



Relative Abundance of Mammalian Fauna of Chitral Gol National Park, Pakistan

Muhammad Younis¹, Sami Ullah¹, Fathul Bari¹, Muhammad Asif²,
Muhammad Ilyas², Mahvish Rauf², Ejaz Ur Rehman³, Rubina Noor⁴,
Muhammad Arif⁴ and Muhammad Ali Nawaz^{5*}

¹Wildlife and Ecosystem Research Lab, Department of Zoology, University of Chitral, KPK, Pakistan.

²Carnivore Conservation Lab, Department of Zoology, Quaid-I-Azam University, Islamabad

³Snow Leopard Foundation, Islamabad, Pakistan

⁴Directorate of National Parks, Wildlife Department Khyber Pakhtunkhwa, Pakistan

⁵Department of Biological and Environmental Sciences, Qatar University, Doha Qatar

ABSTRACT

Chitral Gol National Park (CGNP) harbors a large number of mammals. However, population size, estimated density or any other ecological parameter is not available for those species except annual census counts for markhor *Capra falconeri*. Management and conservation efforts are assessed by using relative abundance estimates. The current study aimed to estimate relative abundance of mammalian fauna of CGNP. During the current study, 30 camera traps (motion triggered camera (Reconyx™) with infrared flash were deployed for a period of 47 days. The survey resulted in 1052 functional trap nights obtaining 5906 photographs. Results of the study show that large carnivores like common leopard, grey wolf, Himalayan lynx are present in the National Park. Snow leopard which used to be a symbol of fame for the National Park was not detected in the current study. Among other meso-carnivores golden jackal, leopard cat and red fox were also captured at different stations while small mammals included stone marten, Kashmir flying squirrel, Himalayan wood mouse, and golden marmot. Relative abundance of markhor (RAI= 49.631), cape hare (RAI= 23.832) and red fox (RAI= 6.879) were found to be higher as compared to other species. Relative abundance of other mammals like common leopard, leopard cat, grey wolf, golden marmot and Himalayan wood mouse was lower than one. Overall, 13 mammal species were recorded during the study whereas some of the previously reported species were not detected. This may probably be due to single season survey; conducting a multi-season camera trapping and targeting all different types of microhabitats is recommended for future studies.

Article Information

Received 24 May 2019

Revised 03 November 2021

Accepted 14 November, 2021

Available online 01 March 2022
(early access)

Authors' Contribution

MAN provided overall supervision, conception and review. MAN designed the study with help of FB. MA, MI, MR, RN and MAR carried out liaison and field support FB. MY, SU, MA, MI and MR conducted field study and collected data with help from ER. MY and SU analyzed the data, wrote the manuscript, FB supervised and reviewed the draft.

Key words

CGNP, Conservation, Relative abundance, Absolute abundance, Markhor, microhabitats

INTRODUCTION

Mammals are ecologically important and they directly or indirectly affect communities and ecosystems (Ripple and Beschta, 2004; Ray *et al.*, 2005; Roemer *et al.*, 2009). Both carnivorous and herbivorous mammals play critical role in maintaining the integrity of the ecosystem (Marcot and Heyden, 2001; Bakker *et al.*, 2016). Carnivorous mammals are ecologically significant, as only a limited number of species cause strong predation, that both directly and indirectly affects ecosystem structure and function (Ray *et al.*, 2005; Roemer *et al.*, 2009). Many mammals are ecosystem engineers that significantly create or destroy habitats that changes the ecosystem structure and function (Lacher *et al.*, 2019). These are the species that

can shape both the biotic and abiotic component of the ecosystem in which they live (Jones *et al.*, 1994; Jones and Safi, 2011; Sinclair *et al.*, 2015). Relative to their abundance, mammals affect plant structure and function to the greater extent as compared to any other animal group (Hulbert, 1997; Paine, 2000; Sinclair *et al.*, 2015). Mammals, like markhor *Capra falconeri* also generate revenue for the local community through trophy hunting programs (Ashraf *et al.*, 2014; Nawaz *et al.*, 2016). Pakistan has varied range of ecosystems and unique ecological regions that support rich diversity of animals including mammals, birds, reptiles, amphibians and fishes (Altat *et al.*, 2014). Variations in climatic conditions and topography are the significant predictors of mammalian species diversity where different habitats support different species of mammals (Vaughan *et al.*, 2000; Atnafu and Yihune, 2018). Faunal diversity also corresponds to the altitudinal variations which exist throughout the landscape of Pakistan (Altat *et al.*, 2014), particularly the mountain

* Corresponding author: nawazma@gmail.com

0030-9923/2022/0001-0001 \$ 9.00/0

Copyright 2022 Zoological Society of Pakistan

areas of the country show abrupt change in elevation and have many distinct habitat types which harbor large number of wildlife species (IUCN, 1996).

Estimating species abundance is necessary for assessing extinction risk of endangered species, monitoring invasive species and particularly in managing population of threatened species (Yin and He, 2014). Knowledge of species abundance is necessary for decision making in biological management and conservation and for understanding the dynamics of population (Yin and He, 2014). Estimating abundance helps in setting hunting quotas, gauging prey availability for carnivores and managing wildlife areas for tourism (Palmer *et al.*, 2018). Conservation efforts are assessed by using abundance estimates, it also provides insight into how a community functions (Danell *et al.*, 2006; Verberk, 2011; Cox *et al.*, 2017).

Investigation on abundance of mammals provides information for appropriate conservation actions (Galetti *et al.*, 2009; Rabira *et al.*, 2015; Atnafu and Yihune, 2018). Relative abundance is usually expressed as an index value calculated from the frequency of signs or observations per standardized unit of sampling effort (Wilson and Delahay, 2001). Relative abundance is used because it requires fewer resources and less sampling efforts as compared to population estimation (Lettink, 2012). The data obtained from camera traps can be used to estimate relative abundance of species (O'Brien *et al.*, 2003; Lahang, 2005; O'Brien, 2011). Measure of relative abundance is the key element of biodiversity required for the estimation of species diversity (Hubbell, 2001; Yoccoz *et al.*, 2001). The data of species relative abundance can be used by ecologists to infer relationships among different species in certain communities (Odat *et al.*, 2009). It is also used to estimate ecological disturbance and perform population viability analysis (Odat *et al.*, 2009).

Chitral Gol National Park (CGNP) harbors a large number of mammals; however, information on population size, estimated densities or any other ecological parameter is not available for those species except annual census counts for markhor. Since, absolute abundance, density and population size estimation are not possible due to financial and time constraints. The current study was conducted with the aim to determine the relative abundance of mammals in CGNP because it can be used as an alternative way to explore diversity of species in the National Park. It is of great importance for the species occurring there and utilizing the NP resources. Estimating relative abundance of mammals in CGNP could provide useful information needed for management of the National Park.

MATERIALS AND METHODS

Study area

The study was conducted in Chitral Gol National Park, situated in the District Chitral (Lower), Pakistan. It is located on 35°51' and 35°57' N latitude and 71°43' and 71°47' E longitude while elevation ranges from 1500 to 4950 meters, having an estimated area of 78.6 km². It is located in the Hindu Kush Mountain range lying in the west of Chitral town. The fauna of district Chitral shows affinity towards fauna of Palearctic region, and a little affinity with Oriental region in the south (Din and Nawaz, 2010). CGNP was established in 1984 meeting the criterion of the IUCN management category 2 of protected areas to protect populations and habitat of Snow leopard (*Panthera unica*) and Kashmir markhor (*Capra falconeri cashmiriensis*) (Arshad *et al.*, 2012). The area of the NP is relatively steep with sharp ridges and vertical slopes with incline slope ranging from 45° to 120° (Hess, 2002; Arshad *et al.*, 2012). CGNP has mean annual temperature of 16.8°C (Ali, 2008; Shabbir *et al.*, 2013). The climate of Chitral is dry temperate and the area of the national park is out of the range of monsoon and it receives 462 mm of mean annual precipitation, mainly in spring and winter (Hess, 2002; Khan *et al.*, 2010, 2011). During winter the mountains are covered with snow, and summer is long and dry (Fig. 1).

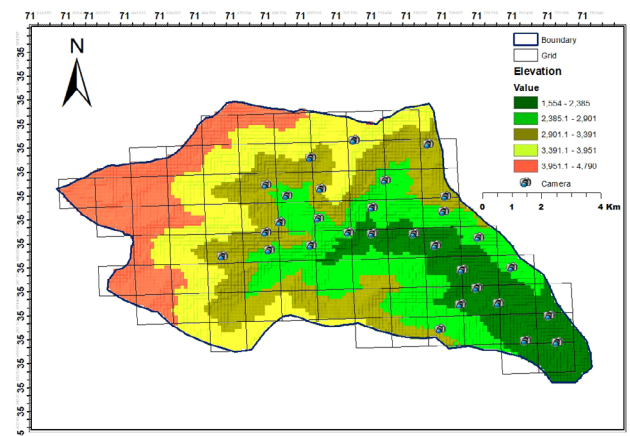


Fig. 1. Map of the study area and camera trap's location in Chitral Gol National Park.

Survey design

The study was carried out from June 17 to August 3, 2019. During the study, 30 camera traps were deployed within CGNP. The minimum Aerial distance between two (2) camera traps was kept one km. In every suitable location, a single motion triggered camera (Reconyx™)

with infrared flash was installed. All the cameras were set to a steel pole at a height of 50 cm to capture both large and small sized wild animals. The steel pole was driven into the ground. The cameras were placed facing away from the sun, dense vegetation or any large object that could cause false trigger event. Camera trap units were programmed to take 3 images of size 3.1 MP at the interval of one second. Each image had time and date of capture. Coordinates and elevation of each camera were documented through geographic positioning system (GPS MAP 62s Garmin). The memory cards were of 64 GB and the batteries composed of lithium ions. The approach for sampling was passive as we did not use attractants (i.e. scent) to attract mammals towards the camera trap location. After 47 days of survey period, the cameras were taken off. A zoologist familiar with the region's mammalian fauna independently identified the species photographed by cameras. Photographs that could not be identified were not included in the analysis.

Data analysis

Independent detection event

Detection for a species is considered an independent event, when the time interval between consecutive photographs of the same species is more than one-hour interval.

Trap night

It is a 24 h period when camera trap is set to be active. It is calculated by multiplying the total number of camera traps used with total number of nights of active trapping.

Operational day (for camera)

It is the number of days for which the camera traps remain in active condition.

Photos capture Rate

It is the total number of photos captured for one species divided by the total number of photos obtained during the survey per 100 trap nights.

Relative abundance estimation

Relative abundance was calculated using the following formula which is frequently used to calculate relative abundance index from the data generated by using camera traps (Din *et al.*, 2013; Liu *et al.*, 2013).

$$RAI = \frac{A_i}{N} \times 100$$

Where, A_i refers to the overall number of independent detections of species I during the survey period. N represents the overall number of independent events of all species during the survey period.

RESULTS

Camera trapping survey

Thirty cameras were installed for a period of 47 days. Most of the cameras remained operational throughout the study period while three cameras stopped functioning after some days of installation. The survey resulted in 1052 functional trap nights and 478 non-functional trap nights.

Table I. Number of events, with one hour interval, different animals were detected in Chitral Gol National Park, Pakistan results of Camera Trap Study.

Species captured	Detection events one hour interval
Human being	200
Leopard cat	2
Himalayan lynx	19
Common leopard	3
Grey wolf	3
Red fox	28
Golden jackal	14
Golden marmot	2
Feral dog	18
Stone marten	9
Cape hare	97
Kashmir flying squirrel	6
Mice	4
Markhor	202
Monal pheasant	3
Lizard	3
Unidentified bird	9
Snow cock	3
Chukor partridge	16
Live stock	92
False image	7
Grand total	740

Capture summary

The camera trapping survey documented 13 different animals other than human beings, domestic livestock and feral dogs *Canis familiaris*, while some false images were also present. The results show that large carnivores like common leopard *Panthera pardus*, grey wolf *Canis lupus*, Himalayan lynx *Lynx lynx isabellinus* are present in the National Park. Among other meso-carnivores, golden jackal *Canis aureus*, leopard cat *Prionailurus bengalensis*, red fox *Vulpes vulpes* were also captured at

different stations. Small mammals were also captured at different locations which included stone marten *Martes foina*, Kashmir flying squirrel *Eoglaucomys fimbriatus*, Himalayan wood mouse *Apodemus sylvaticus*, golden marmot *Marmota caudate*, and cape hare *Lepus capensis* (Fig. 2). Prominent avian species captured through camera traps include monal pheasant *Lophophorus impejanus*, chukor partridge *Alectoris chukar* and snow cock *Tertagallus himalayensis* while some other species were also captured which couldn't be clearly identified (Table I).

Relative abundance of mammalian fauna

Markhor had the highest relative abundance of 49.631 with 19 spatial captures while golden jackal and golden marmot had the lowest spatial capture accounting for respective relative abundance index of 0.491 and 3.439 respectively. Relative abundance index of rest of the species was as follows: Cape hare 23.832, red fox 6.879, Himalayan lynx 4.668, feral dogs 4.422, stone marten 2.211, Kashmir flying squirrel 1.474, while 0.737 both for common leopard and grey wolf (Table II).

Taxonomic groups of recorded mammals

The results show that different animals belonging to different functional guilds and different taxonomic groups are dwelling in CGNP. Order carnivora was represented by eight species viz., leopard cat, Himalayan lynx, common leopard, grey wolf, golden jackal, red fox and stone marten. Order Artiodactyla is represented by one species,

markhor which is near threatened in the IUCN red list and endangered in the IUCN red list of Pakistan. Lagomorpha is represented with only one species that is cape hare. Order Rodentia was represented by three species viz., Himalayan wood mouse, golden marmot and Kashmir flying squirrel (Table III).

Table II. Relative Abundance Index of mammalian species in CGNP.

Mammalian species	Spatial captures	Species count	Photo capture rate	RAI
Cape hare	10	97	21.647	23.832
Common leopard	3	3	0.284	0.737
Feral dog	5	18	2.903	4.422
Golden jackal	1	14	2.083	3.439
Golden marmot	1	2	0.189	0.491
Grey wolf	2	3	0.568	0.737
Leopard cat	2	2	0.410	0.491
Himalayan lynx	6	19	2.430	4.668
Markhor	19	202	64.847	49.631
Mice	3	4	0.473	0.982
Red fox	12	28	2.998	6.879
Kashmir flying squirrel	2	6	0.316	1.474
Stone marten	4	9	0.852	2.211
Total		407		100

Table III. Taxonomic position and red list status of mammalian fauna of CGNP.

Family	Common and Scientific names	IUCN red list status	National red list status
Order/ Carnivora			
Felidae	Leopard cat (<i>Prionailurus bengalensis</i>)	Least concern	Data deficient
	Himalayan lynx (<i>Lynx lynx isabellinus</i>)	Near threatened	Least concern
	Common leopard (<i>Panthera pardus</i>)	Vulnerable	Critically endangered
Canidae	Grey wolf (<i>Canis lupus</i>)	Least concern	Endangered
	Golden jackal (<i>Canis aureus</i>)	Least concern	Near threatened
	Red fox (<i>Vulpes vulpes</i>)	Least concern	Near threatened
	Feral dog	-----NA----	-----NA----
Mustelidae	Stone marten (<i>Martes foina</i>)	Least concern	Data deficient
Artiodactyla			
Bovidae	Markhor (<i>Capra falconeri</i>)	Near threatened	Endangered
Lagomorpha			
Leporids	Cape hare (<i>Lepus capensis</i>)	Least concern	Vulnerable
Rodentia			
Murids	Mice (<i>Apodemus sylvaticus</i>)	Least concern	Vulnerable
Sciuridae	Golden marmot (<i>Marota caudata</i>)	Least concern	Least concern
	Kashmir flying squirrel (<i>Eoglaucomys fimbriatus</i>)	Least concern	Vulnerable

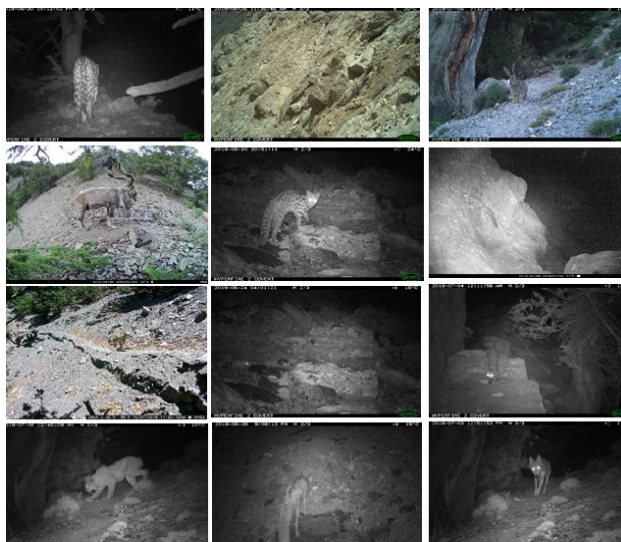


Fig. 2. Camera trap photographs of different mammals from the study area.

DISCUSSION

CGNP has been a protected area since 1984 and gained much fame for successful conservation and increasing population of the markhor which has now been raised to around 3000 inside the park (Kakakhel, 2020). Markhor also turned out to be the most abundant species of the park with relative abundance index of 49.631 in the current study.

The relative abundance of cape hare was 23.832 in the study area. Cape hare was the only species photo captured (detected) from the Leporidae family. This species is of least concern status in the IUCN red list of species while in the national red list of Pakistan it is vulnerable (Sheikh and Moular, 2003). In Pakistan the genus *Lepus* is represented by 3 species *Lepus capensis*, *Lepus nigricollis*, *Lepus arabisicus* (Ghazi et al., 2005). Its vertical distribution ranges from 600 meters to 5200 meters in winter and summer season respectively (Roberts, 1997). Most of the animals were captured at elevation varying from 1750 to 3500 meters.

Grey wolf, red fox and golden jackal are abundant species in the study area (Din et al., 2013). In the current study red fox and golden jackal had respective relative abundance index of 6.879 and 3.439. Abundance of red fox and golden jackal may be due to the reason that the National Park is comparatively safe and they are facing less human induced threats (Din et al., 2013). Their generalist food habits and scavenging nature allows them to thrive in the NP where multiple large predators exist along with many prey species (Flower, 1932; Roberts, 1997; Awan

et al. 2004; Akrim et al., 2019). Roberts (1997) declared golden jackal to be uncommon in the mountains of Chitral but other latest studies indicate its presence in different parts of Chitral including the study area (Din et al., 2013). The species is highly adaptable, consumes variety of foods and rapidly expands to new habitats (IUCN, 2004; Laszlo et al., 2007; Shabbir et al., 2013). It is important to note that photo capture rate of wolf was lower in the current study as compared to the study conducted by Din et al. (2013) despite the extended duration of study and more cameras. The reason may be season of the study as wolves are known to change habitat during summer and winter seasons (Milacovik et al., 2011; Uboni et al., 2015). Although it is ranked with least concern status in the IUCN Red List, its global population has declined by 33% while it is listed as endangered in Pakistan (Sheikh and Moular, 2003). Feral dogs were also photo captured in large numbers with relative abundance index of 4.422. The NP might be proving a better place for them as compared to the nearby town. Staff of the park and local people report that packs of feral dog hunt on markhor fawns in eastern parts of the NP. According to the official sources, during 2014-2019 (n=183) feral dogs were killed by the park management in order to get rid of the menace, but the problem still stands (Khattak et al., 2021). A significant rise in the dog population has led to undesirable relations with both public and wildlife worldwide (Kumar and Paliwal, 2015; Home et al., 2017).

Family felidae was represented by Himalayan lynx, leopard cat and common leopard during the current study, each having relative abundance of 4.668, 0.491 and 0.737 respectively. Himalayan lynx has been reported from various parts of Pakistan but authentic and comprehensive reports on its population and interactions with humans are available only from Chitral; where the study area is an important stronghold of the species (Sheikh and Moular, 2003; Din and Nawaz, 2011; Din et al., 2015). The current findings and frequent sightings depict a stable and increasing population of the species in the NP and surrounding valleys. Leopard cat is more cryptic species of the Felidae family as compared to lynx and associated with forest habitats (Roberts, 1997). The species has been reported from Chitral, Azad Jammu and Kashmir and Gilgit Baltistan (Ahmad et al., 2016). The species is data deficient according to the national red list of mammals of Pakistan (Sheikh and Moular, 2003) due to lack of information on its distribution, habitat, population and environment (Sheikh and Moular, 2003; Shehzad et al., 2012). For the last five years, common leopard is frequently sighted and reported from the NP, it was also recorded in the current study whereas historically CGNP was famous for snow leopard. Common leopard is highly adaptable

and wide ranging of the big cats and listed as vulnerable due to habitat loss, fragmentation and persecution (Nowell and Jackson, 1996; Bibi *et al.*, 2013; IUCN, 2021). Presence of four subspecies of common leopard has been reported and claimed from different parts of Pakistan but molecular characterization of samples from the country doesn't support this notion (Ijaz *et al.*, 2017). During the past several years, common leopard has been sighted or photographed in the snow leopard range and even in some cases a single camera recorded both leopard species (SLT, 2017). But in Chitral Gol National Park snow leopard has not been sighted or photographed since 2012, which needs plausible explanation.

Order Rodentia was represented by Kashmir flying squirrel, golden marmot and Himalayan wood mouse which are frequent inhabitants of alpine and subalpine zones between 1000 to 4000-meter elevation (Roberts, 1997). Other studies have documented around nine species of rodents from the study area (Nasir, 2004). Golden marmot and Himalayan wood mouse are important food source for many large carnivores thus very important for ecological integrity of the park.

It has been established that body mass of the species has some effect on likelihood of being trapped through camera (Bengsen *et al.*, 2011; Anile and Davillard, 2015). Some larger species may move more slowly and they have higher population density which results in a higher relative abundance for species like markhor in the park (Rowcliffe *et al.*, 2008; Bengsen *et al.*, 2011). We recognize that element of bias couldn't be eliminated in calculating RAI by using capture events (Anile and Davillard, 2015). Some species are more frequently seen in the NP premises such as markhor, feral dogs and Himalayan lynx although the relative abundance calculated from this study may not reflect the actual abundance of many species. An optimized survey based on knowledge of species' ecology and familiarity with the area coupled with multi-seasonal trapping efforts would increase the number of species recorded and more reliable estimation of their abundance.

CONCLUSION

The current work is the first comprehensive camera trapping effort on mammalian fauna in CGNP, which confirmed the presence of thirteen different species of mammals in the park. Herbivores like markhor, cape hare and carnivores like Himalayan lynx, golden jackal, red fox, grey wolf and common leopard are some major species dwelling in the NP. Although the previous reports are based on anecdotal surveys, the non-detection may be due to single season survey. Camera trapping study involving different seasons and targeting all different types

of microhabitats of the park is suggested.

ACKNOWLEDGEMENTS

We are thankful to the Directorate of National Parks, Khyber Pakhtunkhwa Wildlife Department for financial resources and logistic support and all the field staff of Chitral Gol National Park. We acknowledge the technical and equipment support from Carnivore Conservation Lab, Department of Zoology, Quaid-i-Azam University, Islamabad.

Statement of conflict of interest

The authors have declared no conflict of interest.

REFERENCES

- Ahmad, S., Hameed, S., Ali, H., Khan, T.U., Mehmood, T., and Nawaz, M.A., 2016. Carnivores' diversity and conflicts with humans in Musk deer national Park, azad Jammu and Kashmir, Pakistan. *Eur. J. Wildl. Res.*, **62**: 565-576. <https://doi.org/10.1007/s10344-016-1029-6>
- Akrim, F., Mahmood, T., Nadeem, M.S., Dhendup, T., Fatima, H., and Andleeb, S., 2019. Diet composition and niche overlap of two sympatric carnivores: Asiatic jackal *Canis aureus* and Kashmir hill fox *Vulpes vulpes griffithii*, inhabiting Pir Lasura National Park, northeastern Himalayan region, Pakistan. *Wildl. Biol.*, **2019**: 1-9. <https://doi.org/10.2981/wlb.00440>
- Ali, S., 2008. *Conservation and status of Markhor (Capra falconeri) in the North West Frontier Province, Pakistan*. Graduate student thesis, Dissertations, and Professional Papers. 10919. <https://scholarworks.umt.edu/etd/10919>
- Altaf, M., Javid, A., Irfan, M., M., Ashraf, S., Umair, M., Iqbal, K., Khan, A., M., and Ali, Z., 2014. Diversity of wild mammalian fauna of Chenab Riverine Forest, Punjab, Pakistan. *J. Anim. Pl. Sci.*, **24**(5): 1342-1347.
- Anile, S., and Devillard, S., 2015. Study design and body mass influence RAIs from camera trap studies: Evidence from the Felidae. *Anim. Conserv.*, pp. 1-11. <https://doi.org/10.1111/acv.12214>
- Arshad, M., Qamer, F.M., Saleem, R., and Riffat, N.M., 2012. Prediction of Kashmir Markhor habitat suitability in Chitral Gol National Park, Pakistan. *Biodiversity*, **13**: 78-87. <https://doi.org/10.1080/1488386.2012.684206>
- Ashraf, N., Anwar, M., Hussain, I., and Nawaz, M.A., 2014. Competition for food between the markhor

- and domestic goat in Chitral, Pakistan. *Turk. J. Zool.*, **38**: 191-198. <https://doi.org/10.3906/zoo-1306-6>
- Atnafu, G., and Yihune, M., 2018. Species composition and relative abundance of medium and large mammals in Mengaza communal forest, East Gojjam, Ethiopia. *J. Ecol. Natl. Environ.*, **10**: 34-40. <https://doi.org/10.5897/JENE2017.0667>
- Awan, M.S., Minhaz, R.A., Ahmad, K.B., and Dar, N.I., 2004. Distribution, food and habitat preferences of small mammals in Machiara National Park, District Muzaffarabad, Azad Kashmir, Pakistan. *Punjab Univ. J. Zool.*, **19**: 17-31.
- Bakker, E.S., Jordi, F.P., Rohan, A., and Teresa, A., 2016. Assessing the role of large herbivores in the structuring and functioning of freshwater and marine angiosperm ecosystems. *Ecography*, **39**: 162-179. <https://doi.org/10.1111/ecog.01651>
- Bengsen, A.J., Leung, L.K.P., Lapidge, S.J. and Gordon, I.J., 2011. Using a general index approach to analyze camera trap abundance indices. *J. Wildl. Manage.*, **75**: 1222-1227. <https://doi.org/10.1002/jwmg.132>
- Bibi, S.S., Minhas, R.A., Awan, M.S., Ali, U., and Dar, N.I., 2013. Study of ethnocarnivore relationship in Dhirkot, Azad Jammu and Kashmir. *Pak. J. Anim. Pl. Sci.*, **23**: 854-859.
- Cox, K.D., Black, M.J., Filip, N., Miller, M.R., Mohns, K., Mortimor, J., and Dudas, S.E., 2017. Community assessment techniques and the implications for rarefaction and extrapolation with Hill numbers. *Ecol. Evol.*, **7**: 11213-11226. <https://doi.org/10.1002/ece3.3580>
- Danell, K., Duncan, P., Bergstrom, R. and Frontmatter, J.P., 2006. *Large herbivore ecology, ecosystem dynamics and conservation*. Cambridge University Press. <https://doi.org/10.1017/CBO9780511617461>
- Din, J.U., and Nawaz, M.A., 2010. Status of the Himalayan lynx in district Chitral, NWFP, Pakistan. *J. Anim. Pl. Sci.*, **20**: 17-22.
- Din, J.U., Hameed, S., Shah, K.A., Khan, M.A., Ali, S., and Nawaz, M.A., 2013. Assessment of canid abundance and conflict with humans in the Hindu Kush Mountain Range of Pakistan. *Wildl. Biol. Pract.*, **9**: 20-29. <https://doi.org/10.2461/wbp.2013.9.5>
- Din, J.U., Zimmermann, F., Ali, M., Ali, K.S., Ayub, M., Khan, S., and Nawaz, M.A., 2015. Population assessment of Himalayan lynx (*Lynx lynx isabellinus*) and conflict with humans in the Hindu Kush Mountain range of District Chitral, Pakistan. *J. Biodiv. environ. Sci.*, **6**: 31-39.
- Flower, S., 1932. Notes on the recent mammals of Egypt, with a list of the species recorded from that Kingdom. *Proc. zool. Soc.*, **110**: 369-450. <https://doi.org/10.1111/j.1096-3642.1932.tb01081.x>
- Galetti, M., Henrique, C., Giacomini, C., Rafael, S., Bueno, S., Christine, S.S., Bernardo, R.M., Marques, R., Bovendorp, S., Steffler, E., Paulo, R., Sabrina, K., Camila, I., Donatti, G., Rodrigo, A., Meirelles, B.F., Rodrigo, D., Nobre, A., Chiarello, G., and Peres, C.A., 2009. Priority areas for the conservation of Atlantic forest large mammals. *Biol. Conserv.*, **142**: 1229-1241. <https://doi.org/10.1016/j.biocon.2009.01.023>
- Ghazi, R.R., Khatoon, N., Bilqees, F.M., and Rathore, S.M., 2005. *Syphacia caudibandata* sp. N (Nematoda: Oxyuridae) from a Lagomorph host *Lepus capensis* Linn in Karachi, Sindh, Pakistan. *Türk. Parazit. Derg.*, **29**: 131-134.
- Hess, R., 2002. *The ecological niche of markhor Capra falconeri between wild goat Capra aegagrus and Asiatic ibex Capra ibex*. PhD diss., University of Zurich.
- Home, C., Bhatnagar, Y.V., and Vanak, A.T., 2017. Canine conundrum: Domestic dogs as an invasive species and their impacts on wildlife in India. *Anim. Conserv.*, **21**: 275-282. <https://doi.org/10.1111/acv.12389>
- Hubbell, S.P., 2001. *A unified theory of biodiversity and biogeography*. Princeton University Press, Princeton.
- Hulbert, S.H., 1997. Functional importance vs keystone: Reforming some questions in theoretical biocenology. *Aust. J. Ecol.*, **22**: 369-382. <https://doi.org/10.1111/j.1442-9993.1997.tb00687.x>
- Ijaz, U., Tahir, M.S., Majeed, K.A., Iqbal, S., Firyal, S., Ahmed, I., Chohan, S.K., and Aamir, R., 2017. *Molecular characterization and phylogeny of Panthera pardus (common leopard) in Pakistan*. World Wildlife Fund, Ferozepur Road, Lahore, Pakistan. <https://doi.org/10.17582/journal.pjz/2017.49.1.65.69>
- IUCN and Government of Kyber Paktun Khawan, 1996. *Sarhad provincial conservation strategy*. IUCN Pakistan and Government of Pakistan, Karachi.
- IUCN, 2004. Canids foxes, wolves, jackals and dogs. Status survey and conservation action plan. In: *IUCN/SSC canid specialist group* (eds. C.S. Zubiri, M. Hoffmann and D.W. Macdonald). Gland, Switzerland and Cambridge, UK. pp. 430-460.
- IUCN, 2021. *The IUCN red list of threatened species*. Accessed on June 30, 2021.

- Jones, C., Lawton, J., and Shachak, M., 1994. Organisms as ecosystem engineers. *Oikos*, **69**: 373-386. <https://doi.org/10.2307/3545850>
- Jones, K.E., and Safi, K., 2011. Ecology and evolution of mammal's biodiversity. *Philos. Trans. R. Soc. B*, **366**: 2451-2461. <https://doi.org/10.1098/rstb.2011.0090>
- Kakakhel, F.B., 2020. A review on markhor (*Capra falconeri falconeri* Wagner 1839) population trends (2016-2019) and community-based conservation in Toshi Shasha, Gehrait Goleen, Kaigah Kohistan Conservancies and Chitral Gol National Park, Khyber Pakhtunkhwa, Pakistan. *Am. J. natl. Sci.*, **3**: 1-18.
- Khan, N., Ahmed, M., Ahmed, A., Shaukat, S.S., Wahab, M., Ajaib, M., Siddiqui, M.F., Nasir, M., 2011. Important medicinal plants of Chitral Gol National Park (CGNP), Pakistan. *Pak. J. Bot.*, **43**: 797-809.
- Khan, N., Ahmed, M., Wahab, M., and Ajaib, M., 2010. Phytosociology, structure and physiochemical analysis of soil in quercus baloot griff, District Chitral, Paksitan. *Pak. J. Bot.*, **42**: 2429-2441.
- Khattak, R.H., Zin, Z., Ahmad, S., Bari, F., Khan, A., Nabi, G., Shah, A.A., Khan, S., and Rehman, U.E., 2021. Feral dogs in Chitral Gol National Park, Pakistan: A potential threat to the future of threatened Kashmir markhor (*Capra falconeri cashmiriensis*). *Braz. J. Zool.*, **2023-83**: e245867. <https://doi.org/10.1590/1519-6984.245867>
- Kumar, A., and Paliwal, R., 2015. Feral dogs of Spiti Valley, Himachal Pradesh an emerging threat for wildlife and human life. *Curr. Sci.*, **108**: 1799-1800.
- Lacher, Jr, T.E., Davidson, A.D., Fleming, T.H., Gómez-Ruiz, E.P., McCracken, G.F., Owen-Smith, N., and Vander W.S.B., 2019. The functional roles of mammals in ecosystems. *J. Mammal.*, **100**: 942-964. <https://doi.org/10.1093/jmammal/gyy183>
- Lahang, P., 2005. *Using camera trapping data to calculate diversity, activity pattern and relative abundance of terrestrial mammals at Lambir Hills National Park*. Bachelor of Science with Honors in Animal Resource and Management Science thesis submitted to the Faculty of Resource Science and Technology, Universiti Malaysia, Sarawak. pp. 1-24.
- Laszlo, S., Heltai, M., Lanszki, J., and Szöcs, E., 2007. An indigenous predator, the golden jackal (*Canis aureus* L.1758) spreading like an invasive species in hungary. *Bull. USAMV-CN*, **6**: 63-64.
- Lettink, M., 2012. Herpetofauna: Population estimates (using capture-mark-recapture data). v1. 0. In: *Inventory and monitoring toolbox: Herpetofauna*. Report DOCDM-833600. Department of Conservation Te Papa Atawhai. Wellington, New Zealand.
- Liu, X., Wu, P., Songer, M., Cai, Q., He, X., Zhu, Y., and Shao, X., 2013. Monitoring wildlife abundance and diversity with infra-red camera traps in guanyinshan nature reserve of Shaanxi Province, China. *Ecol. Indic.*, **33**: 121-128. <https://doi.org/10.1016/j.ecolind.2012.09.022>
- Marcot, B.G., and Vander, H.M., 2001. Key ecological functions of wildlife species. *Communities*, **1**: 14-41.
- Milakovic, B., Parker, K.L., Gustine, D.D., Lay, R.J., Walker, A.B., and Gillingham, M.P., 2011. Habitat selection by a focal predator (*Canis lupus*) in a multiprey ecosystem of the northern Rockies. *J. Mammal.*, **92**: 568-582. <https://doi.org/10.1644/10-MAMM-A-040.1>
- Nasir, S.M., 2004. *Management plan for Chitral Gol National Park*. https://wwfasia.awsassets.panda.org/downloads/planfor_chitralgolnationalpark
- Nawaz, M.A., Din, J.U., Shah, S.A., and Khan, A.A., 2016. The trophy hunting program: Enhancing snow leopard prey populations through community participation. In: *Snow leopards: Biodiversity of the world: Conservation from genes to landscapes*, pp. 220-229.
- Nowell, K. and Jackson, P., 1996. *Wild cats. Status survey and conservation action plan*. IUCN/SSC Cat Specialist Group. IUCN, Gland, pp. 382.
- O'Brien, T.G., 2011. Abundance, density and relative abundance: A conceptual framework. In: *Camera traps in animal ecology*. Springer, Tokyo. pp. 71-96. https://doi.org/10.1007/978-4-431-99495-4_6
- O'Brien, T.G., Kinnaird, M.F., and Wibisono, H.T., 2003. Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. *Anim. Conserv. Forum*, **6**: 131-139. <https://doi.org/10.1017/S1367943003003172>
- Odat, Nidal., Moh'd, M.T.L., Riyadh, M., Faisal, A., Abdel, R.M., Al-Tawaha, and Saleem, L., 2009. Predicting species relative abundance in ecological communities. *Jordan J. biol. Sci.*, **2**: 83-88.
- Paine, R.T., 2000. Phycology for the mammalogist: Marine rocky shores and mammal-dominated communities how different are the structuring processes? *J. Mammal.*, **81**: 637-648. [https://doi.org/10.1644/1545-1542\(2000\)081<0637:PFTMMR>2.3.CO;2](https://doi.org/10.1644/1545-1542(2000)081<0637:PFTMMR>2.3.CO;2)
- Palmer, M.S., Packer, C., Swanson, A., Kosmala,

- M., and Arnold, T., 2018. Evaluating relative abundance indices for terrestrial herbivores from large scale camera trap surveys. *Afr. J. Ecol.*, **56**: 791-803. <https://doi.org/10.1111/aje.12566>
- Rabira, G.T.G., and Tadesse, H., 2015. The diversity, abundance and habitat association of medium and large-sized mammals of DatiWolel National Park, Western Ethiopia. *Int. J. Biod. Conserv.*, **7**: 112-118. <https://doi.org/10.5897/IJBC2014.0808>
- Ray, J.C., Redford, K.H., Steneck, R.S., and Berger, J., 2005. *Large carnivores and the conservation of biodiversity*. Island Press, Washington (DC). pp. 165-166. [https://doi.org/10.1641/0006-3568\(2004\)054\[0755:WATEOF\]2.0.CO;2](https://doi.org/10.1641/0006-3568(2004)054[0755:WATEOF]2.0.CO;2)
- Ripple, W.J., and Beschta, R.L., 2004. Wolves and the ecology of fear. Can predation risk structure ecosystems. *BioScience*, **54**: 165-166.
- Roberts, T.J., 1997. *The mammals of Pakistan*, Oxford University Press, Karachi, Pakistan.
- Roemer, G.W., Matthew, E.G., and Blaire, V.V., 2009. The ecological role of the mammalian mesocarnivore. *BioScience*, **59**: 165-173. <https://doi.org/10.1525/bio.2009.59.2.9>
- Rowcliffe, M.J., Field, J., Turvey, S.T. and Carbone, C., 2008. Estimating animal density using camera traps without the need for individual recognition. *J. appl. Ecol.*, **45**: 1228-1236. <https://doi.org/10.1111/j.1365-2664.2008.01473.x>
- Shabbir, S., Anwar, M., Hussain, I., and Nawaz, M.A., 2013. Food habits and diet overlap of two sympatric carnivore species in chitral. *Pakistan J. Anim. Pl. Sci.*, **23**: 100-107.
- Shehzad, W., Riaz, T., Nawaz, M.A., Miquel, C., Poillot, C., Shah, S.A., and Taberlet, P., 2012. Arnivore diet analysis based on next-generation sequencing application to the leopard cat (*Prionailurus bengalensis*) in Pakistan. *Mol. Ecol.*, **21**: 1951-1965. <https://doi.org/10.1111/j.1365-294X.2011.05424.x>
- Sheikh, K.M., and Molur, S., 2003. *Status and red list of Pakistan's mammal based on conservation assessment and management plan*. Workshop Islamabad IUCN Pakistan. 2004.
- Sinclair, A.R., Metzger, K.L., Mduma, S.A., and Fryxell, J.M., 2015. *Serengeti IV: Sustaining biodiversity in a coupled human-natural system*. University of Chicago Press. <https://doi.org/10.7208/chicago/9780226196336.001.0001>
- SLT, 2017. *Snow leopard trust*. <https://snowleopard.org/sharing-spots-snow-leopards-common-leopards-share-habitat-china/>
- Uboni, A., Smith, D.W., Mao, J.S., Stahler, D.R., and Vucetich, J.A., 2015. Long and short term temporal variability in habitat selection of a top predator. *Ecosphere*, **6**: 1-16. <https://doi.org/10.1890/ES14-00419.1>
- Vaughan, A.T., Ryan, M.J., and Czaplewski, N., 2000. *Mammalogy*. Saunders College Publishing, 4th edn., New York. pp. 34-40.
- Verberk, W.C.E.P., 2011. Explaining general patterns in species abundance and distributions. *Nat. Educat. Knowl.*, **3**: 38.
- Wilson, G.J., and Delahay, R.J., 2001. A review of methods to estimate the abundance of terrestrial carnivores using field signs and observation. *Wildl. Res.*, **28**: 151-164. <https://doi.org/10.1071/WR00033>
- Yin, D., and He, F., 2014. A simple method for estimating species abundance from occurrence maps. *Methods Ecol. Evol.*, pp. 336-343. <https://doi.org/10.1111/2041-210X.12159>
- Yoccoz, N.G., Nichols, J., and Thierry, D.B., 2001. Monitoring of biological diversity in space and time. *Trends Ecol. Evol.*, pp. 446-453. [https://doi.org/10.1016/S0169-5347\(01\)02205-4](https://doi.org/10.1016/S0169-5347(01)02205-4)