J. Mt. Sci. (2017) 14(7): 1384-1390 e-mail: jms@imde.ac.cn http://jms.imde.ac.cn
DOI: 10.1007/s11629-017-4360-9

Elevational distribution of butterflies in the Himalayas: a case study from Langtang National Park, Nepal

Ranjit PANDEY[1*] http://orcid.org/0000-0001-7130-0201; e-mail: ranjit.pandey@okstate.edu

Kapil K KHADKA[2] http://orcid.org/0000-0002-0632-7245; e-mail: kkkhadka@email.uark.edu

Anuj GHIMIRE[3] http://orcid.org/0000-0002-5128-108X; e-mail: anujghimire1@gmail.com

Puja JHA[4] http://orcid.org/0000-0002-7920-0106; e-mail: puja.jha@okstate.edu

Umesh PATHAK[5] http://orcid.org/0000-0002-9135-4212; e-mail: pathakumesh2010@gmail.com

** Corresponding author*

1 Oklahoma State University, Department of Integrative Biology, 501 Life Sciences West, Stillwater, OK, 74078, USA

2 University of Arkansas, Department of Biological Sciences, Fayetteville, AR, 72701, USA

3 Tribhuvan University, Central Department of Zoology, Kirtipur, Nepal

4 Oklahoma State University, 358 Agricultural Hall, Stillwater, OK, 74078, USA

5 Tribhuvan University, Central Department of Environmental Sciences. Kirtipur, Nepal

Citation: Pandey R, Khadka KK, Ghimire A, et al. (2017) Elevational distribution of butterflies in the Himalayas: a case study from Langtang National Park, Nepal. Journal of Mountain Science 14(7). DOI: 10.1007/s11629-017-4360-9

Abstract: Mountain ecosystems are relatively more vulnerable to climate change since human induced climate change is projected to be higher at high altitudes and latitudes. Climate change induced effects related to glacial response and water hazards have been documented in the Himalayas in recent years, yet studies regarding species' response to climate change are largely lacking from the mountains and Himalayas of Nepal. Changes in distribution and latitudinal/altitudinal range shift, which are primary adaptive responses to climate change in many species, are largely unknown due to unavailability of adequate data from the past. In this study, we explored the elevational distribution of butterflies in Langtang Village Development Committee (VDC) of Langtang National park; a park located in the high altitudes of Nepal. We found a decreasing species richness pattern along the elevational gradient considered here. Interestingly, elevation did not appear to have a significant effect on the altitudinal distribution of butterflies at family level. Also, distribution of butterflies in the area was independent of habitat type, at family level. Besides, we employed indicator group analysis (at family level) and noticed that butterfly families Papilionidae, Riodinidae, and Nymphalidae are significantly associated to high, medium and low elevational zone making them indicator butterfly family for those elevational zones, respectively. We expect that this study could serve as a baseline information for future studies regarding climate change effects and range shifts and provide avenues for further exploration of butterflies in the high altitudes of Nepal.

Keywords: Butterflies; Indicator species; Nepal; Range shift; Climate change; Himalayas

Received: 6 January 2017
Revised: 28 March 2017
Accepted: 11 May 2017

Introduction

Understanding altitudinal distribution of species is important in ecology and climate science since species are confined to specific elevation bands as an adaptive response and are predicted to change their distributions to track their climatic associations in response to changing climate across elevational and latitudinal space (Parmesan and Yohe 2003; Thomas et al. 2004). Since high altitudes and latitudes are projected to face a relatively high rise in temperature and variation in precipitation pattern (IPCC 1996; Hughes 2000), climate change effects on the flora and fauna of high altitudes and people directly and indirectly dependent on the resources and adapted to high altitude ecosystem (i.e., mountain area) are of significant concerns. A wide and dramatic altitudinal range (i.e., from 60 to 8,848 meters above sea level) in Nepal and resulting topographic and climatic variation harbors a diverse array of biological diversity in the country (CBS 2010). The majestic biodiversity of the country, and in particular the biodiversity of high altitudes, is vulnerable to the effects of climate change as the mean annual temperature is increasing at a rate of 0.06°C/year in Nepal Himalaya, a rate that is higher than the global average (Shrestha et al. 1999; Shrestha et al. 2012). Although climate induced effects related to glacial response and water hazards have been documented in the Himalayas in recent years, yet studies regarding species' response to climate change and phenological patterns are generally lacking (Telwala et al. 2013; Xu et al. 2009). Moreover, past information regarding elevational distribution of indicator species like butterfly and their phenological patterns are largely absent adding gaps to compare the current data and findings with.

Owing to their sensitiveness to climate change (Parmesan et al. 1999), and a faster response to environmental alteration compared to other taxa (Devictor et al. 2012), butterflies are considered indicator species to climate change (Pollard 1979). They are ectothermic and change their phenology and physiology as a thermoregulatory response to a small variation in ambient temperature. Hence, they shift their distributions towards higher latitude and altitude as an adaptive response to changing climate making them a relatively better (if not the best) indicator group than many other taxa to gauge the extent and magnitude of climate change effect (Pollard 1979; but see Parmesan 2007). Moreover, climate change effects on butterfly communities in mountain systems are well studied in Europe and North America, and these studies show that butterflies can be reliably used as an indicator group of climate change effects on ecosystems (Roy and Sparks 2000; Roy et al. 2001; Pardikes et al. 2015). Although high altitudes of mountains are a remarkable ground for butterfly species (Khanal et al. 2012) and information about their elevational distribution and shift can potentially aid in understanding the extent and magnitude of climate change in the Himalayas, yet the fundamental ecological questions related to their elevational distribution are still largely unexplored in Nepal.

Besides, local people in the high altitudes are an important component of high altitude ecosystem and are the potential primary victims of climate change impacts. However, exceptionally few studies seem to incorporate the unwitting knowledge of mountain people about mountain biodiversity in scientific studies regarding climate change effects in mountain areas. Citizen science is often overlooked and is not involved while devising scientific studies so that their knowledge is not usually integrated and/or valued during the study. Incorporating citizen science is important because by doing so helps mountain people devise a proxy yardstick for understanding climate change effects and track it through their eyes using their knowledge of surrounding biodiversity; in particular, some indicator species of the area. Also, such approach can offer a huge contribution to climate science as citizen science can potentially act as a source of information about biodiversity distribution and any distributional changes of indicator species.

With these understandings and impressions in mind, this study was devised to understand the elevational distribution of butterflies in high altitudes of Nepal. Besides, the study also aims to find indicator group for different elevational zones so that it can provide a baseline information to compare the distributional shifts of butterfly in the area, and gauge any compositional changes in the future. Also, the study tried to incorporate local people and their unwitting knowledge of local biodiversity (in particular butterfly communities) in scientific study and help them understand the scientific findings regarding climate change and its effects, and motivate them to keep an eye on indicator species in the area for the future information.

1 Methods

1.1 Study area and data collection

The study was carried out in Langtang VDC of Langtang National Park, Nepal (Figure 1). Village Development Committee (VDC) is the smallest administrative boundary in Nepal. Lantang National Park has an area of 1760 km² and situated within the geographic coordinates of 27°57'36'' N to 28°22'48'' N and 85°12'36'' E to 85°52'48'' E. The park consists of 14 vegetation types, ranging from tropical to alpine scrubs, and 18 ecosystem types (Bhuju et al. 2007). An estimated 126 species of butterflies are found in the park within elevation ranging from 1000 to 7245 m (Khanal et al. 2012).

Three sites in Langtang VDC of the park, with an altitudinal gradient of 3000 to 4200m were sampled in March, May and September of 2016. The study sites were separated laterally by at least 1 km apart. Standard transect survey as described by Pollard (1977), and adapted by Zografou et al. (2014), was conducted along the elevational gradient of each site. Thus, seven 200 m long transects with an altitudinal distance of 200m were surveyed along each elevational transect in each patch (3 sites x 7 transects = 21 transects in total). All the butterfly species observed along the transects and within the range of 2 m (both sides) from transects were identified and recorded along with the elevation (some of the butterfly species are shown in Figure 2). Also, the type of habitat condition (i.e., Forest land, Shrub land, and Open land) at each site where the butterflies were noticed was recorded. Although elevational transects in each of the three patches were the sampling units, all the three patches sampled, however, encompassed three different habitat types recorded here along the altitudinal gradient. Thus, the study was balanced to some extent (although not perfectly) in terms of habitat type as well. Four local people with previous knowledge on local butterfly species were involved in laying the transects and butterfly identification with the purpose of incorporating their knowledge and delivering them the goals and significance of the study. Unidentified butterfly species in the field were photographed and were identified later using expert knowledge (Smith 2011).

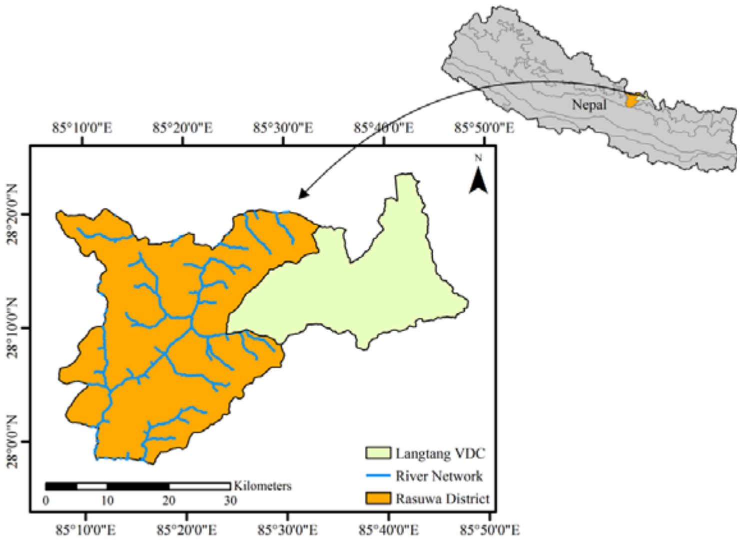

Figure 1 Study area with VDC boundary. Village Development Committee (VDC) is the lower administrative part in Nepal. Study area is labeled as Langtang.

Figure 2 Pictures of few selected species in the study area. Top left *Callerbis scandal*, Top right *Parnassius hardwickii*, bottom left *Issoria lathonia*, and bottom right *Aglais kaschnirensis*.

1.2 Data analyses

All the data analyses were carried out in R (R Development Core Team 2016). Generalized linear model (GLM) with poisson error structures and log link function was employed to assess the elevational pattern of species richness with number of species as response and elevation as predictor variable. The assumption of equal mean and variance (i.e., if any overdispersion is present in the model) of the dependent/response variable was checked via the ratio of residual deviance and residual degrees of freedom, and GLM with poisson error structure was found reasonable. Kruskal-Wallis test was performed to elucidate the variation in distribution of butterfly families (predictor variable) along the elevation (response variable) and chi-square test was employed to test the independence of two categorical variables, i.e., habitat types and butterfly families. Also, non-metric multidimensional (NMDS) ordination with Jaccard dissimilarity was performed to find whether the habitat types were different in terms of butterfly composition. Besides, the altitudinal gradient in the study area was divided into 3 elevational zones; Low (3000 – 3400 m), Medium (3400 – 3800 m), and high (3800 – 4200 m), and indicator species analysis was performed using package '*indicspecies*' v.1.7.2 in R (De Cáceres & Legendre 2009) to find an indicator butterfly group significantly associated to each elevation zone.

2 Results

A total of 28 butterfly species belonging to five families were observed and recorded during the study period (Table 1). Species richness was found highest (i.e., n =20) at an elevation of 3000m and it decreased to two at the elevation of 4200 m. The slope of the model was significantly different from zero suggesting a decreasing species richness pattern along the altitudinal gradient considered here (β1= -0.001, P < 0.01) (Figure 3). Interestingly, elevation was not found to have a significant effect on the distribution of butterfly along the elevational gradient at family level (Kruskal-Wallis χ^2 = 4.8, df = 4, P = 0.29, Figure 4). Also, the distribution of observed butterfly families was statistically independent of habitat types (χ^2= 9.7, df = 8, P = 0.28). Butterfly composition in terms of presence and absence was significantly different among elevation zones (pseudo $F_{2,25}$ = 6.56, P = 0.001). However, the composition in terms of

Table 1 Species and families of butterflies recorded at different elevation in the study area during the study period

Species	Altitude (m)	Family
Abisara fylla	3000	Riodinidae
Aglais kaschmirensis	3000	Nymphalidae
Athyma selenophora	3000	Nymphalidae
Byasa polyeuctes	3000	Papilionidae
Callerebia scanda	3000	Nymphalidae
Celastrina argiolus	3000	Lycaenidae
Cyrestis thyodamas	3000	Nymphalidae
Danaus chrysippus	3000	Nymphalidae
Delias belladonna	3000	Pieridae
Eurema hecabe	3000	Pieridae
Heliophorus epicles	3000	Lycaenidae
Issoria lathonia	3000	Nymphalidae
Lampides boeticus	3000	Lycaenidae
Lycaena phlaeas	3000	Lycaenidae
Neptis hylas	3000	Nymphalidae
Pieris brassicae	3000	Pieridae
Pseudergolis wedah	3000	Nymphalidae
Pseudozizeeria maha	3000	Lycaenidae
Vanessa cardui	3000	Nymphalidae
Ypthima sakra	3000	Nymphalidae
Aglais kaschmirensis	3200	Nymphalidae
Colias erate	3200	Pieridae
Cyrestis thyodamas	3200	Nymphalidae
Dodona egeon	3200	Riodinidae
Eurema hecabe	3200	Pieridae
Lampides boeticus	3200	Lycaenidae
Neptis hylas	3200	Nymphalidae
Vanessa cardui	3200	Nymphalidae
Abisara fylla	3400	Riodinidae
Callerebia hybrida	3400	Nymphalidae
Pieris brassicae	3400	Pieridae
Lampides boeticus	3400	Lycaenidae
Neptis hylas	3400	Nymphalidae
Eurema hecabe	3600	Pieridae
Phalanta phalantha	3600	Nymphalidae
Neptis hylas	3600	Nymphalidae
Callerebia hybrida	3600	Nymphalidae
Aglais kaschmirensis	3800	Nymphalidae
Eurema hecabe	3800	Pieridae
Parnassius hardwickii	3800	Papilionidae
Pieris brassicae	3800	Pieridae
Udara dilecta	3800	Pieridae
Aglais kaschmirensis	4000	Nymphalidae
Issoria isaea	4000	Nymphalidae
Parnassius epaphus	4000	Papilionidae
Parnassius hardwickii	4000	Papilionidae
Aglais kaschmirensis	4200	Nymphalidae
Parnassius hardwickii	4200	Papilionidae

presence/absence was not significantly different among habitat types (pseudo $F_{2,38}$ = 1.57, P = 0.17, Figure 5), further approving the earlier finding of independence of distribution among habitat types. Indicator species analysis found that butterfly families Papilionidae, Riodinidae, and Nymphalidae were significantly associated to elevation class High, Medium, and Low respectively.

3 Discussions

Species richness of the butterfly communities in the study area decreased with elevation considered here revealing a decreasing richness pattern as described by McCain (2009). Several hypotheses have been put forward to explain the species richness patterns along the elevational gradient (for example, see Lomolino 2000; Jones et al. 2003; Chown et al. 2013), and these hypotheses indeed predict a declining species richness pattern along the elevation. Thus, our findings corroborate the hypotheses invoked for the distribution of species richness patterns along the elevational gradient. Moreover, this finding is also in accordance to the findings for butterfly species by Khanal et al. (2012) in the high altitudes of Nepal, and by Leingärtner et al. (2014) elsewhere. Acharya and Vijayan (2015) too have documented a declining species richness pattern of butterflies in eastern Himalaya in Sikkim, however, with a hump at an elevation of 1000 m. Also for plant species like Fern and Rhododendron, unimodal relationships between species richness pattern and elevation have been documented with maximum richness at an elevation of 3300 m for Rhododendron and 2000 m for Fern in the Himalayas of Nepal (Bhattarai et al. 2004; Bhattarai and Upadhyay 2015). Such a unimodal or humped relationship between species richness and elevation is probably due to the wide range of altitudinal gradient considered in those studies. Although we tried to evaluate the unimodal relationship in our data by testing the significance of the model with second order polynomial, it however was not found significant. Hence, we recommend for further studies in the future with increased sample size (both temporal and spatial) to get further insight into the relationship

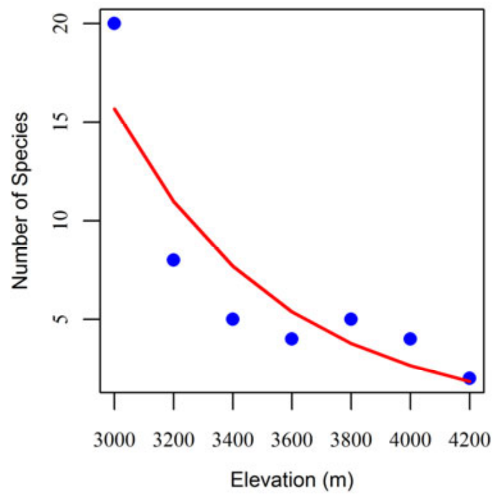

Figure 3 Response to elevational gradient of species richness using Poisson regression.

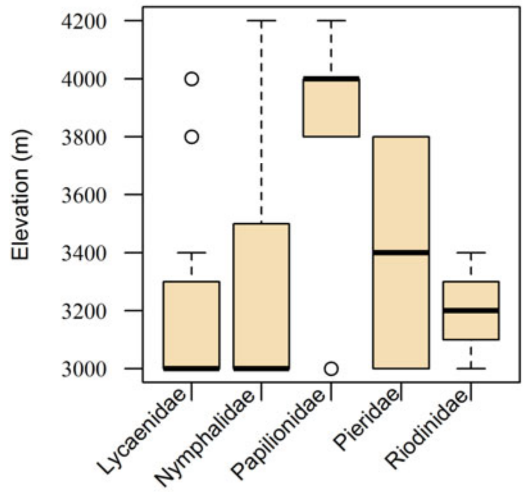

Figure 4 Elevational distribution of butterfly families in the study area.

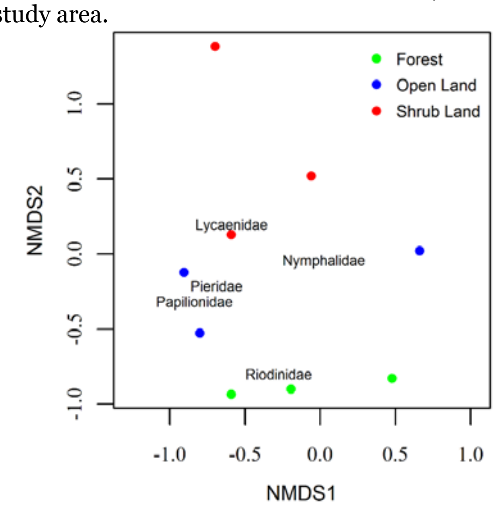

Figure 5 Non-metric multidimensional (NMDS) of Jaccard dissimilarity of butterfly taxon among habitat types. The butterfly composition in terms of presence/absence of butterfly taxon among habitat types was not significant.

regarding richness pattern of butterfly species in the Nepal Himalayas.

Interestingly, elevation was not found to have a considerable effect on the altitudinal distribution of butterflies at family level. Also, the distribution of butterfly at family level was independent of habitat type in the area. Although butterflies' phenological and physiological responses are sensitive to a small variation in climatic pattern (Roy et al. 2001) and hence their distributions are considerably driven by availability of optimal thermal level (Bryant et al. 2002; Smetacek 2011), yet our finding provides a suggestive evidence that distribution pattern of butterfly at family level may not provide a proxy measure for changes in climatic pattern along the elevation (Palmer et al. 2015). Hence, species-specific distribution pattern could offer more insight into the potential impacts of changing climatic pattern on the distributional and range shift of butterfly communities. Mountain species respond to climate change more rapidly compared to lowland because higher elevational gradient facilitates species to shift their range with changing climate (Pounds et al. 1999). Thus, the distribution of butterfly species in the area could reshuffle in the future in response to climate change (Konvicka et al. 2003; Parmesan and Yohe 2003; Wilson et al. 2007) leading also to changes in compositional pattern. Therefore, identification of indicator butterflies group for different elevational zones as found in the study could ease the task of tracking compositional changes in the future. For example, we found that butterfly families Papilionidae, Riodinidae, and Nymphalidae as an indicator group of high (> 3800m), mid (3400 – 3800m), and low (3000 – 3400m) elevational zone, respectively. Hence, we expect that this finding could provide a baseline information for future studies to track any compositional changes in the future.

Despite being rich in biodiversity, Nepal suffers a huge geographic and taxonomic bias in terms of research conducted regarding biodiversity conservation and/or exploration (Pandey et al. 2015). Besides, it appears that citizen science is often overlooked while conducting any scientific studies in the area although it represents an effective mean for collecting data to answer a wide a variety of ecological questions (Tulloch et al. 2013). Inclusion of citizen science making local people involved during scientific studies (for example, during the process of data collection) could help to better design the scientific studies and enhance the understanding of the ecological question. For example, we involved four local people with a prior knowledge about butterfly in the area in our studies and discussed our scientific question. By so doing, we expect that the people were motivated to be vigilant on local flora and fauna and could serve as a powerful source of information in the future. Finally, despite some limitations in terms of temporal and spatial extent of the study, we expect that the study could offer avenues for further exploration of butterflies and their distribution in the Himalayas. Also, we expect that the study could serve as a model for the future studies in the area.

4 Conclusions

To sum up, this study explored the altitudinal distribution of butterfly families and species richness pattern along the elevational gradient in Langtang VDC of central Nepal Himalaya. Decreasing richness pattern of butterfly species was found along the elevational gradient considered here. Also, the study determined the indicator butterfly group at family level that are significantly associated to different elevational class. Papilionidae, Riodinidae, and Nymphalidae were found as the indicator group for elevational class high, medium and low, respectively. Moreover, the study attempted to utilize the local citizen science to deliver the importance of local knowledge and its incorporation in scientific exploration. It is expected that the study could serve as a baseline information and as a model for future studies in the Himalayas.

Acknowledgment

This study was funded by The Rufford Foundation (http://www.rufford.org/). We would like to thank Dr. Monica Papeş (graduate supervisor of the first author) for her constructive guidance during the proposal development. Also, we thank all the referees and the reviewers.

References

Acharya BK, Vijayan L (2015) Butterfly diversity along the elevation gradient of Eastern Himalaya, India. Ecological Research 30: 909-919. DOI: 10.1007/s11284-015-1292-0

Bhattarai KR, Upadhyay TP (2015) Rhododendron species richness patterns and impacts of global warming on its distribution in Central Himalayas, Nepal. Botanica Orientalis – Journal of Plant Science 9: 12-19. DOI:10.1046/j.0305-0270.2003.01013.x

Bhattarai KR, Vetaas OR, Grytnes JA (2004) Fern species richness along a central Himalayan elevational gradient, Nepal. Journal of Biogeography 31: 389-400.

Bhuju UR, Shakya PR, et al. (2007) Nepal Biodiversity Resource Book: Protected Areas, Ramsar Sites, and World Heritage Sites. International Centre for Integrated Mountain Development, Ministry of Environment, Science and Technology, in cooperation with United Nations Environment Programme, Regional Office for Asia and the Pacific. Kathmandu, ISBN 978-92-9115-033-5

Bryant SR, Thomas CD, Bale JS (2002) The influence of thermal ecology on the distribution of three nymphalid butterflies. Journal of Applied Ecology 39: 43-55. DOI: 10.1046/j.1365-2664.2002.00688.x

Central Bureau of statistics, Nepal (CBS, 2010) (http://www.cbs.gov.np/, accessed on 2016-10-05)

Chown SL, le Roux PC, Ramaswiela T, et al (2013) Climate change and elevational diversity capacity: do weedy species take up the slack? Biology Letters 9(1): 20120806. DOI:10.1098/rsbl.2012. 0806

Devictor V, Van Swaay C, Brereton T, et al. (2012) Differences in the climatic debts of birds and butterflies at a continental scale. Nature Climate Change 2: 121-124. DOI: 10.1038/ NCLIMATE 1347

De Cáceres, M. & Legendre, P. (2009). Associations between species and groups of sites: Indices and statistical inference. Ecology 90: 3566–3574

Intergovernmental Panel on Climate Change (IPCC), 1996. Climate Change 1995: The Science of Climate Change. Contribution of Working Group I to the Second Assessment Report of the IPCC. Cambridge University Press, New York.

Hughes L (2000) Biological consequences of global warming: is the signal already apparent? Trends Ecology & Evolution 15: 56–61. DOI: 10.1016/S0169-5347(99)01764-4

Jones JI, Li W, Maberly SC (2003) Area, altitude and aquatic plant diversity. Ecography 26: 411–420. DOI:10.1034/j.1600-0587.2003.03554.x

Khanal B, Chalise M, Solanki G (2012) Diversity of butterflies with respect to altitudinal rise at various pockets of the Langtang National Park, central Nepal. International Multidisciplinary Research Journal 2: 41-48

Konvicka M, Maradova M, Benes J, et al. (2003) Uphill shifts in distribution of butterflies in the Czech Republic: effects of changing climate detected on a regional scale. Global Ecology and Biogeography 12: 403-410.

Leingärtner A, Krauss J, Steffan-Dewenter I (2014) Species richness and trait composition of butterfly assemblages change along an altitudinal gradient. Oecologia 175: 613-623. DOI 10.1007/s00442-014-2917-7

Lomolino MV (2000) Ecology's most general, yet protean pattern: the species–area relationship. Journal of Biogeography 27: 17–26. DOI:10.1046/j.1365-2699.2000. 00377.x

McCain CM (2009) Global analysis of bird elevational diversity. Global Ecology and Biogeography 18: 346–360. DOI: 10.1111/ j.1466-8238.2008.00443.x

Palmer G, Hill JK, Brereton TM, et al. (2015) Individualistic sensitivities and exposure to climate change explain variation in species' distribution and abundance changes. Science Advances 1: e1400220. DOI 10.1126/sciadv.1400220

Pandey R, Khadka KK, Papes M (2015) Geographic and taxonomic biases in conservation research efforts in Nepal. Asian Journal of Conservation Biology 4: 89-91.

Pardikes NA, Shapiro AM, Dyer LA, et al. (2015) Global weather and local butterflies: variable responses to a large-scale climate pattern along an elevational gradient. Ecology 96: 2891-2901. DOI: 10.1890/15-0661.1.sm

Parmesan C, Ryrholm N, Stefanescu C, et al. (1999) Poleward shifts in geographical ranges of butterfly species associated with regional warming. Nature 399: 579-583. DOI:10.1038/ 21181

Parmesan C (2007) Influences of species, latitudes and methodologies on estimates of phenological response to global warming. Global Change Biology 13: 1860-1872. DOI: 10.1111/ j.1365-2486.2007.01404.x

Parmesan C, Yohe G (2003) A globally coherent fingerprint of climate change impacts across natural systems. Nature 421: 37-42. DOI: 10.1038/nature01286

Pollard E (1977) A method for assessing changes in the abundance of butterflies. Biological Conservation 12: 115-134. DOI: 10.1016/0006-3207(77)90065-9

Pollard E (1979) Population ecology and change in range of the White Admiral butterfly *Ladoga camilla* L. in England. Ecological Entomology 4: 61-74. DOI: 10.1111/j.1365-2311. 1979.tb00561.x

Pounds JA, Fogden MP, Campbell JH (1999) Biological response to climate change on a tropical mountain. Nature 398: 611-615. DOI: 10.1038/19297

R Core Team (2016) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

Roy D, Sparks T (2000) Phenology of British butterflies and climate change. Global Change Biology 6: 407-416. DOI: 10. 1046/j.1365-2486.2000.00322.x

Roy DB, Rothery P, Moss D, et al. (2001) Butterfly numbers and weather: predicting historical trends in abundance and the future effects of climate change. Journal of Animal Ecology 70: 201-217. DOI: 10.1111/j.1365-2656.2001. 00480.x

Shrestha AB, Wake CP, Mayewski PA, et al. (1999) Maximum temperature trends in the Himalaya and its vicinity: An analysis based on temperature records from Nepal for the period 1971-94. Journal of climate 12: 2775-2786. DOI: 10.1175/1520-0442(1999)012<2775:MTTITH>2.0.CO;2

Shrestha UB, Gautam S, Bawa KS (2012) Widespread climate change in the Himalayas and associated changes in local ecosystems. PLoS One 7: e36741. DOI: 10.1371/journal.pone. 0036741

Smetacek P (2011) On the Anomalous Altitudinal Distribution of West Himalayan Troidini and Papilionini (Papilionidae). Journal of the Lepidopterists' Society 65: 126-132. DOI: 10.18473/lepi.v65i2.a5

Smith C (2011) Illustrated Checklist of Nepal's Butterflies. Department of Biological and Environmental Sciences, Kathmandu University, Nepal.

Telwala Y, Brook BW, Manish K, Pandit MK (2013) Climate-induced elevational range shifts and increase in plant species richness in a Himalayan biodiversity epicentre. PLoS One 8: e57103. DOI: 10.1371/journal.pone.0057103

Thomas CD, Cameron A, Green RE. et al. (2004) Extinction risk from climate change. Nature 427: 145-147. DOI: 10.1038/ nature02121

Tulloch AIT, Possingham HP, Joseph LN, et al. (2013) Realising the full potential of citizen science monitoring programs. Biological Conservation 165: 128-138. DOI: 10.1016/ j.biocon.2013.05.025

Wilson RJ, Gutierrez D, Gutierrez J, et al. (2007) An elevational shift in butterfly species richness and composition accompanying recent climate change. Global Change Biology 13: 1873-1887. DOI: 10.1111/j.1365-2486.2007.01418.x

Xu J, Grumbine RE, Shrestha A, et al. (2009) The melting Himalayas: cascading effects of climate change on water, biodiversity, and livelihoods. Conservation Biology 23: 520-530. DOI: 10.1111/j.1523-1739.2009.01237.x

Zografou K, Kati V, Grill A, et al. (2014) Signals of climate change in butterfly communities in a Mediterranean protected area. PLoS One 9, e87245. DOI: 10.1371/ journal.pone.0087245