree-line is around 4500 m asl (Kawamichi, 1968). The LNP harbors 46 mammalian species including two species of pika viz., *O. roylei* and *O. macrotis* (Kawamichi, 1968; Deo *et al*., 2008; Koju & Chalise, 2013). Most of the park the area is covered with pastures, rocks, bare grounds, and snow/glaciers. The study was conducted in the Kyanjing Valley situated at 3900 masl within the LNP (Figure 2). The Valley was selected as the study site since it was the only area equipped with the meteorological station that had recorded the temperature data above 3000 m asl.

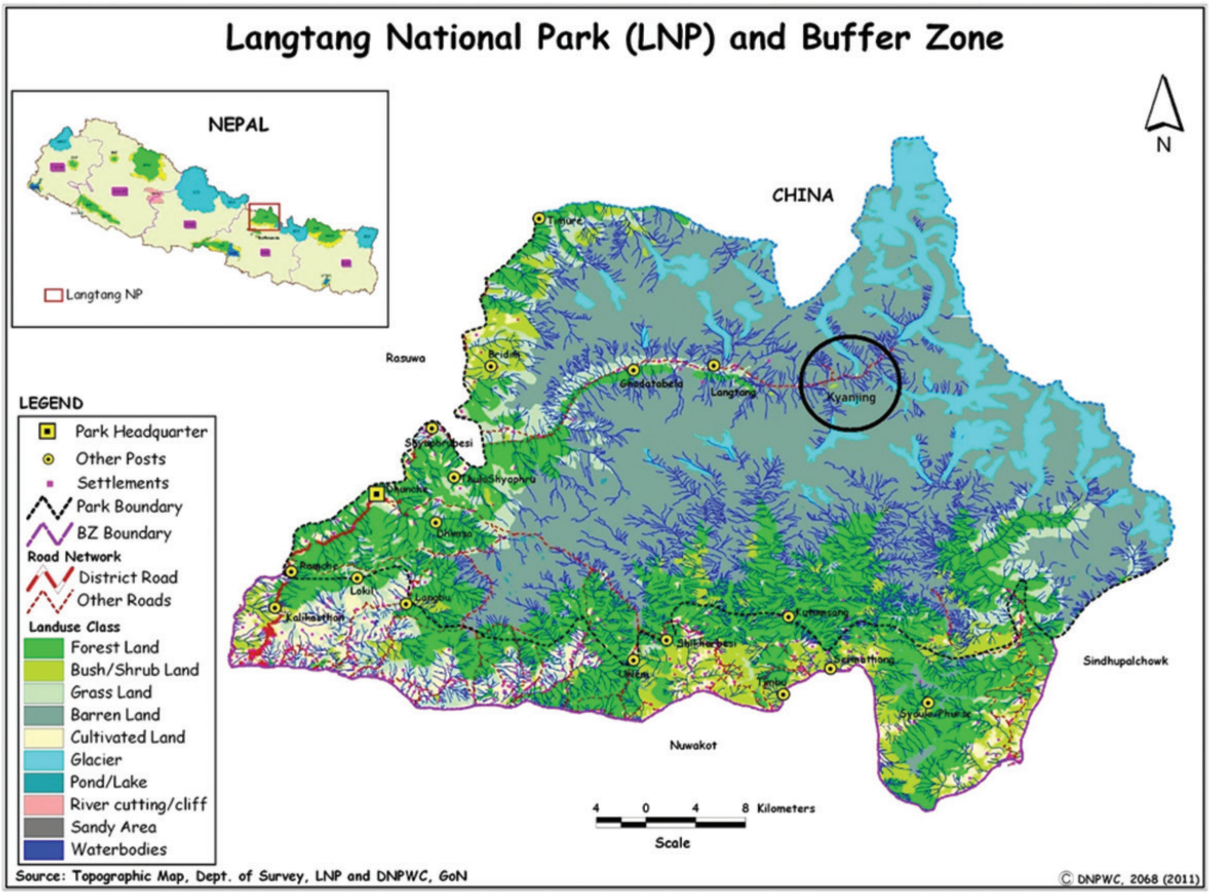

Figure 2: Map showing the location of the study area, Kyanjing (encircled) within the LNP (Source: DNPWC/GoN)

Data collection

Population abundance

The direct and indirect sign of pika's presence/ absence was studied along the transect of 53 km length starting from the elevation of 2500 m asl to 5000 m asl. The lowest elevation having the pika's sign was noted during the entire period of fieldwork. The signs of fresh pellets, hay-piles, call and live observation of pika were used to note its active habitat at the lowest elevation.

Ten quadrates, each with the size of 50m × 50m were randomly established within the Kyanjing Valley in 2011, and six fieldworks were conducted in the three consecutive years starting from 2011 to 2013. During every fieldwork, quadrates were plotted at the same spots using GPS coordinates, and the population of pika was observed thoroughly by recording the number of the animals encountered within the quadrates. Each quadrat was observed for two complete days in every visit following the method applied by Bhattacharya *et al.* (2009) and Haleem *et al.* (2012), and the encountered individuals were recorded. The number of the animals so recorded per quadrat was later on converted to density per ha. To prohibit the mixed-up of the individuals and repetition in the population count, close photographs of various marks like a tear, wounds, scares, and coloration was used for individual identification.

Climatic data

The meteorological data recorded at the Meteorological Station located in the Kyanjing Valley were collected from the Department of Hydrology and Meteorology (DHM). The temperature was taken into account from 1987 to 2013 AD. Two data loggers (DS1921G

Thermochron iButtons, Maxim Integrated Products, Sunnyvale, CA, USA) were installed within the pika's habitat near the meteorological station, one inside burrow (2 feet deep from the surface) and another on the ground surface beneath a big rock to avoid direct sunlight for recording temperature from January 2012 to October 2013 (22 months). The iButtons recorded the temperature of respective elevation and location at an interval of 90 minutes as practiced by Beever *et al*. (2010); Millar & Westfall (2010). The setting was changed to a 4-hour interval to increase the time length with the memory of the iButtons after six months. Altogether, 6000 counts of temperature, both inside and outside the burrow, were recorded by the iButtons during 22 months. The installed iButtons were unable to record the temperature of 10 days in May 2012 and 15 days in October 2012 due to a delay in downloading data. The One-wire Drivers X86 Software was used to download data from iButton and was used for data analysis. We assumed that the temperatures above +25°C and below −5°C were a thermal survival threat for pikas causing hyperthermia (Smith, 1974) and hypothermia (Beever *et al*., 2010) due to acute heat stress and acute cold stress, respectively.

Results

The density of pika was maximum (14.8/ha) during the monsoon season (July 2011) while least (2.4/ha) during the winter season (January 2012; Figure 3). The average density of pika in the Kyanging Valley was found to be 7.4 individuals per ha with 10.8, 5.8, and 5.6 individuals per ha, respectively in 2011, 2012, and 2013.

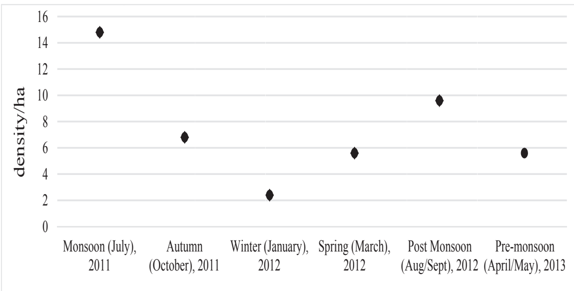

Figure 3: Population density of pika recorded in different seasons in the Kyanjing Valley, LNP

The comparative study on the trend-lines of the annual mean maximum, the annual mean minimum, and the annual average temperatures over the last 25 years (1988−2013) showed that only the mean minimum temperature was significantly increasing (R^2 = 0.75) along with time-period (Figure 4), indicating that the minimum temperature in the Kyanjing Valley was increasing significantly. On the other hand, the trend lines of the annual mean maximum temperature (R^2 = 0.06) were found to be almost intact. However, the annual average temperature (R^2 = 0.32) was found to be increasing slowly.

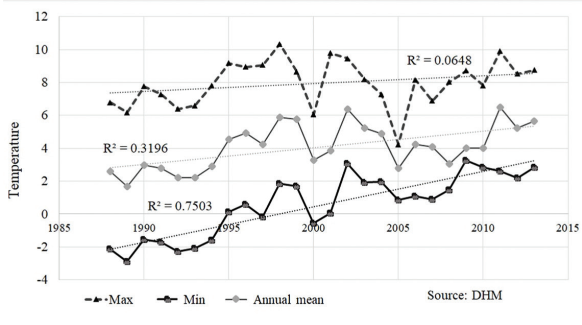

Figure 4: Temperature trends during 25 years (1988−2013) at Kyanjing, LNP

Moreover, the temperatures recorded by iButtons inside and outside the burrow were highly correlated (r=0.97). The maximum temperatures recorded outside and inside the burrow were 19°C and 14°C, respectively in June 2013 (Figure 5). On the other hand, the minimum temperatures recorded were −9°C and −9.5°C, respectively in January 2012. The average temperature outside the burrow during the summer and winter was 10.78°C and ٧,٦٧°C, respectively. Similarly, the average temperatures inside the burrow during the summer and winter were 5.4°C and 3.3°C, respectively.

Altogether, 362 counts with above 15°C temperature were recorded outside the burrow, but the temperature inside the burrow was always observed to be below 15°C. Likewise, 1401 and 1315 counts with below 0°C temperature were recorded inside and outside the burrow, respectively. Furthermore, 119 and 337 counts with the temperature below −5°C were recorded inside and outside the burrow, respectively.

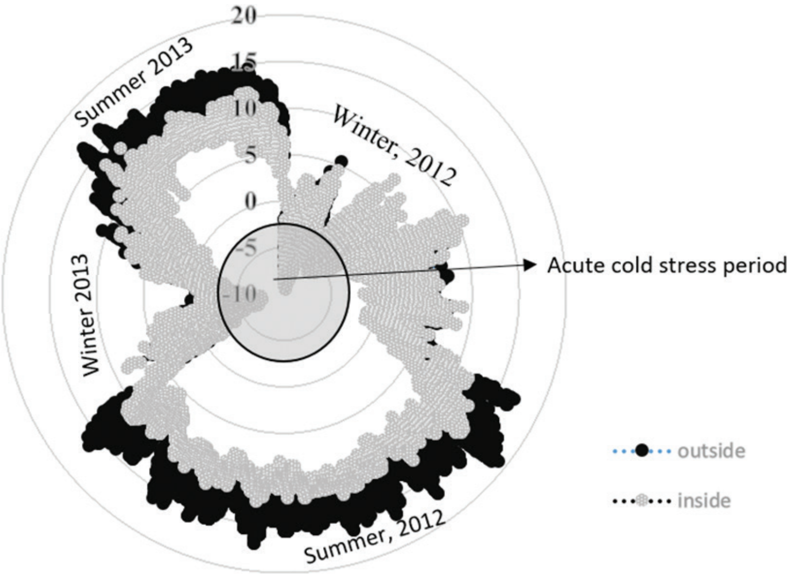

Figure 5: Temperatures recorded by iButtons (inside and outside the burrow) at Kyanjing in 2012 and 2013

So far, not a single day with a temperature above 25°C (threshold temperature for survival of pika) was recorded both inside and outside the burrow in two years' period (2012 and 2013). Similarly, the ambient temperature was not recorded so during 25 years (1988–2013) as reported by the Meteorological Station at Kyanjing. However, the days below −5°C (temperature below the threshold for the survival of pikas) were recorded both outside and inside the burrow during December–March of the respective years.

In terms of the period, 31.25% period of January 2012; 16.87 % of February 2012; 6.05% of March 2012; 9.1% of December 2012; 50.8% of January 2013; and 9.16 % of February 2013 inside the burrow were recorded by the iButtons as acute cold stress (with the temperature below −5°C). Ninety percent of this time was recorded during the night and early morning (between 21:00 PM–7:00 AM). Similarly, 22% time in January 2012; 2.5% in February 2012; 0.83% in December 2012; and 2.5% in January 2013 outside the burrow were recorded below −5°C. Thus, these records reveal that the winter temperature inside the burrow is colder than outside, especially at night.

In totality, it was observed that 40.6% of time outside the burrow and 23.5% inside the burrow had a temperature range of 10°C to 15°C whereas 29.9% outside the burrow and 49.9% inside the burrow had a temperature range of above 0°C to below 10°C, respectively. Thus, these records indicate that the burrows help to keep the summer cooler but cannot help to keep the winter warmer in comparison to the temperature change outside the burrow.

Discussion

The population density of Himalaya pika is not constant throughout the Central Himalayas. Bhattacharya *et al*. (2009) recorded the mean density of Royle's Pika as 15.3 individuals per ha in Uttarakhand, India. On the other hand, Haleem *et al*. (2012) recorded the mean density of pika as 48.44/ha (maximum) in the tree-line region and 20.76/ha (minimum) in the alpine region of the Kedarnath Wildlife Sanctuary, Uttarakhand, India. Koju & Chalise (2013) described the population density of pika in the Api Nampa Conservation Area as 7.2 per ha in July 2012 and 8 per ha in July 2013. Koju *et al*. (2015) reported the population density of Royle's pika to be 7.3 individuals per ha in the forest and its edge area, 18.2 in the subalpine area, and 11.8 per ha in the alpine area of the LNP. Similarly, Kawamichi (1968) and Smith *et al*. (1990) found the density of Royle's Pika as 14.1 and 12.5 individuals per ha, respectively in the LNP, Nepal. These studies revealed that the population density of the pika in the LNP was less than those reported by the Indian researchers and also less than the one reported by the Nepalese researchers who had conducted the studies in the same area in the past.

The lowest elevation showing the evidence of the presence of pika during this study was 3005 m asl in the LNP (Figure 6), which is 200 m higher than the one reported by Kawamichi (1968) and 100 m higher than the one reported by Khanal & Shrestha (2000). Deo *et al*. (2008) also suggested that the pika in the LNP migrated upwards by 100 m in eight years. These results indicated that either the pikas in the LNP might have migrated upward or might be facing extinction locally at lower elevation (Figure 4); however, further long-term studies need to be conducted to conclude so. Our results were similar to those of some studies conducted in the USA, which revealed the relation of pika and climate change. In this regard, Beever *et al*. (2003) reported that the population of pika in the Great Basin of the USA was highly vulnerable to climate change. Likewise, Beever *et al*. (2010) reported 150 m up-slope migration of pika in the past decade, roughly 12 m per decade in California, USA. The authors indicated the adverse impact of acute cold stress on pika's distribution due to temperature warming in the USA. Wilkening *et al.* (2011) and Ray *et al*. (2012) also supported the negative impact of acute cold stress on the survival of pikas. Beever *et al*. (2003), Beever *et al*. (2010), and Rodhouse *et al*. (2010) also recently reported the loss of pikas from a significant fraction from their historically occupied locations in the USA.

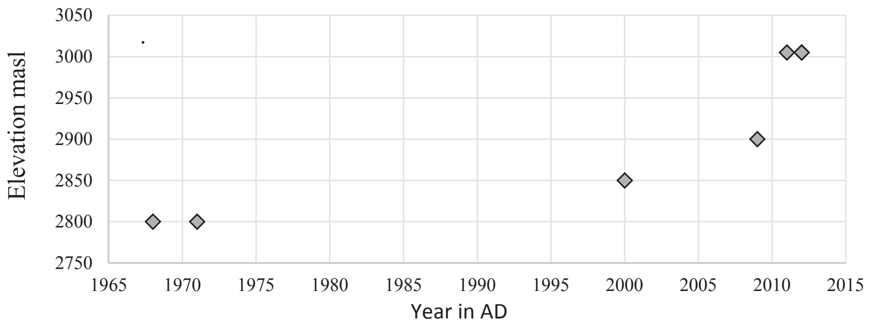

Figure 6: Graph showing the lowest elevations with the evidence of the presence of pika in the LNP based on the studies conducted in different years

Sources: Kawamichi (1968); Khanal & Shrestha (2000); Deo et al. (2008); Koju et al., 2015.

Conclusion

In the LNP, not a single day with an ambient temperature of more than 25° was recorded during the fieldwork of this study. Therefore, no evidence of hyperthermia in the pikas owing to acute heat stress was reported during our study period, but acute cold stress was significant in winter, especially in January and February. These months had a significant number of days and times with the temperature below −5°. The low temperature inside the burrow force pikas to bear acute cold stress in winter. The possible cause may be the reduction of insulation effect of snow as an increase in ambient minimum temperature that accelerates melting of snow cover. So, the pikas in the LNP are facing the impact of climate change- due to the increase in average minimum temperature in winter that leads the snowpack to melt and reduce insulation effect, and not due to the increasing heat in summer, but. Thus, acute cold stress on pikas in the LNP needs to be taken into account. Acute cold stress might be the possible reason behind the local extinction of pikas or the declining population of pika at a higher elevation. Therefore, the pikas in the Central Himalayas are under threat of thermal stress and the acute cold caused by the increase in minimum temperature. However, further long-term studies need to be carried out in the future to find out the severe and acute impact of climate change on pika's population density and distribution, and their relation with different climatic parameters.

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References

Beever, E. A., Brussard, P. F. and Berger, J. (2003). Patterns of apparent extirpation among isolated populations of pikas (*Ochotona princeps*) in the Great Basin. *Journal of Mammalogy* 84 (1): 37–54.

Beever, E. A., Ray, C., Mote, P. W., and Wilkening, J. L. (2010). Testing alternative models of climate-mediated extirpations. *Ecological Applications* 20 (1): 164–178.

Bhattacharya, S., Adhikari, B. and Rawat, G. (2009). Abundance of Royle's Pika (*Ochotona roylei*) along an altitudinal gradient in Uttarakhand, Western Himalaya. *Hystrix, the Italian Journal of Mammalogy* 20 (2): 111–119.

Deo, R. K., Shrestha, H. K., Khanal, B. and Devkota, S. (2008). A Study on Venerability Assessment and Formulation of Climate Change Adaptation Strategies for Langtang National Park and Buffer Zone. Socio-economic, Agro-Forestry and Environment (SAFE), Kathmandu, Nepal. Retrieved from http://mofe.gov.np/noticefile/Report_VIA_Final-2019_1562308949.pdf Accessed on May 14. 2021.

DNPWC (2020). Protected area of Nepal. Retrieved from http://www.dnpwc.gov.np Accessed on December 12, 2020.

Haleem, A., Ilyas, O., Syed, Z. and Arya, S. K. (2012). Abundance and distribution of Royle's Pika (*Ochotona roylei*) along different altitudinal ranges of Kedarnath Wildlife Sanctuary, Uttarakhand Himalayas, India. *Journal of Environmental Science, Toxicology and Food Technology* 1 (2): 13–16.

Hoffmann, R. S. and Smith, A. T. (2005). Order Lagomorpha. Mammal species of the world, 3.

Hughes, L. (2000). Biological consequences of global warming: is the signal already apparent? *Trends in Ecology and Evolution* 15 (2): 56–61.

IPCC (2007). AR4 Climate Change, 2007: The Physical Science Basis. International Panel on Climate Change, New York: Cambridge University Press.

Isaac, J. L. (2009). Effects of climate change on life history: implications for extinction risk in mammals. *Endangered Species Research* 7: 115–123.

IUCN, (2016). *Ochotona roylei*. *The IUCN Red List of Threatened Species* ٢٠١٦: e. T41268A45184591. https://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T41268A45184 591.en. Accessed on 14 May 2021.

Kawamichi, T. (1968). Winter Behaviour of the Himalayan Pika (*Ochotona roylei*). Hkkaido University. *Journal of Faculty of Science* VI (16): 582–554.

Kawamichi, T. (1998). Can pika on high mountains survive the greenhouse effect? IUCN Chapter. *Japan Biodiversity* 21: 136–140.

Khanal, B. and Shrestha, K. (2000). Habitat preferences by Royle's Pika (*Ochotona roylei*) in Gosainkund, Rasuwa district of central Nepal. *Journal of Natural History Museum Nepal* 19: 27–33.

Koju, N. P. and Chalise, M. K. (2013). Royle's Pika (*Ochotona roylei*) observation in Api Nampa Conservation area, Nepal. *Journal of Natural History Museum* 27: 78–86 DOI**:** https://doi.org/10.3126/jnhm.v27i0.14156

Koju, N. P., Chalise, M. K. and Xuelong, J. (2015). Population abundance of Royle's Pikas (*Ochotona roylei*) along altitudinal gradients in Langtang National Park, Nepal. *South Asian Journal of Multidisciplinary Studies* 2 (1): 1–6.

Koju, N. P., He, K., Chalise, M. K., Ray, C., Chen, Z., Zhang, B. and Jiang, X. (2017). Multilocus approaches reveal underestimated species diversity and inter-specific gene flow in pikas (*Ochotona*) from southwestern China. *Molecular Phylogenetics and Evolution* 107: 239–245.

MacArthur, R. A. and Wang, L. C. (1973). Physiology of thermoregulation in the pika, *Ochotona princeps*. *Canadian Journal of Zoology* 51 (1): 11–16.

Millar, C. I. and Westfall, R. D. (2010). Distribution and climatic relationships of the American pika (*Ochotona princeps*) in the Sierra Nevada and western Great Basin, USA; Periglacial Landforms as Refugia in Warming Climates. *Arctic, Antarctic, and Alpine Research* 42 (1): 76–88.

Naftz, D. L., Susong, D. D., Schuster, P. F., Cecil, L. D., Dettinger, M. D., Michel, R. L. and Kendall, C. (2002). Ice core evidence of rapid air temperature increases since 1960 in alpine areas of the Wind River Range, Wyoming, United States. *Journal of Geophysical Research: Atmospheres* 107 (D13): 4171. https://doi.org/10.1029/2001JD000621

Peters, R. L. (1985). The greenhouse effect and nature reserves. *Bioscience* 35 (11): 707–717.

Post, E. and Forchhammer, M. C. (2002). Synchronization of animal population dynamics by large-scale climate. *Nature* 420: 168–171.

Post, E. and Stenseth, N. C. (1999). Climatic variability, plant phenology, and northern ungulates. *Ecology* 80: 1322–1339.

Primack, R. B. (1998). Essential of Conservation Biology (Vol. 2). Massachusetts, USA: Sinauer, Massachusetts.

Ray, C., Beever, E. and Loarie, S. (2012). Wildlife conservation in a changing climate (Chapter 12. Retreat of the American Pika: Up the Mountain or into the Void?). University of Chicago Press. pp. 245–270.

Reese, A. and Roles, E. (2014). Animal Diversity Web. Retrieved from discoverlife.org

Rodhouse, T. J., Beever, E. A., Garrett, L. K., Irvine, K. M., Jeffress, M. R., Munts, M. and Ray, C. (2010). Distribution of American pikas in a low-elevation lava landscape: conservation implications from the range periphery. *Journal of Mammalogy* 91 (5): 1287–1299.

Smith, A. T. (1974). The distribution and dispersal of pikas: Influences of Behavior and Climate. *Ecology* 55 (6): 368–1376.

Smith, A. T., Formozov, N., Hoffmann, R. S., Changlin, Z. and Erbajena, M. A. (1990). The pikas. In: Rabbits, Hares and Pikas: Status Survey and Conservation Action Plan. J. A. Chapman & J. E. C. Flux (Eds.). International Union for Conservation of Nature, Switzerland. Lagomorph Specialist Group. pp. 14–60.

Wilkening, J. L., Ray, C., Beever, E. A. and Brussard, P. F. (2011). Modeling contemporary range retraction in Great Basin pikas (*Ochotona princeps*) using data on microclimate and microhabitat. *Quaternary international* 235 (1–2): 77–88.