Assessment of impacts on wildlife of Kedarnath Musk Deer Sanctuary due to Helicopter services

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Assessment of Impacts on Wildlife of Kedarnath Musk Deer Sanctuary due to Helicopter Services

A Report Submitted to the Uttarakhand State Forest Department

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Team members

Executive Summary

The Kedarnath shrine is an important and famous Hindu religious site situated at 3,583 m near the source of the Mandakini River in Uttarakhand. For centuries, large numbers of pilgrims visit the shrine in the summer months. The stretch between Gaurikund and Rambara of the pilgrim route passes through the Kedarnath Musk Deer Sanctuary (WS). Helicopter services were initiated during 2007-08 to ferry pilgrims. In June 2013, devastating flash floods swept through the region, and almost half of the old pilgrim route was damaged, and a new slightly longer route was constructed. After 2013, the number of helicopters operating daily flights to Kedarnath shrine increased dramatically. Some of the local residents raised concerns over the potential impact on wildlife of Kedarnath WS due to high intensity sound produced by the helicopters. Based on the request from Uttarakhand State Forest Department, the Wildlife Institute of India carried out a study to assess the impacts of helicopter flights on wildlife of Kedarnath WS and to suggest mitigation measures.

The Mandakini valley was selected as the main study site, where the helicopter flights operate. The adjacent Kaliganga valley, and Shokharakh area were taken as control sites. The sampling was carried out in Mandakini valley in two different study periods – September to December 2015 and April to June 2016; coinciding with the helicopter flying period. Helicopter aviation data and noise levels in different elevation and habitat types were recorded in the Mandakini Valley to detect wildlife species presence, Trails (n=7) and vantage points (n=2) were sampled, and camera traps (n= 23) were deployed. Comparative studies on wildlife species presence in Kaliganga Valley and Shokharkh (control sites) were carried out using trail sampling and camera trapping. Fresh faecal samples of wild mammals were collected from Mandakini Valley and the two control sites to analyse the levels of stress hormone using Enzyme Immuno-Assay procedure at the CCMB-LaCONES, Hyderabad. A detailed literature review was carried out on impacts of aircraft flights on wildlife carried out in different parts of the world to understand likely impacts on wildlife and various mitigation measures proposed.

The results showed that May is the month when maximum number of flights operated (305/day) in Mandakini Valley followed by June and October, as Sersi helipad is nearest to Kedarnath, the onward journey to Kedarnath from Sersi reached the lowest mean flight height (152.4 ± 6.11 m). Noise levels recorded from six recording sites in Mandakini valley had a mean well above the 50 dB upper noise limit for silence zones. Negative correlation (R^2 = 0.33 and 0.25) was observed between flight height and noise level for open coniferous and broadleaved forest. Presence of 20 mammal species (carnivore-8, ungulate-7, primate-2, rodent- 2, lagomorph-1) and five galliformes species (pheasants-3, partridge-2) has been confirmed from the study area.

In general, the study area is already exposed to immense anthropogenic pressure (pilgrims, constructions, etc.) it is very difficult to decouple the effects of helicopter flying and other anthropogenic disturbances. Based on the findings of this study and a perusal of published information on impacts of aircraft flights on wildlife, the following conclusions are arrived at:

1. All the common wildlife species of Kedarnath WS are present in Mandakini valley. The comparison among the photo-capture rates of different wild animals

depicts the consistent use of available habitat in the Mandakini valley despite a high level of helicopter operations.

2. Some wildlife species altered their activity pattern to either crepuscular or nocturnal due to the cumulative effects of anthropogenic pressures in this area mostly in the form of pilgrimage and associated human activities. However, in the case of Himalayan monal pheasant, there was a marginal overlap in peak activity period with that of peak helicopter operations.

3. Results of stress hormone studies are in-conclusive due to low sample sizes. However, the results can be used as baseline for future comparative studies on similar investigations pertaining to helicopter flight impacts on wildlife.

4. Taking the above three observations into consideration, it appears that most of the mammals have adapted to the anthropogenic disturbances in Mandakini valley. However, repeated observations in the future would be needed to draw robust conclusions.

5. There is a high negative correlation between flying height and noise levels and the current levels of noise due to anthropogenic activities and helicopter flights. Thus, prescribing a minimal flight height would be useful to reduce the noise levels.

6. Helicopter sorties ranged from 2 to >300 flights per day in Mandakini Valley. Since most of the mammals appear to have adapted to this level of noise, it should not be allowed to go beyond the current levels of helicopter flights. Therefore, efforts has to be made to ensure that the upper limit for number of flights per day does not exceed 300 flights/day.

The study recommends the following measures:

1. Restricting helicopter flight heights to at least 600 m (2000') with the exception of take-off and landing times. This would help in reducing noise levels in the area.

2. Monitoring the helicopter operations with regard to adherence to the prescribed heights will be required. This could be done using laser distometers or lidar guns or set up an Automatic Dependent Surveillance-Broadcast (ADS-B) within the Kedarnath Wildlife Sanctuary. Monitoring of impacts of helicopter flights on wildlife could be carried out on a regular basis (every 3 to 5 years) including stress hormone studies so that a comprehensive database can be developed for rigorous statistical analysis

3. As a long-term measure, passenger ropeway for transportation of pilgrims as an environment friendly alternative could be planned and constructed as this will reduce pilgrim foot falls in the trekking path to the shrine and helicopter services. The passenger ropeway will not require building a motorable road through the Kedarnath WS as all the material and machines required for building ropeway could be transported by air using specialized helicopters.

Assessment of Impacts on Wildlife of Kedarnath Musk Deer Sanctuary due to Helicopter Services

Introduction

India, being one of the 18 mega biodiversity regions of the world has rich and diverse natural ecosystems ranging from high Himalayan regions to the coastal areas, and habitats ranging from tropical wet evergreen forests to hot arid deserts (Myers *et al.* 2000). There are three biodiversity hotspots within the country *viz.*, Eastern Himalaya, Indo-Burma and Western Ghat that harbours several endangered and endemic flora and fauna (Mittermier *et al.* 2000). The country with its 1.2 billion people exert enormous pressure on natural resources and biodiversity. In most of the areas, lack of sustainable use of different ecosystem services have led to irreversible changes in the ecosystem and thus, causing the loss of biodiversity. India has international obligations to protect its biodiversity and therefore some steps have been taken at the national and regional levels to address this issue (Agenda 21).

As a developing country, there is growing demand for major infrastructural development. Linear infrastructure such as roads, highways, power transmission lines, railways, and irrigation canals are being developed at a great pace. Linear infrastructure passing through wilderness areas led to habitat loss and fragmentation. Most importantly, linear developments act as barriers for animal movements and in cases such as roads and railways, cause animal mortalities. The infrastructure expansion and proliferation of linear intrusions without heed to ecological and social impacts is creating immense pressures on natural areas, thereby compromising long-term value of these areas and their ecosystem services (WII 2016).

Many protected areas in India are also recognized for their religious, spiritual or cultural values. In India, the presence of religious places inside or near protected areas is quite common and historical. Although the religious sites inside the protected areas link people with conservation of nature and natural resources but excessive use of any protected area by pilgrims lead to destruction of natural environment, as shown in cases such as Periyar Tiger Reserve (Sateesh 1990), and Gir National Park (Sinha and Sinha 2008).

The Kedarnath shrine is an important and famous Hindu religious site, situated at 3,583 m, near the source of the Mandakini River. For centuries, pilgrims from across India have flocked to the shrine in the summer months, journeying on foot or on mule *via* a single footpath, which passes through parts (Gaurikund to Kedarnath stretch) of the Kedarnath Musk Deer Sanctuary (hereafter Kedarnath Wildlife Sanctuary or WS), Uttarakhand. More than 500,000 pilgrims visited the shrine annually between the years 2010-2012. In June 2013, devastating flash floods swept through the region, washing away large areas of the Kedar Valley. Much of the old pilgrim route was damaged, and a new one has since been constructed on the left bank of the Mandakini River.

Helicopter services were initiated during 2007-08 to ferry pilgrims – particularly the aged and the infirm – to and from Kedarnath. Phata was the base for the helicopter companies. These helicopters operated from May to early November, with a break during the monsoon (July to September). After the June 2013 flash floods in Kedarnath Valley and the consequent destruction, the Uttarakhand administration through the support from the State Disaster Management Department and Nehru Institute of Mountaineering carried out a massive restoration operation leading to construction of better path, shelters and monitoring of pilgrims during the Yatra. After 2013, the frequency of helicopter flights steadily increased as there was a growing demand from pilgrims. With many tourists opting for a 9-minute chopper flight instead of a full day's walk or horse/mule ride, the number of helicopter companies operating in the area has also increased. Roughly, 8 to 14 companies, spread between Phata and Guptkashi, each with one helicopter, were operating during the post-monsoon season of 2015. A few more companies provided their services during the summer season, from May to June 2016. Because of pilgrimage restoration efforts both on land and by air by the Government agencies, and several regulatory mechanisms in the services offered to the pilgrims, many members of the villages in Mandakini Valley lost their livelihoods leading to a severe 'public backlash'. As most of the villagers had a grudge against helicopter operations, some raised concerns over the potential impact of the helicopters on the wildlife of the Kedarnath WS. They felt that the high intensity sound produced by the helicopters could potentially disturb the wildlife in the Protected Area.

Till date, there has been no assessment of the impact of aircraft flight operations on wildlife in India. However, similar studies have been carried out in other countries, leading to varying results. Studies conducted on these aspects in other countries were not conclusive about whether helicopter flights have a detrimental effect on wildlife or not, and if they do, to what extent. Some studies claim that animals get habituated to the disturbance, while others state they do not. The main threat posed to wildlife is from the noise caused by helicopters, especially when flying at low altitudes.

The Uttarakhand State Forest Department had requested the Wildlife Institute of India to conduct a study on impacts of helicopter flights on wildlife of Kedarnath WS and provided the necessary funds and logistic support.

The objectives of the study were:

1. To assess the impacts of helicopter flying operations on wildlife of Kedarnath Wildlife Sanctuary

2. To suggest mitigation measures for impact of the helicopter flying operation on wildlife, if any.

The Study area

The Kedarnath Wildlife Sanctuary (30°25'-30°45'N, 78°55'-79°22'E) is one of the largest Protected Areas (PAs) in Uttarakhand (975 km^2) and is named after the famous Hindu shrine located just outside the northern boundary. The Kedarnath WS spans across Rudraprayag and Chamoli districts and is located in the upper catchment of Mandakini and Alaknanda rivers, that are major tributaries of Ganga. It is bordered by peaks Kedarnath (6940 m), Mandani (6193 m) and Chaukhamba (7138 m) in the north; the Gopeshwar - Mandal - Chopta - Okhimath motor road in the south; Urgam Reserve Forest (RF) in the east and by the river Mandakini and boundaries of Tehri and Uttarkashi districts in the west. The Kedarnath WS has a broad elevation range from 1200m (near Phata) to 7138 m and consequently this protected area encompasses varied habitat types, from subtropical chir pine to temperate forests, subalpine forests, and alpine scrub and meadows. The varying climate, vegetation and topography across the valley have led to rich and diverse biodiversity in this protected area. As a result, the Kedarnath WS is home to several rare and endangered species of flora and fauna (Green 1985, Sathyakumar 1994). Important mammalian fauna of this area include the snow leopard (*Panthera uncia*), common leopard (*Panthera pardus*), Himalayan brown bear (*Ursus arctos isabellinus*), Asiatic black bear (*Ursus thibetanus*), leopard cat (*Prionailurus bengalensis*), red fox (*Vulpes vulpes*), jackal (*Canis aureus*), Himalayan yellow-throated marten (*Martes flavigula*), musk deer (*Moschus* spp.), Himalayan tahr (*Hemitragus jemlahicus*), goral (*Nemorhaedus goral*), serow (*Capricornis thar*), sambar (*Rusa unicolor*), barking deer (*Muntiacus vaginalis*), wild pig (*Sus scrofa*), rhesus macaque (*Macaca mulatta*), and Himalayan langur (*Semnopithecus scijestus*). The Kedarnath WS is a very important bird area with over 240 species, many resident and migratory. Galliformes such as Himalayan monal (*Lophophorus impejanus*) (the State bird of Uttarakhand), Kalij pheasant (*Lophura leucomelanos*), Koklass pheasant (*Pucrasia macrolopha*), hill partridge (*Arborophilla torqueola*), Himalayan snowcock (*Tetraogalus himalayensis*) and snow partridge (*Lerwa lerwa*) are also an important part of the avifauna of the area (Sathyakumar 1994).

Helicopter services operate along the Mandakini river or the Kedar Valley, starting from Guptakashi and Phata to the Kedarnath Shrine. To investigate the impacts of helicopter operation on wildlife, one intensive study area and two control study sites were selected based on varying degrees of human disturbances. The Kedar or Mandakini valley was selected as the intensive study area as helicopter flights operate here. The adjacent Kaliganga valley, and Shokharakh area near Tungnath temple were chosen as control sites for comparisons (Figure 1).

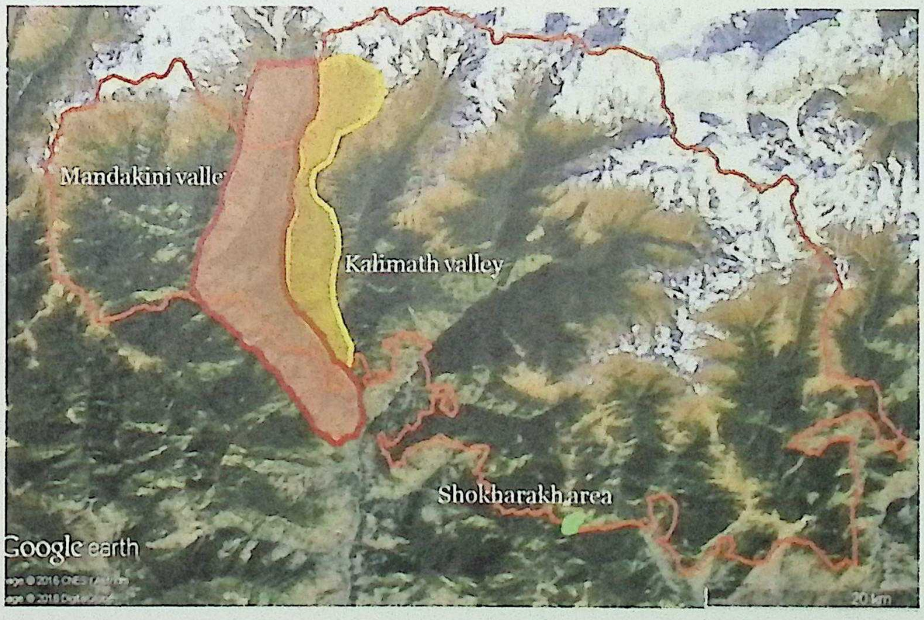


Figure 1 Map showing the three study sites in Kedarnath Wildlife Sanctuary (Orange line) on Google earth Satellite image

Of these three study sites, Shokharakh is the least disturbed area with no or minimal human interference and no helicopter flights. The Kaliganga valley has moderate to high human pressure and no helicopter flights. The Kedar or Mandakini valley experiences very high anthropogenic presence and activities and very large number of helicopter flights during May to October (Table 1).

Table 1 Description of the three different study sites in Kedarnath Wildlife Sanctuary, September 2015 to June 2016

Study site	Altitude range (m)	Human disturbance	Helicopter service
Mandakini valley	1200-3500	Very high from May to October, moderate to low during the winter	Very intense service from May to October
Kaliganga valley (Control)	1800-3500	Moderate to high due to road construction	Very few occasions during May to October
Shokharakh (Control)	2800-3500	Negligible human use	No helicopter flying activity

The Study period

The sampling was carried out in Mandakini valley from Guptkashi(1200m) to Lincholi (3450m) in two different study periods, *viz*., September to December 2015 and April to June 2016. During April to June 2016, simultaneous sampling was carried out in the control sites i.e., Kaliganga valley and Shokharkh.

Methods

For Objective 1

To assess the impacts of helicopter flying operations on wildlife of Kedarnath WS, three different field methods were used.

Field methods

a) Helicopter aviation details and noise level recording: The aviation details of the helicopters including height, frequency and timing at four different places, representing four different altitudinal ranges (Figure 2) were recorded. These were Rail village (1300-1500m), Soneprayag (1500-2000m), Gaurikund/Jungle Chatti Helipad (2000-25000m), and Bheembali Helipad (2500-3000m). The height of the helicopter was estimated through ocular estimation of radial distance from the observer and classified into five distance classes as very high (>100m), high (70-100m), medium (40-70m), low (10-40m) and very low (<10m) (Figure 3). Noise caused by the helicopters was recorded at these locations along the flight path using sound level meters (RT/SR-5786P). The noise levels in Mandakini valley, Kaliganga valley, and Shokharakh during non-flying season (November to April), was recorded to obtain ambient noise levels, when there are no helicopter services in these areas. Flight height and path was recorded using GPS during flights undertaken from different operating stations *viz*., Guptakashi, Phata and Sersi.

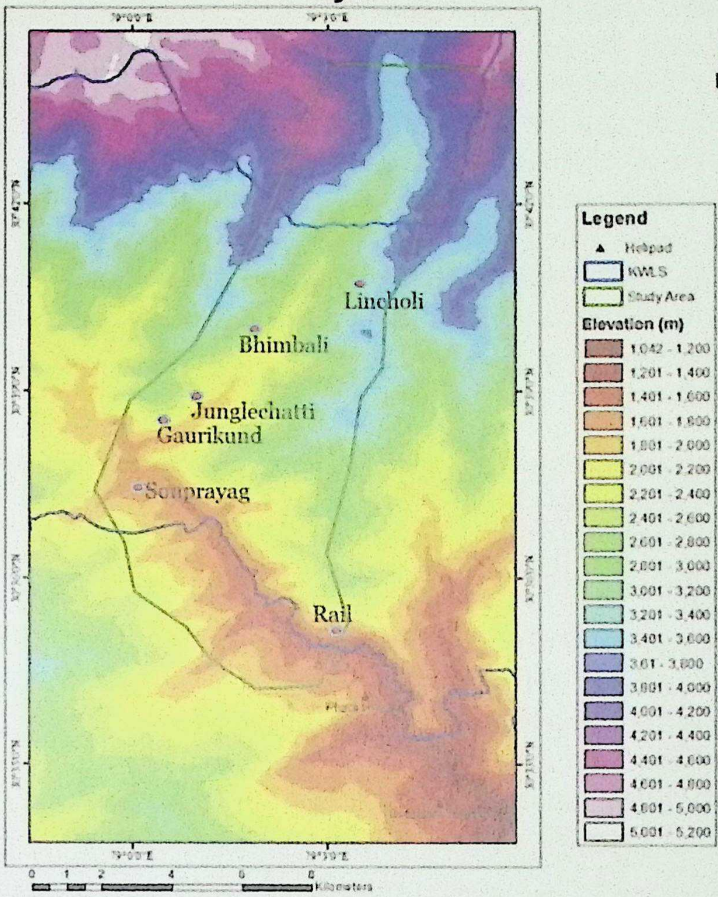


Figure 2 Helicopter aviation information collection points along the elevation gradient in Mandakini valley, the background Digital Elevation Model show different elevation classes at every 200m interval. The blue line depicts the boundary of Kedarnath Wildlife Sanctuary

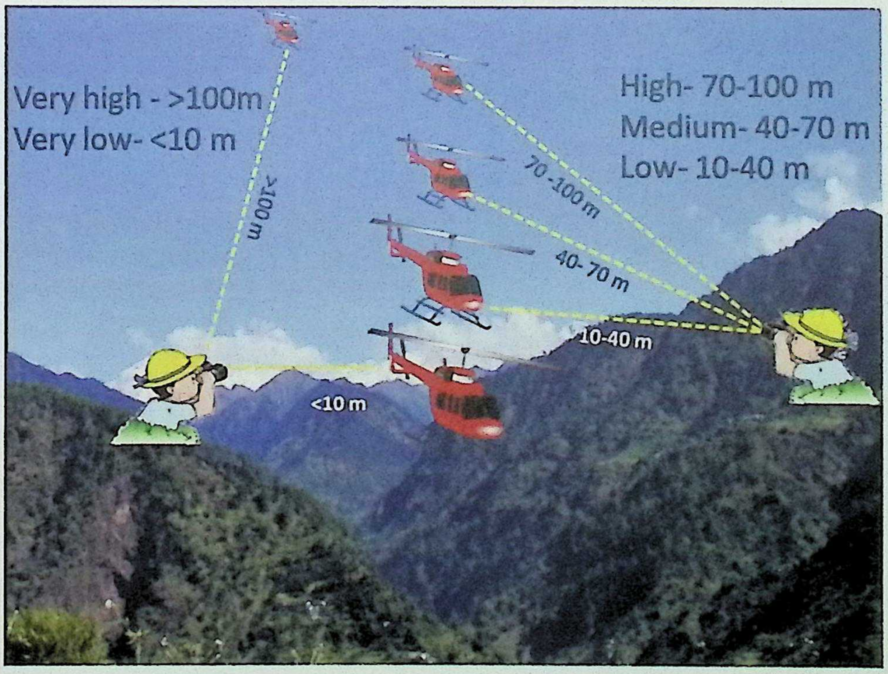


Figure 3 Visual representation of the ocular estimation of helicopter heights during noise recording in Kedarnath Wildlife Sanctuary from September 2015 to June 2016

b) Trail sampling, scanning and faecal sample collection: Trail sampling was carried out to detect the presence of mammals and galliformes in the study area, during the flight operation period, non-flying period (November 2015 and April 2016). Several trails in different elevation categories were selected, at Bheemabali (2700m), Gaurikund (2100m), Triyuginarayan (1700m) and Rail (1400m). In Kaliganga valley, one trail of 14km covering 1800m to 3500m elevation (Figure 4a) was sampled. In Shokharakh, two trails covering 2800 to 3500m (Figure 4b) were sampled. Scanning from vantage points in Lincholi and Shokharakh was carried out to record the presence of mountain ungulates and to record their activity. Mountain ungulate behaviour and response to the disturbance caused by the helicopter flights were recorded in Lincholi area.

Fresh pellet groups of mountain ungulates (musk deer, Himalayan tahr, goral, barking deer and serow) and scats of red fox, jackal, yellow-throated marten, common leopard, Asiatic black bear and other small carnivores were collected during trail sampling and stored to quantify stress using non-invasive techniques in laboratory.

c) Camera trapping: Camera traps were deployed at strategic locations (below the Helicopter flight path) on trails in Rail, Soneprayag and Gaurikund, and Rambara, covering all the habitat types and elevation gradients (Figure 4a). The camera traps were operational for 24 hours a day over several days to record the activity of wildlife, particularly mammals and galliformes. Camera traps were also deployed in Kaliganga valley (Figure 4a) and in Shokharakh, covering all the available habitat types (Figure 4b).

Analysis

Helicopter frequency, flight path, flight height and noise level

The helicopter flight frequency data provided by the State Aviation Department and noise levels (in dB) recorded during the study were analysed using Microsoft Excel and SPSS 16. Flight paths and average flight heights of each helicopter flight were calculated using the Google Earth pro.

Relative abundance and activity pattern of mammals

Wildlife sign encounter rates (number/km walk) were calculated from the data recorded from different trail walks. Information from camera traps such as photo-capture rates (number/100days) were calculated using Excel and activity pattern graphs were plotted using Oriana 6 (Kovach Computing Services). Wherever possible, data from the three study sites were compared, for two different seasons (flying and non-flying), and between species (for activity pattern). All the statistical tests were carried out in SPSS 16 and all the circular statistics were carried out in Oriana 6.

Direct visual encounters of wildlife were recorded and if a helicopter happened to fly past overhead at the same time, behavioural observations were made including videography whenever possible.

Faecal samples were analysed for faecal glucocorticoid metabolites and progesterone in LaCONES, Center for Cellular and Molecular Biology (CCMB), Hyderabad.

Extraction of feacal hormone metabolites

Hormone extraction was carried out using earlier described procedures (Umapathy *et al.*, 2013; Mithileshwari *et al.*, 2016). Between 0.2–0.3 g of dried, mixed and pulverized faeces were boiled in 5 ml of 90% aqueous ethanol for 20 min. After centrifugation at 500 g for 10 min, the supernatant was recovered and the pellet resuspended in 5 ml of 90% aqueous ethanol, vortexed for 1 min and re-centrifuged to recover the supernatant. Supernatants were combined, dried (in an oven at 40°C), re-suspended in 1 ml of absolute methanol, vortexed for 1 min and sonicated for 30 s (Branson Ultrasonics 250, CT, USA), and stored at -20°C

Hormone assays

Faecal glucocorticoid metabolites were measured using cortisol polyclonal antibody (R4866) diluted to 1:9000, HRP-conjugated cortisol 1:250,000 (C. Munro, University of California, Davis) and cortisol standards (1000–1.95 pg/well). This cortisol assay was successfully validated for other animals to provide reliable quantitative information regarding glucocorticoid output and found to cross-react with cortisol 100%, prednisolone 9.9%, prednisone 6.3% cortisone 5% and <1% with corticosterone, desoxycorticosterone, 21 desoxycortisone, testosterone, androstenedione, androsterone and 11-desoxycortisol (Kumar *et al.*, 2014., Bhattacharjee *et al* 2015).

Faecal progestogen metabolites levels were measured using a progesterone monoclonal antibody (Quidel clone No. CL 425, C. Munro, University of California, Davis) diluted to 1:6000, horseradish peroxidase (HRP) conjugated progesterone 1:100,000 (C. Munro, University of California, Davis) and progesterone standards (200–0.39 pg/well). This antibody cross reacts with progesterone (100%), and a variety of reduced pregnane metabolites as determined by Graham *et al.* (2001).

Enzyme Immuno-Assay (EIA) procedure

Antibodies were diluted in coating buffer (0.05 M sodium bicarbonate buffer, pH 9.6) to optimum dilution and coated (50 ul/well) onto 96-well plate (Nunc-Immuno maxisorp, Fisher scientific, USA), incubated overnight at 4 C and washed four times with washing buffer (0.15 M NaCl and 0.05% Tween 20, Sigma, India). Steroid standards or faecal extracts (50 ul) diluted in assay buffer (0.1 M PBS, pH 7, containing 0.1% BSA) were added to the wells followed by 50 ul of conjugated HRPs steroids. After 2 h of incubation at room temperature, the plate was washed and 50 ul of TMB/H_2O_2 (Genei, Bangalore) substrate was added and kept in the dark for 10–15 min. The reaction was stopped by addition of 50 ll of 1 N HCl and absorbance read at 450 nm in the ELISA reader (Thermo Multiskan Spectrum Plate Reader, version 2.4.2, Thermo Scientific, Finland).

Figure 4 (a) Trails (blue), camera trap locations (yellow) and commercial helipads (orange) in Mandakini and Kaliganga valley (Above) (b) in Shokharakh area on Google Earth imagery of the study area (Below)

Objective 2

To suggest mitigation measures for impact of the helicopter flying operation on wildlife, a detailed literature review was carried out.

Literature review

A detailed literature review was conducted to understand the impacts of aircraft flight operations on wildlife and the mitigation measures suggested by various studies carried out in different parts of the world. Such information was used not only to make an assessment of impacts on wildlife in Kedarnath WS due to helicopter flights but also to propose appropriate mitigation measures. As no such long/short term impact assessment has been carried out in India, information available from international sources were consulted. The results of the aviation details, probable impact on wildlife as documented from the field observations, along with comparisons and the results obtained from the laboratory for stress evaluation were utilized for suggesting mitigation measures.

Results

The study was carried out over two consecutive seasons, autumn 2015 and spring/summer 2016. The results are thus presented separately for the two different study periods, i.e., September – December 2015 and April – June 2016. In the 2015 session, sampling was conducted in Mandakini valley only, while in the following session sampling was extended to Kaliganga valley and Shokharakh. In each session, sampling took place both during helicopter flying periods and the non-flying periods. Faecal samples collected during this time were also labelled as during-flying season and non-flying season. Results of different field procedures are described as follows.

Frequency of helicopter operations

To calculate the frequency of helicopter operations, information provided by the State Aviation Department for the year 2015 and 2016 was used. The results showed that May is the month when maximum number of flights operated followed by June and October (before the closure of the shrine for winter). During May, on an average 205 flights operated in a single day. Whereas, in the monsoon months (July, August and September) frequency of flight was very low. A comparison of total flights, average number of flights per day and per hour has been presented graphically (Figure 5) for 2015. Similar trend has been observed in 2016. However, the average number of flights per day increased to 305 in May 2016, which indicates a considerable increase in the intensity of helicopter operation in the study area. The entire helicopter operation period was classified into four different classes according to the frequency of flight per day (in 2016). These classes were: very high (305flights/day), high (225 flights/day), moderate (142 flights/day) and low (81flights/day). This categorization was used for comparison with the animal relative abundance in the respective helicopter frequency periods (in Mandakini valley only). The flight frequency of each operator in different months was also calculated (Figure 6) and Himalayan Heli Service from Sersi was found to be the most frequent of all.

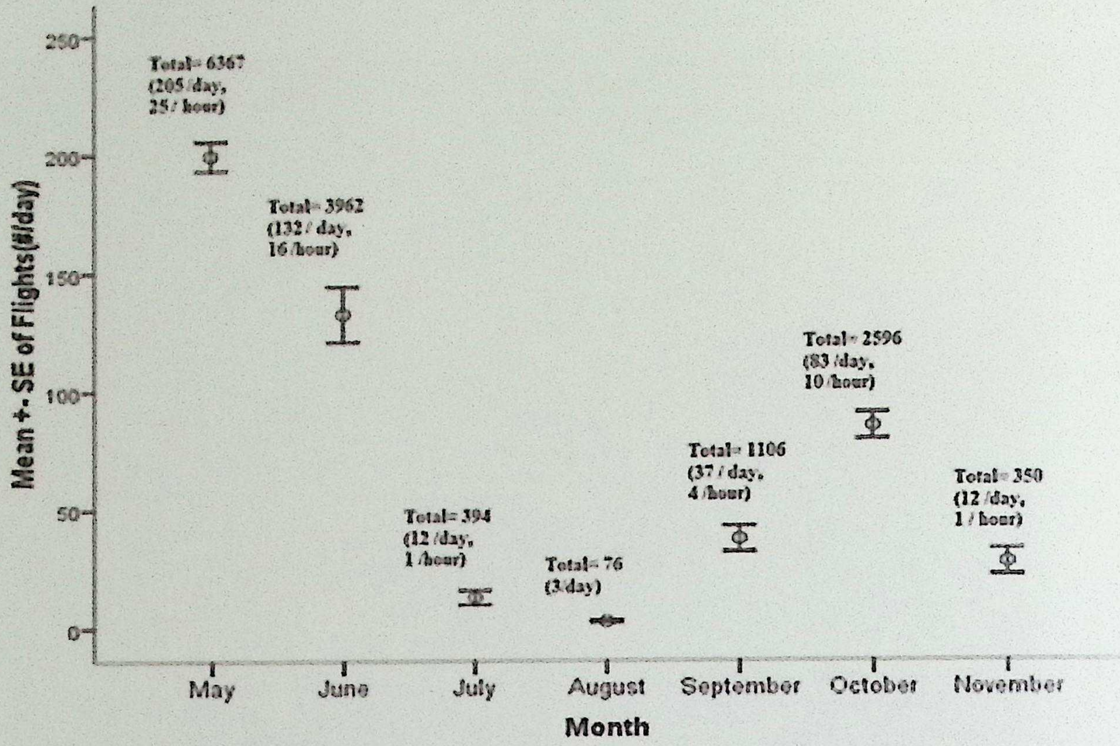


Figure 5 Mean flight frequency (per day and per hour) and total number of helicopter flights in different months in Mandakini valley during 2015 (Data source: State Aviation Department, 2015)

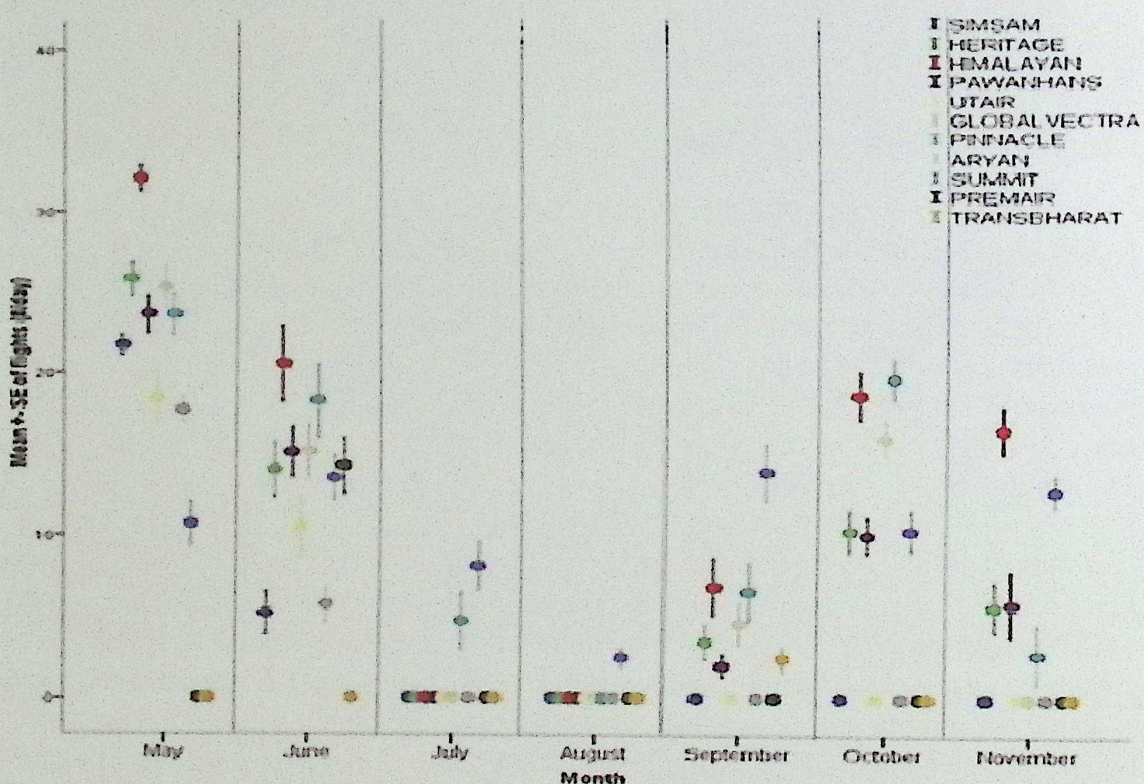


Figure 6 Mean flight frequency of each operator in different months of 2015 in Mandakini valley (Data source: State Aviation Department, 2015).

Flight paths and heights of helicopter

Elevation profiles for flight paths of helicopter (onwards and return) from Guptakashi, Phata and Sersi were created by recording flight paths on board using GPS, and constructed on terrestrial maps using Google Earth Pro. However, created maps need to be compared with flight height information from the State Aviation Department.

All the companies followed the same aerial route following the river gorge and bends. For each operator maximum elevation from ground was at Soneprayag where the River Mandakini has a sharp bend (Figure 7a, 7b and 7c).

The mean flight height was calculated by averaging the elevation of the flight path at every 100m. The elevation of each point was calculated from the ground vertically below using the Google Earth pro. The average flight height for each back and forth journey from three different helipads is given in Table 2. As Sersi helipad is nearest to Kedarnath, the onward journey to Kedarnath from Sersi reached the lowest mean flight height (152.4 ± 6.11 m) in 2015. In 2016, the helicopter flight to Guptakashi from Kedarnath reached the highest mean flight height (499.93 ±14.45 m) as Guptakashi is the most distant helipad from Kedarnath (Table 2).

Table 2 Mean flight heights of helicopters based on return flights from different helipads to Kedarnath during 2015 and 2016

From	To	No. of flights (N)	Mean flight height (m) 2016	Mean flight height (m) 2015
Sersi	**Kedarnath**	2	152.4 ± 6.11	240.76±7.63
Kedarnath	**Sersi**	2	346.53 ± 15.52	358.40±17.38
Phata	**Kedarnath**	2	180.68 ± 5.39	262.30±8.94
Kedarnath	**Phata**	2	467.27 ± 12.47	375.60±6.53
Guptakashi	**Kedarnath**	1	-	324.37±11.10
Kedarnath	**Guptakashi**	1	-	499.93±14.45

The results indicated that the private Helicopter service located at Sersi (i.e. the Himalayan Heli Service) is operating the flights at comparatively lower altitudes and due to its proximity to the Kedarnath helipad, the flight path is also the shortest among all the helicopter service providers. This explains why and how this particular operator maintained high flight frequency throughout the pilgrimage season.

a)

b)

c)

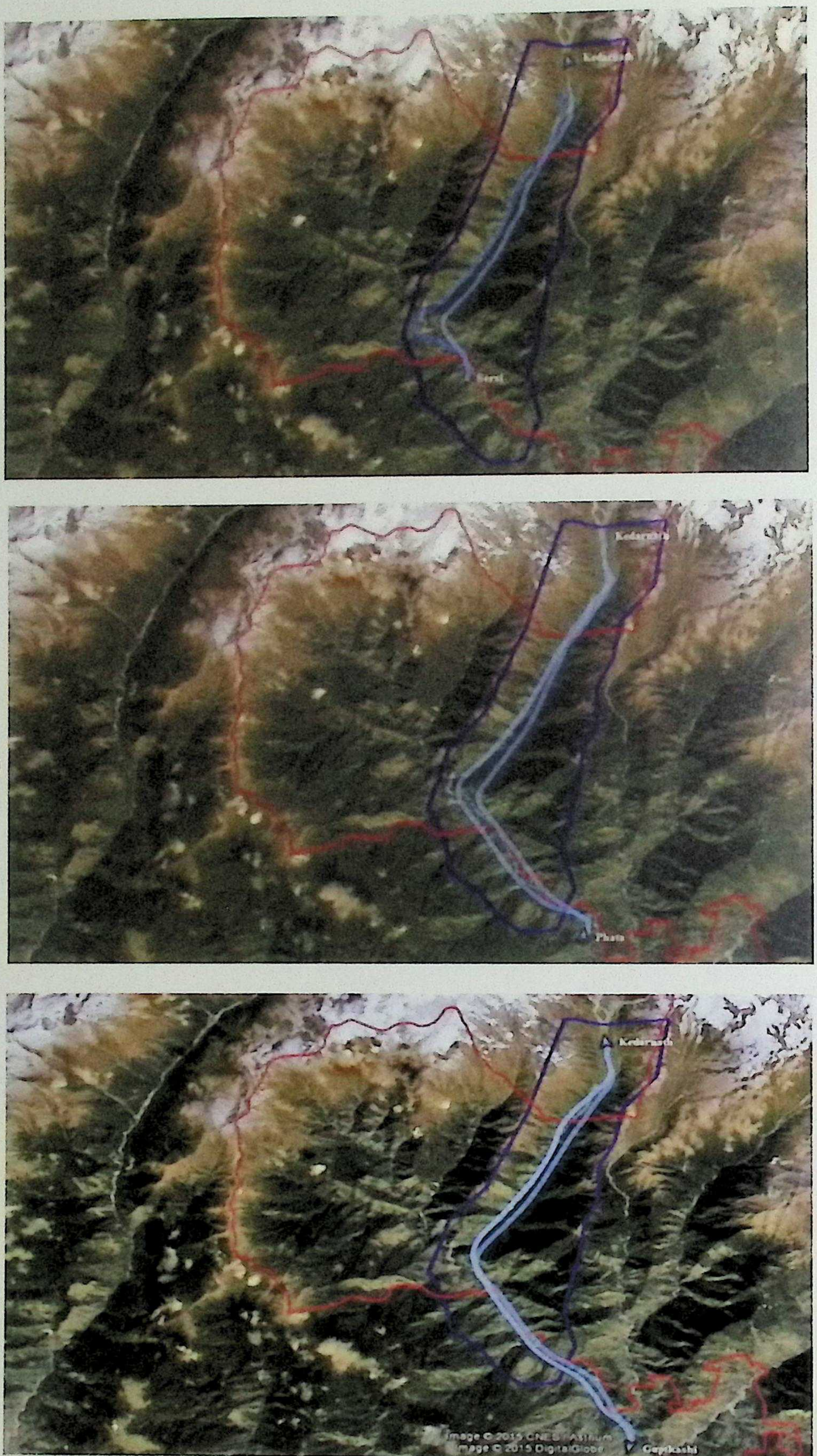


Figure 7 Onward and return flight paths on Google Earth imagery for helicopters from (a) Sersi to Kedarnath, (b) Phata to Kedarnath and (c) Guptakashi to Kedarnath as recorded during 2015-16 (light blue lines-flight paths, dark blue lines- study area, red lines-Kedarnath Wildlife Sanctuary boundary)

Helicopter Noise Levels: In Mandakini Valley, Helicopter noise levels were recorded from six locations during the 2015 session and from three locations during the 2016 session. Similar observations were made in Kaliganga valley and Shokharakh (control sites with no helicopter flights) during 2016 session to compare disturbances due to noise.

Noise levels recorded from six recording sites in Mandakini valley had a mean well above the 50 dB noise limit (Figure 8), according to the Noise Pollution (Regulation and Control) Rules, 2000. The lowest noise levels were observed at Soneprayag where helicopters tend to fly highest, due to the bend in the valley.

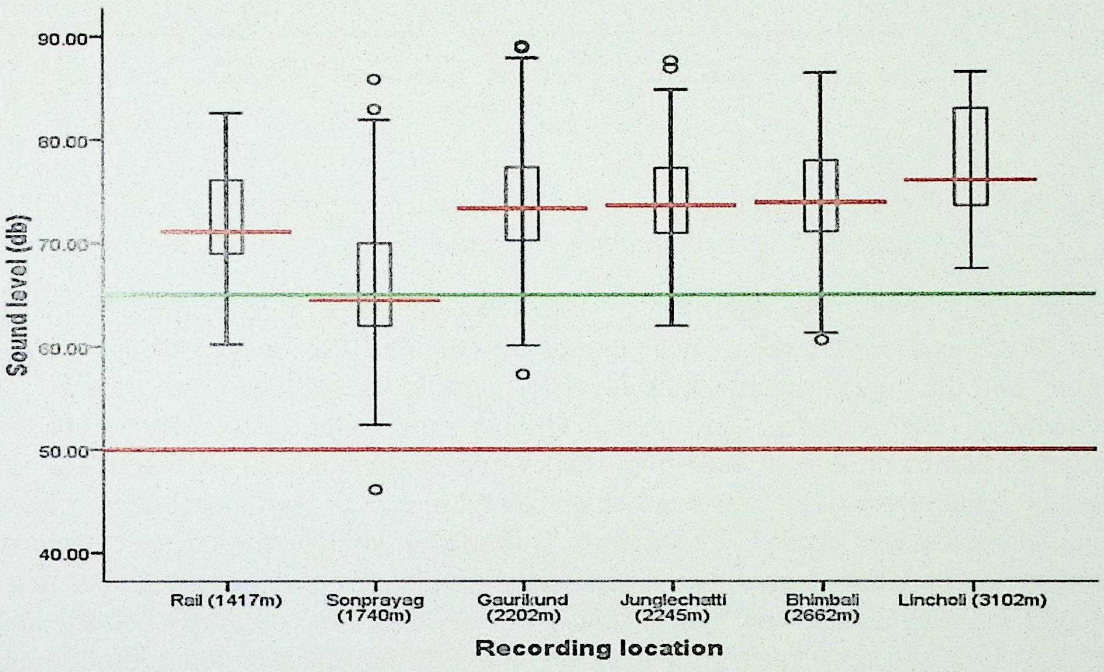


Figure 8 Noise recorded at different recording locations in Mandakini Valley (Sep-Nov 2015), the red line signifies 50 dB as permissible limit in silence zone, green line signifies 65 dB as permissible limit for human habitation

To detect the pattern of noise in a day in Mandakini valley, the noise level information gathered from Soneprayag was averaged according to two hour segments of a usual day in Mandakini valley in the flying season. The average sound level was much higher than the permissible limit of 50 dB throughout the day, and it varied from 65 to 67 dB for all the time segments in a Day (Figure 9).

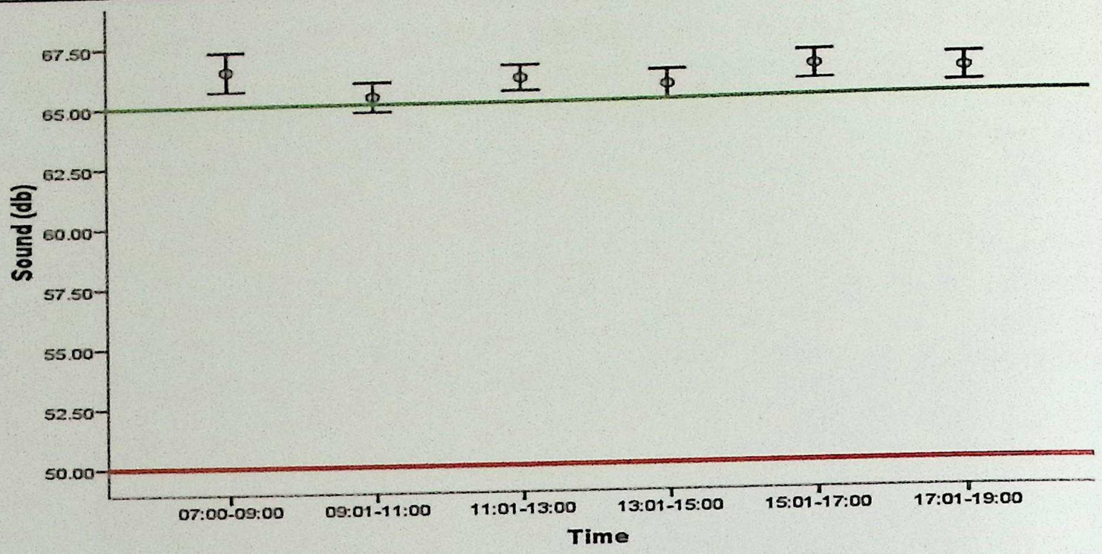


Figure 9 Helicopter flight noise levels recorded at different times of the day at Soneprayag, September – November 2015

Mean noise levels (as recorded in 2016) of the three study areas (Mandakini, Kaliganga and Shokharakh) were compared (Figure 10). As expected, Mandakini valley had the highest mean sound levels – these noise readings were recorded when helicopters flew overhead. Noise levels were recorded opportunistically and regularly to get baseline readings in Kaliganga valley and Shokharakh for less-disturbed areas. Lowest noise levels were observed at Shokharakh, one of the control sites, where no helicopters services operate. Disturbance is limited to vehicular traffic on a man-made road a few hundred metres away. Kaliganga Valley, the other control site, had the second lowest noise levels. Noise levels in this area were slightly elevated due to strong winds and disturbance due to cattle and domestic animals, in addition to heavy human presence due to bridle path construction (alternate route to Kedarnath).

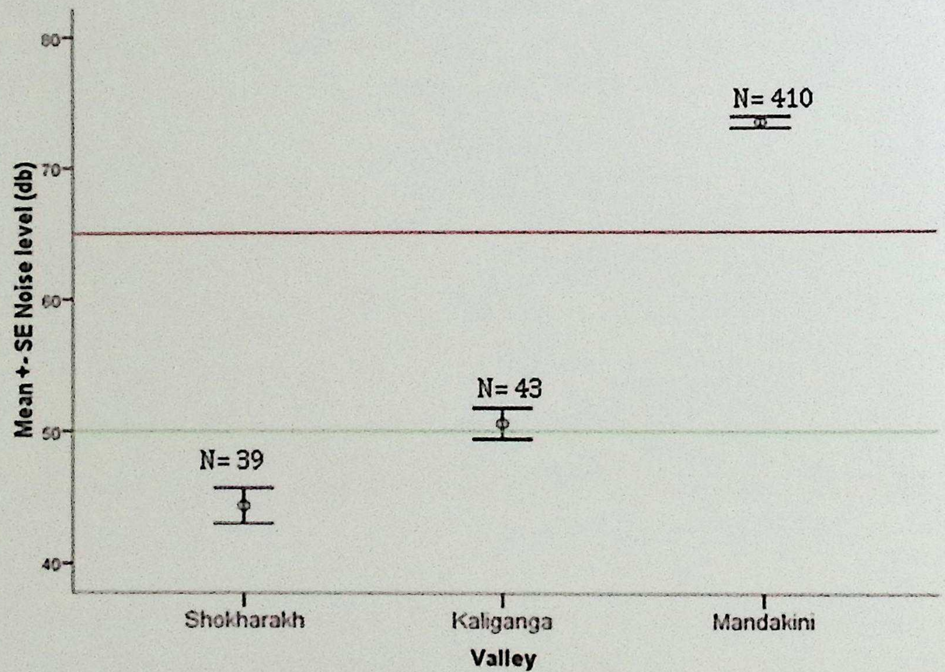


Figure 10 Mean noise levels recorded in three different study sites – Mandakini valley, Kaliganga valley and Shokharkh (April – June 2016)

Mean noise levels at multiple sites across different elevation zones in Mandakini valley (Figure 11) were compared for helicopter peak flying (May-June 2016) and non-flying periods (April 2016). Mean noise levels at four recording sites (Rail - 1400m, Soneprayag -1700m and Rambara-2500m) were well above the 50 dB upper noise limit for silence zones during flying period, with a mean of over 72 dB, and there was a significant difference between flying and non-flying period noise levels (Kruskal-Wallis Test, $p<0.05$).

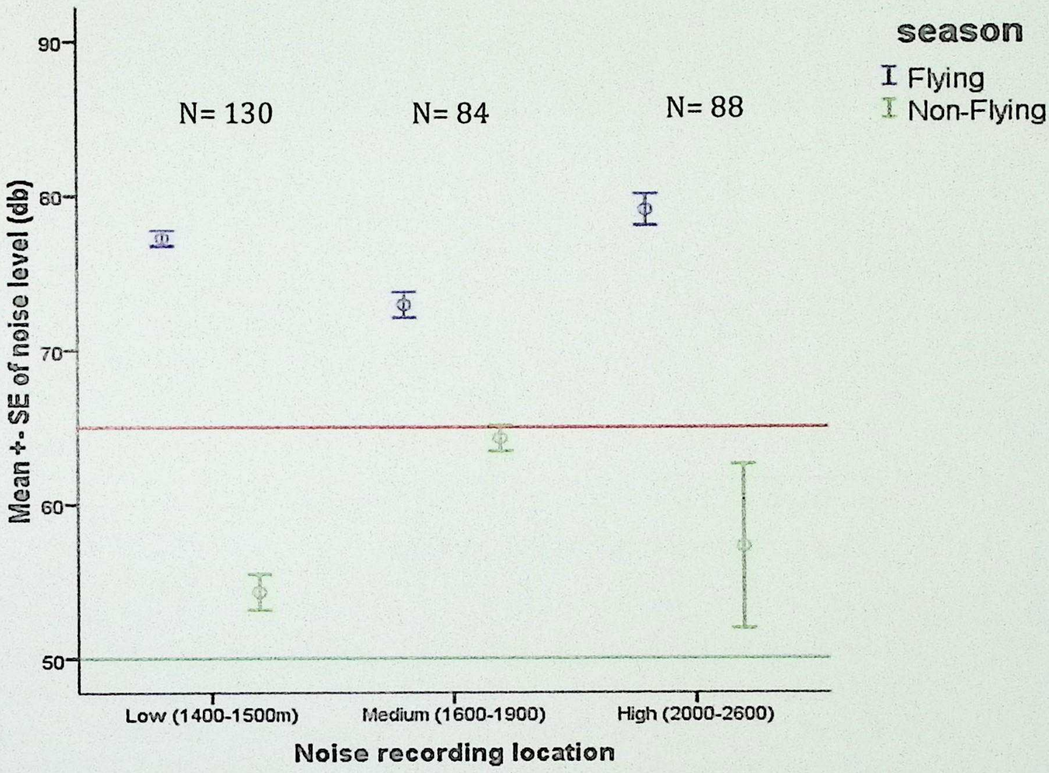


Figure 11 Mean noise levels recorded at different locations in Mandakini Valley during non-flying (April 2016) and flying periods (May – June 2016)

To find the relationship between helicopter flight height and noise level, the flight height categories (as describe in Figure 3) and the noise level recorded for all records (n=1,225) were plotted. Each of the records was also categorized according to the vegetation type of the noise level recording station (subtropical forest, broadleaved forest and open coniferous forest). Negative correlation (R^2 = 0.33 and 0.25) was observed between flight height and noise level for open coniferous and broadleaved forest (Figure 12). Most of the high-level noise (>80dB) was observed in open coniferous forests followed by mixed broad-leaved forests. In the subtropical forests, majority of the noise level records were below 70dB, in a few cases the noise level was less than 60dB (Figure 12). As more radial distance from the observer implies higher flight heights, it is evident from Figure 12 that helicopters, which are flying very low (radial distance <100m) are contributing more to the noise in Mandakini valley. It also indicates that, higher noise levels (>80dB) were recorded majorly in Mixed broadleaved and open coniferous forests, whereas >70dB noise was recorded in many instances from the subtropical forests.

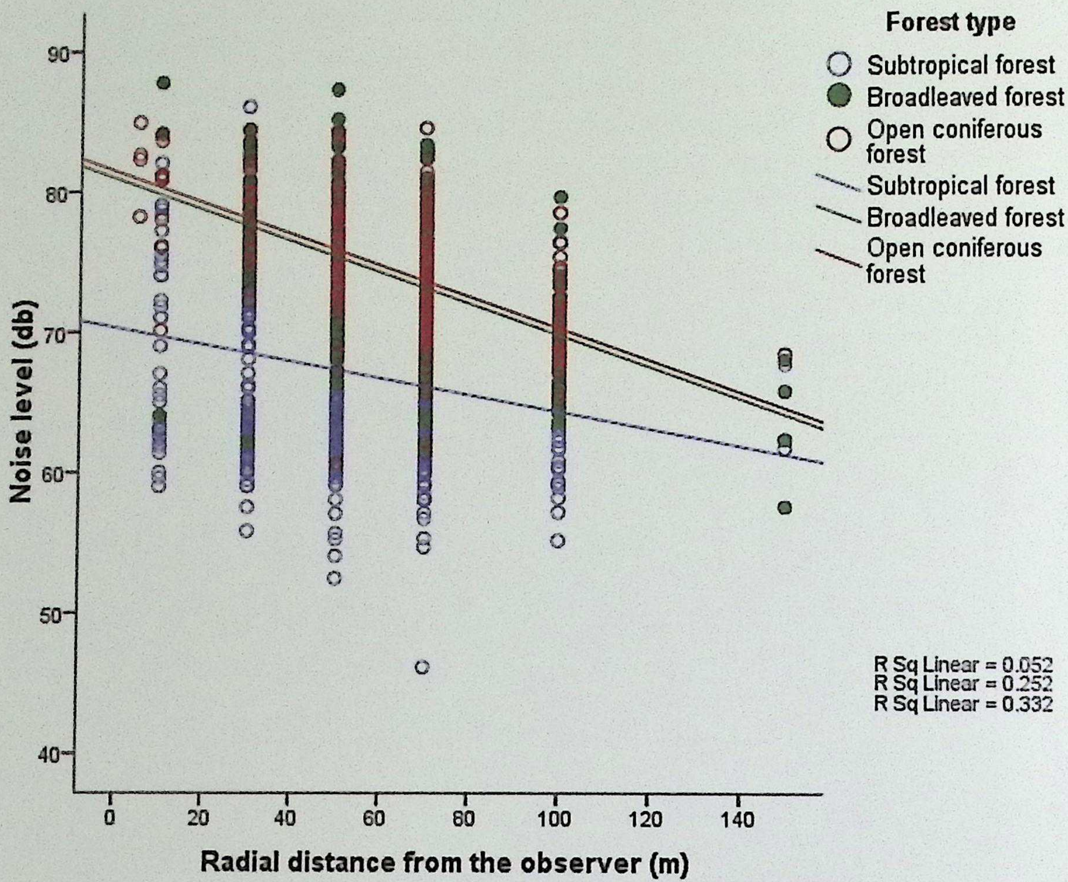


Figure 12 Variation in noise levels in different forest types of Mandakini valley plotted against the variation in radial distance of the helicopters (this is representing the flight height of the helicopter, increment in radial distance denotes higher flight height) as recorded in 2015-16. The red open circles are denoting the noise level records taken in open coniferous forests, the green circles are noise level recording taken at mixed broadleaved forests and the open blue circles are the noise level records taken in the subtropical forests. The lines in red green and blue are denoting the negative correlations between the noise level observations in each forest type and the radial distance of the helicopter from the observer (R^2 values for each regression are given at the bottom of the figure, the order is as follows: subtropical, mixed broadleaved and open coniferous)

Presence/absence of mammals and galliformes in the study area

Presence of wildlife species (mammals and galliformes) was confirmed / recorded based on visual encounters during trail walk and scan sampling, and based on animal signs (track, spoor and dung) encountered during trail sampling, and through camera trap photo-captures. In 2015, six camera traps were deployed in the Mandakini valley totalling to 109 trap nights effort. In 2016, 17 camera traps were deployed – eight in Mandakini valley, five in Shokharakh, and four in Kaliganga valley, totalling 964 trap nights. Presence of 20 mammal species (carnivore-8, ungulate-7, primate-2, rodent- 2, lagomorph-1) and five galliformes species (pheasants-3, partridge-2) has been confirmed from the study area (Tables 3 and 4).

Table 3 **Presence of mammals in three study areas of the Kedarnath Wildlife Sanctuary during September 2015 to June 2016**
(P=present, ND= Not Detected, NA= Not Available as the area falls outside species natural distribution range)

Species	Mandakini Valley effort= 531 days	Kaliganga Valley effort= 132 days	Shokharakh effort= 301 days
Asiatic black bear	P	P	P
Common leopard	P	P	P
Leopard cat	P	P	P
Jungle cat	P	ND	ND
Red fox	P	P	P
Yellow-throated marten	P	ND	P
Siberian weasel	P	P	P
Himalayan Masked palm civet	P	P	P
Barking deer	P	ND	NA
Goral	P	P	P
Himalayan tahr	P	ND	P
Sambar	P	P	P
Serow	P	P	P
Wild pig	P	P	ND
Musk deer	P	ND	P
Himalayan langur	P	P	P
Rhesus Macaque	P	P	ND
Pika	P	ND	P
Indian porcupine	P	P	ND
Rat species	P	P	P

Table 4 **Presence of galliformes in three study areas of the Kedarnath Wildlife Sanctuary during September 2015 to June 2016**
(P=present, ND= Not Detected, NA= Not Available as the area falls outside species natural distribution range)

Species	Mandakini Valley	Kaliganga Valley	Shokharakh
Himalayan monal	P	P	P
Koklass pheasant	P	ND	P
Kalij pheasant	P	P	P
Black francolin	P	ND	NA
Hill partridge	P	ND	P

Contradictory to the general belief that wildlife has deserted the Mandakini valley due to very high level of anthropogenic disturbances, the results revealed that almost all mammals and galliformes that are present in other parts of Kedarnath WS are also present in Mandakini valley. The encounter rate of mammals and galliformes in Mandakini Valley showed that endangered and vulnerable mammals such as musk deer and Asiatic black bear, near threatened ungulates such as Himalayan tahr, Himalayan serow and Himalayan goral are present in the Mandakini Valley (Table 5). Large carnivores such as common leopard and small carnivores such as leopard cat, jungle cat, yellow-throated marten and Himalayan masked palm civet were also captured in camera traps deployed in Mandakini Valley (Table 5 and Figure 13). Among the galliformes, presence of Himalayan monal and hill partridge was confirmed from the upper reaches (>2500m) of Mandakini valley (at *Bheembali* and above) whereas, presence of koklass pheasant was confirmed through calls near 2300m at *Junglechatti*. Kalij pheasant and black francolin were encountered at lower elevation around *Triyuginarayan* (1700m).

Table 5 **Presence of mammals in four different elevation zones of the Mandakini valley during September 2015 to June 2016** (P=present, ND= Not Detected)

Location	Rail (1400m)	Triyugi-narayan (1700m)	Gaurikund (2100m)	Bheembali (2700m)
Asiatic black bear	P	ND	ND	P
Common leopard	P	P	P	P
Leopard cat	P	P	P	P
Jungle cat	P	ND	ND	ND
Red fox	ND	ND	ND	P
Siberian weasel	ND	ND	ND	P
Yellow-throated marten	P	P	ND	P
Palm civet	P	P	ND	ND
Musk deer	ND	ND	ND	P
Himalayan tahr	ND	ND	ND	P
Goral	P	P	P	P
Sambar	P	ND	ND	ND
Serow	ND	P	ND	P
Wild pig	P	ND	ND	ND
Barking deer	P	ND	P	ND
Himalayan langur	P	P	P	P
Rhesus macaque	P	P	ND	ND
Pika	ND	ND	ND	P
Porcupine	P	ND	ND	ND

Figure 13 Wildlife species photo-captured in Mandakini valley where > 200 helicopter flights operate during peak pilgrimage season in 2015-16. (From left to right) **Top** – Common leopard, Serow, Musk deer. **Middle** (Clockwise from top left) – Leopard cat, A helicopter at Kedarnath, porcupine, Wild pig, Barking deer, Goral, Himalayan Monal, Palm civet, Yellow-throated Marten; **Bottom** – Asiatic Black bear, Jungle cat, Himalayan Tahr.

Relative abundance of mammals and galliformes in the study area

Relative abundance of mammals and galliformes was estimated using photo-capture rates (#/100 days) and sign encounter rates (#/km walk). Of the above-mentioned species (Table 5), Asiatic black bear, masked palm civet, Siberian weasel, sambar, musk deer and Himalayan monal were encountered (direct sighting/camera trap captures) during the April-June 2016 sampling period. All other species were observed in both sampling seasons. In 2015, relative abundance of carnivore (Table 6) and prey species (Table 7) was calculated. Yellow-throated marten was the most encountered carnivore species, while rhesus macaque was the most encountered omnivore in the Mandakini valley.

Table 6 **Relative abundance of carnivores in Mandakini valley during autumn 2015 (September-December)** * - sc= small carnivores – leopard cat and jungle cat taken together

Carnivore Species	Photo capture rate (#/day)	Sign encounter rate (#/km)
Leopard	0.073	0.169
Jungle cat	0.009	0.715 (sc)*
Leopard cat	0.046	
Palm civet	0.018	-
YT marten	0.083	0.127

Table 7 **Relative abundance of prey species in Mandakini valley during autumn 2015 (September-December)**

Prey species	Photo capture rate (#/day)	Sign encounter rate (#/km)
Himalayan langur	0.073	0.463
Wild pig	0.083	0
Porcupine	0.009	0.126
Rhesus Macaque	1.349	0
Barking deer	0.009	0.799
Himalayan goral	-	2.54
Himalayan tahr	-	5.01

In 2016, the scale of camera trapping exercise was upgraded and expanded to the two other study areas. Relative abundance (mean photo-capture rate) of carnivore and prey species were compared among main study area and control sites – Mandakini valley, Kaliganga valley and Shokharakh (Table 8). Leopard cat was the most common carnivore in Mandakini valley whereas Rhesus macaque was the most photo-captured species from one site (*Soneprayag*). Among the ungulates sambar and Himalayan tahr were common in Shokharakh area and goral was common in Mandakini valley. In Kaliganga valley, Serow was the most captured ungulate species. In Kaliganga valley, Himalayan masked palm civets and Himalayan langurs were frequently captured in camera trap photographs. The mean capture rate of each species in each of the three valleys is given below (Table 8). Yellow-throated marten was not captured on camera trap in Kaliganga, and no Siberian weasel in either Kaliganga or Mandakini valleys, though a Siberian Weasel was observed in Mandakini valley during the course of the study. Pika was not captured in Mandakini, though it was directly observed on a few occasions. Among the galliformes, only Himalayan monal were frequently captured in camera traps, particularly from Shokharakh area.

Table 8 **Mean photo-capture rates (#/100 days) of carnivores and their prey (ungulates, primates, rodents and galliformes) in three different areas of Kedarnath Wildlife Sanctuary during April to June 2016;** ND= Not Detected in Camera traps, NA= Not Available

Species	Mandakini effort= 531 days	Shokharakh effort= 301 days	Kaliganga effort= 132 days
Asiatic black bear	0.86±0.53	1.33 ± 0.62	2.27 ± 1.45
Common leopard	0.34±0.22	1.00 ± 0.67	4.55 ± 1.51
Leopard cat	**3.79±2.53**	1.33 ± 0.82	4.55 ± 2.62
Yellow throated marten	0.8±0.41	2.67 ± 1.87	ND
Palm civet	0.31±0.21	**8 ± 7.2**	**11.36 ± 7.86**
Siberian weasel	ND	2.67 ± 1.63	ND
Red fox	ND	0.33±0.33	ND
Barking deer	5.13 ± 5.13	NA	ND
Goral	**12.49 ± 8.52**	ND	0.76 ± 0.76
Himalayan tahr	8.63 ± 8.63	4.00 ± 1.45	ND
Musk deer	0.18 ± 0.18	10.67 ± 8.61	ND
Sambar	ND	**23 ± 17.91**	0.76 ± 0.76
Serow	0.51 ± 0.25	0.33 ± 0.33	1.52 ± 0.87
Wild pig	1.09 ± 0.79	ND	0.76 ± 0.76
Himalayan langur	1.72 ± 1.21	0.33 ± 0.33	**31.06 ± 25.21**
Rhesus macaque	**122.47±122.47**	ND	1.52 ± 1.52
Pika	ND	16.67±10.54	ND
Porcupine	1.41 ± 0.93	ND	8.33 ± 6.35
Himalayan monal	2.82 ± 1.74	**19.32±10.41**	3.03 ± 2.14

Comparison of relative abundance of mammals and galliformes between main study area and control sites

Photo capture rate of each species was compared between the main study area (Mandakini valley) and two control sites (Kaliganga and Shokharkh). However, to compare with the relative abundance estimates at Shokharakh area, only the cameras functional above 2600m in Mandakini and Kaliganga valley were used (these are mentioned as upper Kaliganga and upper Mandakini in the text and figures).

The comparative capture rates of carnivores, ungulates, primates and other wildlife are represented in the following figures (Figure 14-17). Among the galliformes, only Himalayan monal was captured in all three sites and the relative abundance is compared (Figure 17). Capture rates in Shokharakh were compared to capture rates from camera traps above 2600m ASL in Mandakini and Kaliganga valleys – referred to here as upper Mandakini and upper Kaliganga – to avoid bias as Shokharakh study area is above 2600 m altitude while the other two valleys range from 1400m in altitude up to 3500m. Barking deer, goral and wild pig have been excluded from this comparison, as they are mostly low to mid-elevation species.

Among the carnivores, only three species have been photo-captured in Kaliganga valley (Figure 14) in a single camera trap, thus the relative abundance estimates may deviate from the true abundance state of the carnivores in Kaliganga valley. Photo-capture rates of Asiatic black bear, common leopard and leopard cat are similar in highly disturbed upper Mandakini valley and least disturbed Shokharakh area. Lesser carnivores such as Yellow throated marten, Siberian weasel, red fox (Figure 14) and Himalayan masked palm civet (Figure 17) were more frequently photo-captured in Shokharakh area. Most of the ungulates and other species were less photo-captured in upper Mandakini than Shokharakh or upper Kaliganga valley, except for Himalayan tahr (Figure 15) and Himalayan langur (Figure 16). The greater capture rate of Himalayan tahr in Mandakini might not be representative of Himalayan tahr abundance in the area than in Shokharakh where long-term monitoring has revealed a density of 10 individuals/km^2 (Kittur *et al.* 2010 & Sathyakumar unpublished data). Himalayan tahr captures in the upper Mandakini Valley were only in one camera trap, where the individuals were also captured resting at night, while in Shokharakh, individuals were captured in multiple camera traps. It is also possible that they avoided the forest areas in Shokharakh where camera traps were placed, instead favouring open rocky slopes that were inaccessible for humans. In upper Mandakini the tahr prefer covered forest areas, where human disturbance is less. In Shokharakh, point counts of tahr were also carried out, mean group size was found to be 9.91 ± 1.33. Maximum group size observed was 23, while minimum was one. (Mean group size was based on opportunistic sightings as well as point counts in Shokharakh). The endangered musk deer was frequently captured in Shokharakh camera traps and captured only once in upper Mandakini valley (Figure 15). Among the other wildlife, Himalayan monal was present in all the three study areas and the relative abundance of monal was comparable among the three study sites (Figure 17), though they were more frequently captured in Shokharakh which was the least disturbed habitat.

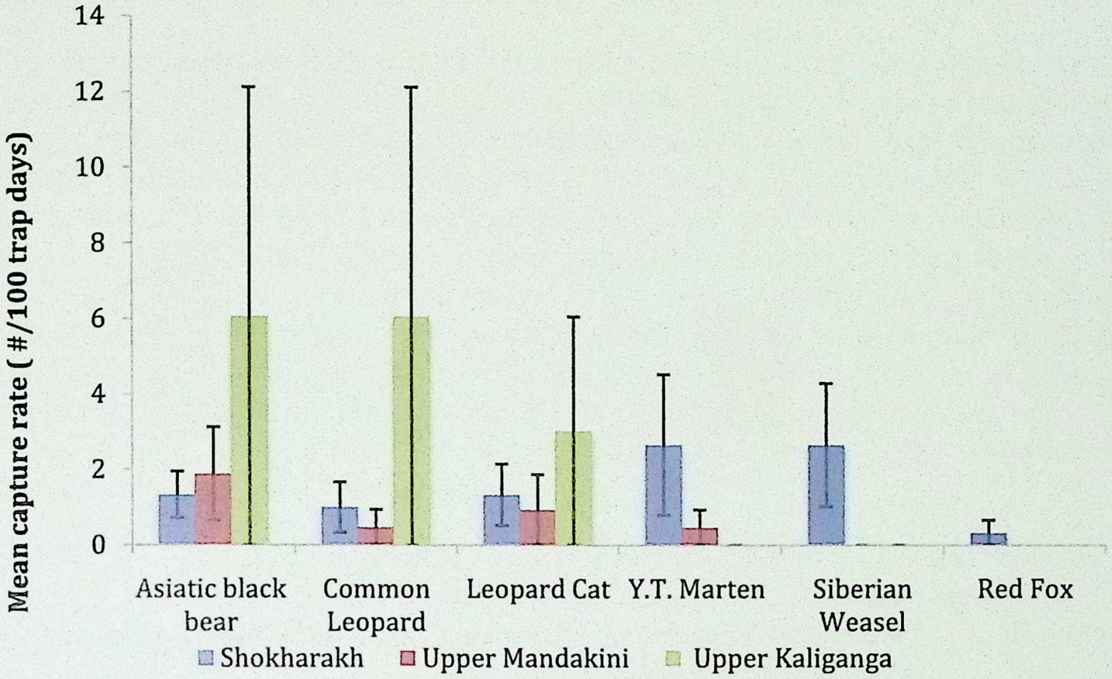


Figure 14 Mean photo- capture rate of carnivore species in all three study sites in Kedarnath Wildlife Sanctuary, April-June 2016

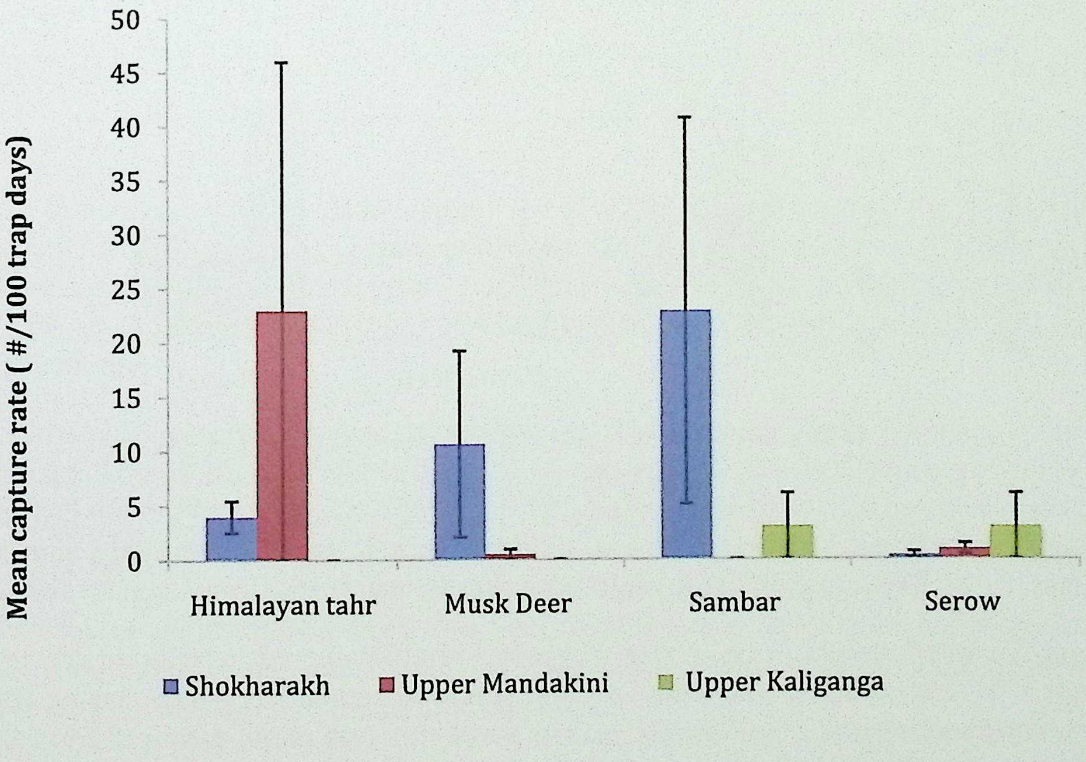


Figure 15 Mean photo-capture rate of ungulate species in all three study sites in Kedarnath Wildlife Sanctuary, April-June 2016

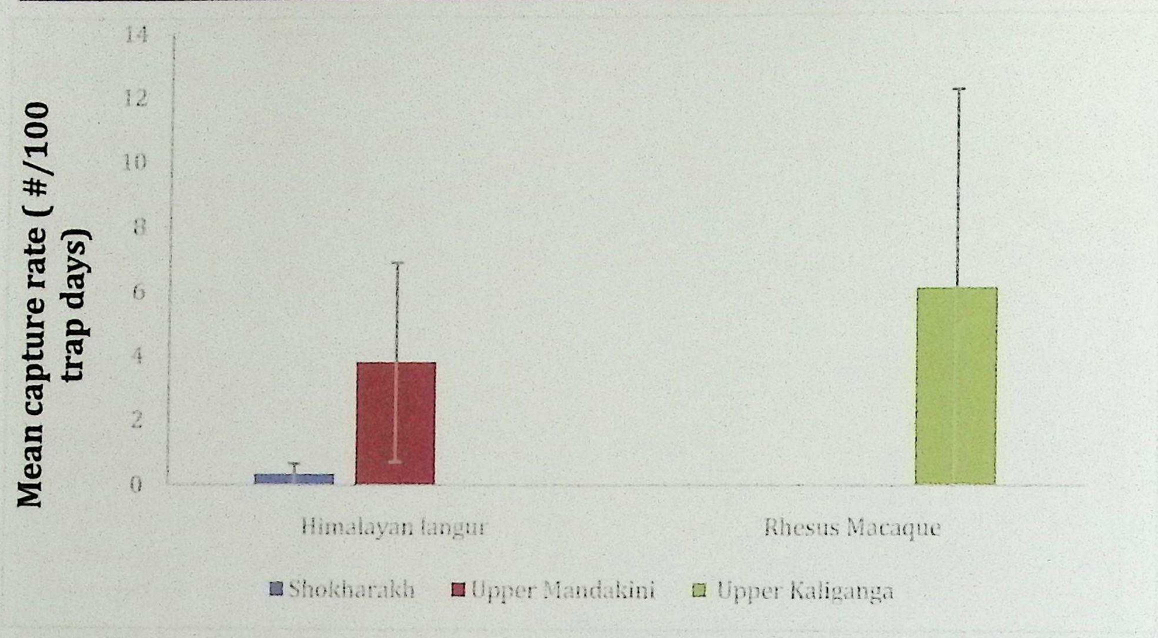


Figure 16 Mean photo-capture rate of primates in all study sites in Kedarnath Wildlife Sanctuary, April-June 2016

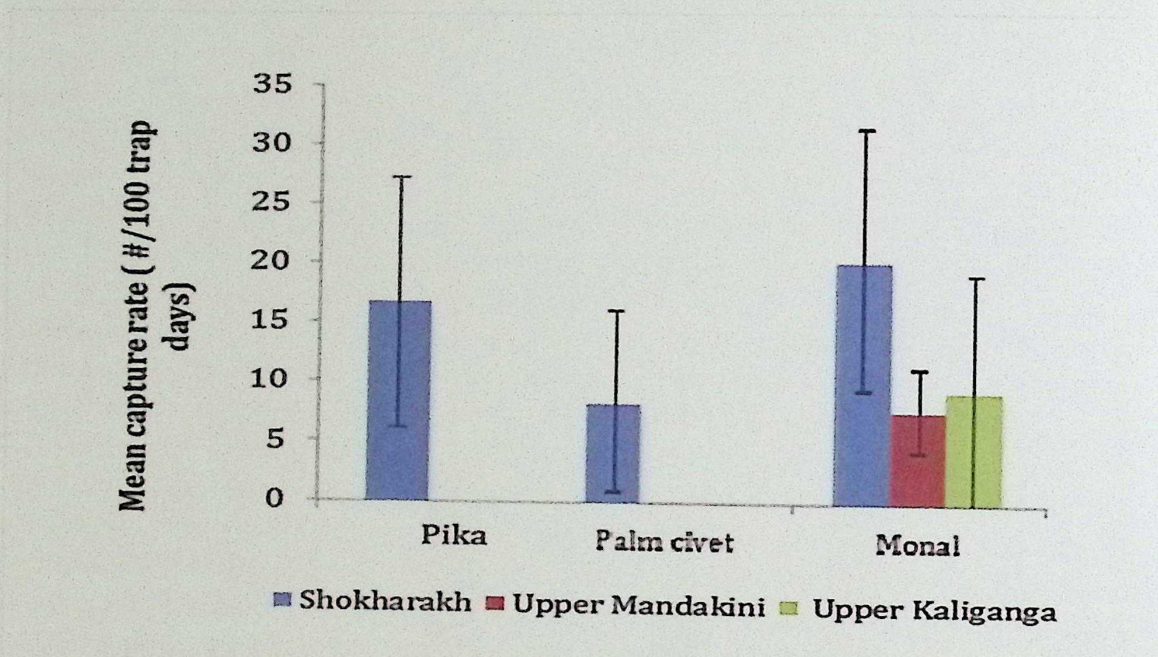


Figure 17 Mean photo-capture rate of other species in all three study sites in Kedarnath Wildlife Sanctuary, April-June 2016

Among the small mammals, pika was frequently photo-captured in Shokharakh area (Figure 17). However, in Mandakini valley, it was observed frequently during trail walks and opportunistic observations. Indian porcupine was photo-captured from the lower parts of Mandakini valley and many of the signs were also encountered in Mandakini valley but none of them were at more than 2500m, thus it has not figured in the comparison (Figure 17). Among the galliformes other than Himalayan monal, kalij pheasant was detected in camera traps deployed at lower elevations of Mandakini and Kaliganga valley and only once, hill partridge was photo-captured at 2600m in Mandakini valley. Koklass pheasant was present in both Shokharakh and Mandakini valley (pre-dawn calls heard) but was never photo-captured.

Photo-capture rates of human and livestock in the study area

Mean capture rates for humans and livestock in the three study sites was calculated using camera trap data (Table 9). Camera traps in Kaliganga valley were placed along a single trek route, which had increased human disturbance as it was the only path between a village and the area where a bridle path was being built towards Kedarnath. Hence, labourers and porters as well as shepherds and cattle herders frequently used the path. In contrast, the Mandakini camera traps were also placed along forest trails, but human disturbance along these trails was less as cemented pilgrim path was used in most cases. These camera trap captures does not represent actual number of people passing through the pilgrimage route to Kedarnath shrine, but only the number of people who are venturing into the forested areas and trails. Actual number of people passing through the Sanctuary to visit the Kedarnath Shrine is being recorded and maintained by the State Government.

Table 9 Mean photo- capture rate of humans, livestock and horses/mules in all three study sites in Kedarnath Wildlife Sanctuary, April-June 2016

Species	Mandakini (Trapping effort= 531 days)	Kaliganga (Trapping effort= 132 days)	Shokharakh (Trapping effort= 301 days)	All 3 study sites
Humans	63.59 ± 32.89	1046.21 ± 457.04	3 ± 2.60	276.97 ± 144.43
Livestock	81.19 ± 65.09	1172.73 ± 553.95	0 ± 0	328.7 ± 178.87
Horses/Mules	0.32 ± 0.32	112.12 ± 64.78	0 ± 0	26.53 ± 18.06

For Mandakini valley, mean capture rates were also calculated for the October-December 2015 sampling period, using data from four cameras (total 170 trap nights). Mean capture rate for humans in Mandakini valley in this time period was 170.83 ± 76.25 (n=246), and 184.72 ± 174.69 (n=266) and 0 for livestock and mules respectively.

Shokharakh clearly has the lowest human disturbance, while Kaliganga has the highest. This is because the route used in the rapid survey of Kaliganga valley was utilized not only by villagers and shepherds, but also labourers who were constructing a bridle path between the Kaliganga and Mandakini valleys, as an alternate pilgrimage route to Kedarnath. Kaliganga also had the highest livestock mean capture rate. No livestock or mules were captured in Shokharakh, while Mandakini had significantly less disturbance along forest trails than Kaliganga valley, despite some trails being near villages and the Kedarnath pilgrims path.

From the above-mentioned findings, it is clear that Shokharakh is an undisturbed control site. Kaliganga, while undisturbed by helicopters, is highly disturbed by humans, and this explains comparatively low species presence and low mean capture rates for some species in the area.

Comparison of photo-capture rates of wild animals between helicopter flying and non-flying seasons

As mentioned earlier, human disturbances were at peak in Mandakini valley and helicopter operations were very frequent during the peak pilgrimage season (May to June). To compare the photo-capture rate of different wild animals the entire study period was divided into two parts- helicopter flying season (May to June) and non-flying season (April). While some species such as Asiatic black bear (Figure 18), wild pig (Figure 19), porcupine (Figure 20) and rhesus macaque (Figure 21) were captured more when helicopters were not flying, most of the carnivores, ungulates and other species were captured in good abundance during the helicopter-flying season. However, the differences of photo-capture rate estimates between helicopter flying and non-flying seasons were not statistically significant for any of the above-mentioned species (Mann-Whitney U test, $p>0.05$ for Asiatic black bear, common leopard, leopard cat, barking deer and goral). The flying season also overlapped with breeding season for most of these species, hence, movement and activity increased even in habitats adjacent to very busy pilgrimage path, where there was also frequent overhead noise from helicopters.

To investigate the impact of helicopter frequency on relative abundance of wild animals in Mandakini valley, the photo-capture rates during very frequent flying period (305 flights/day), frequent flying period (225 flights/day), moderate flying period (142 flights/day) and low flight period (81 flights/day) was compared. During peak and high flight intensity, some carnivores and ungulates were present in the Mandakini valley (Figure 22), but the number of species captured during the low flying period, which also coincided with the advent of monsoon when individual detection in the Himalaya becomes difficult, was low. However, for most of the animals present in Mandakini valley, peak flying season coincides with their breeding activities and many of them are territorial animals, hence, their presence in the valley, particularly within their already established ranges, explains their compelled presence amidst frequent noise and disturbances.

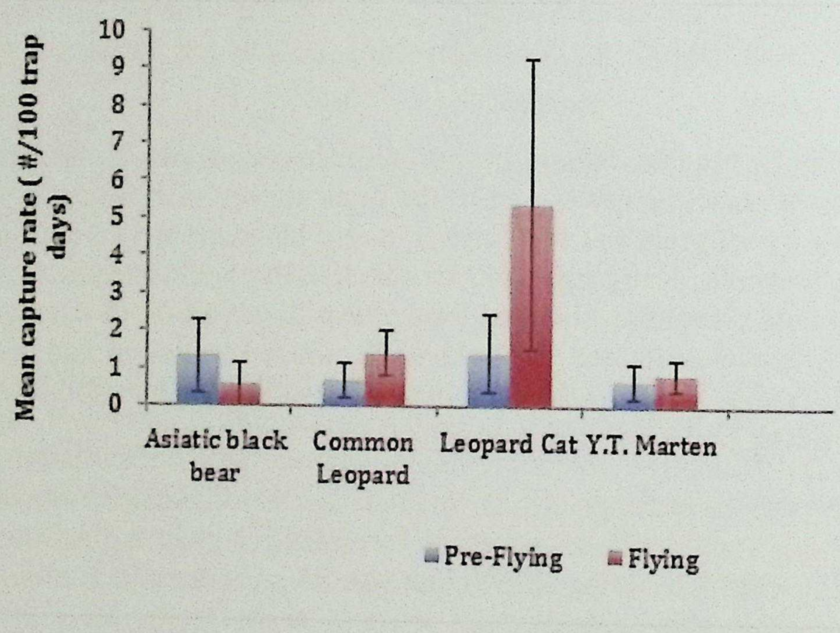


Figure 18 Mean capture rates of carnivore species during pre-flying and flying seasons in Mandakini Valley, April-June 2016

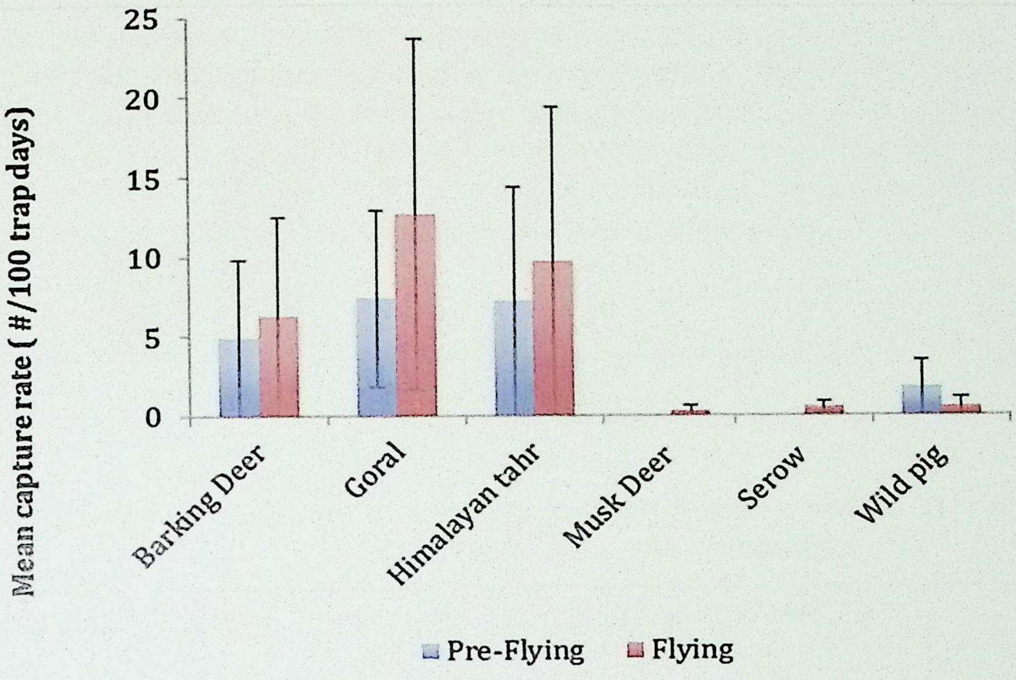


Figure 19 Mean capture rates of ungulate species in pre-flying and flying seasons in Mandakini Valley, April-June 2016

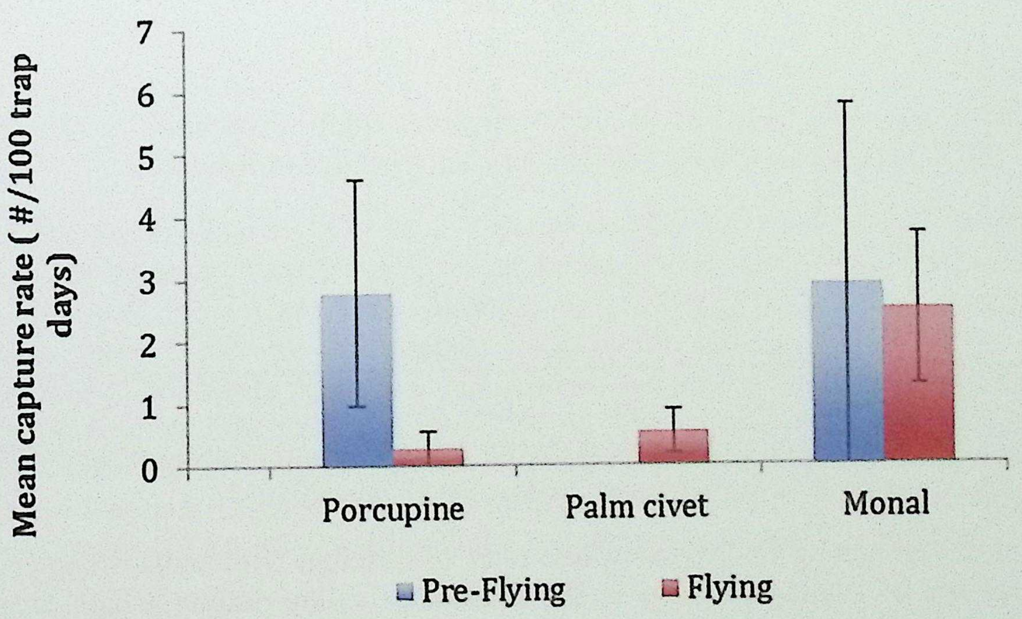


Figure 20 Mean capture rates of other species in pre-flying and flying seasons in Mandakini Valley, April-June 2016

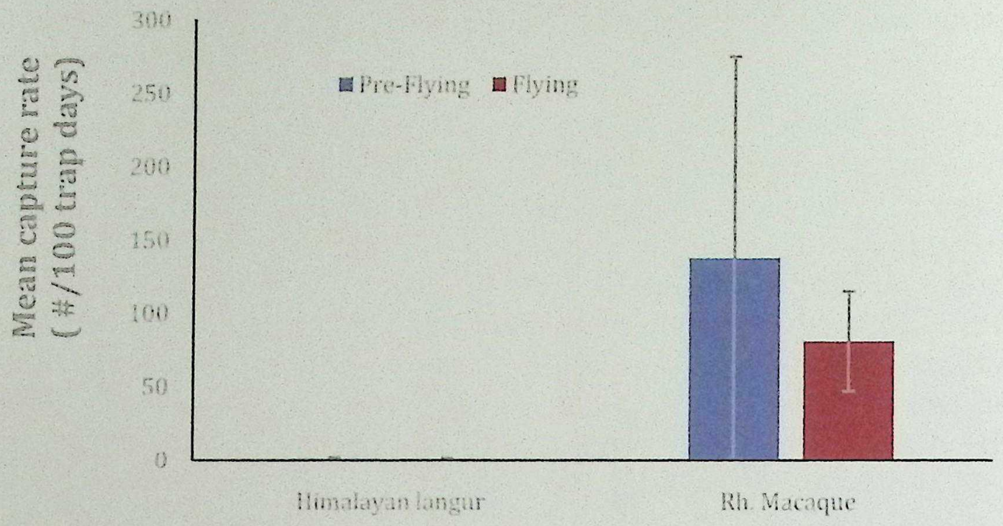


Figure 21 Mean capture rates of primates in pre-flying and flying seasons in Mandakini Valley, April-June 2016

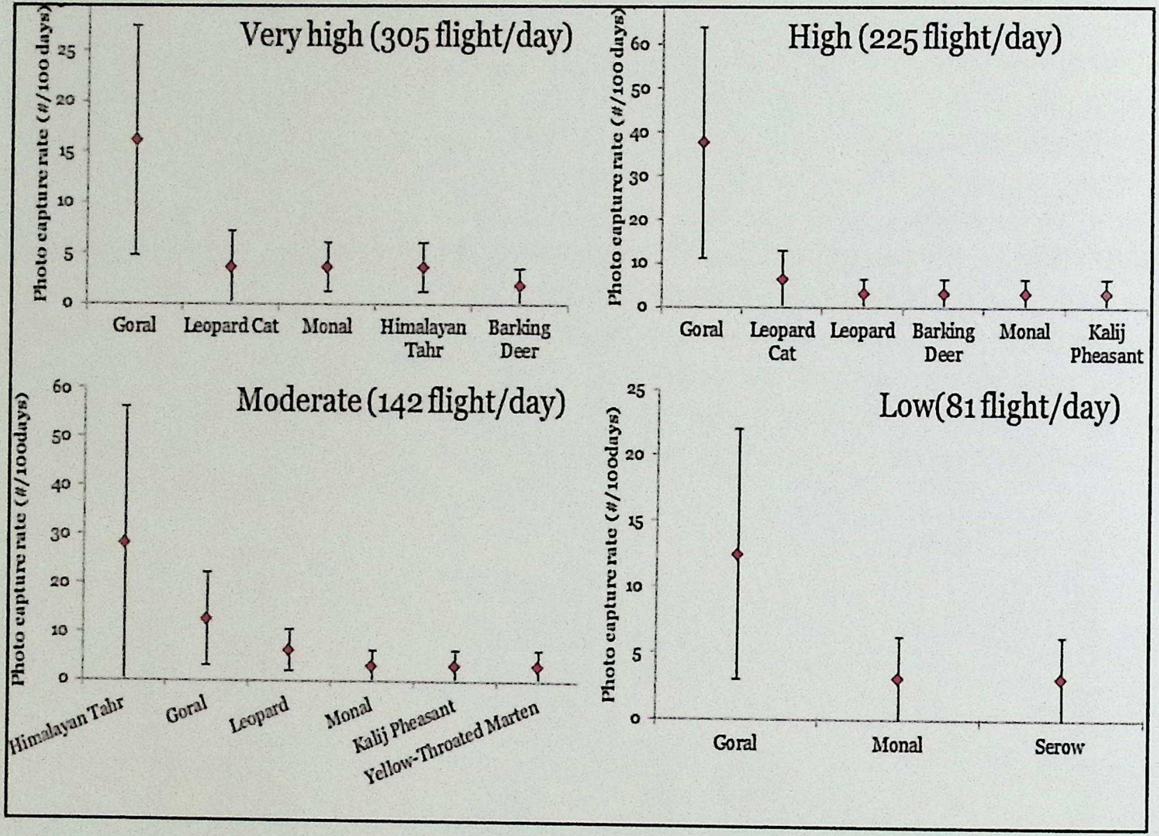


Figure 22 Mean capture rates of different wildlife species during different flight intensities in Mandakini valley, April-June 2016

The comparison among the photo-capture rates of different wild animals depicts the consistent use of available habitat in the Mandakini valley despite a high level of anthropogenic disturbances including helicopter flights and assoicated noise. Some elusive species such as Himalayan serow was captured only during the low flight intensity period and the endangered musk deer was not detected during the peak pilgrimage and helicopter-flying season. These findings also raise questions regarding the impacts of anthropogenic pressures on the activity pattern of these animals that live in Mandakini valley during the peak pilgrimage season.

Comparison of activity patterns of different wild animals in three study areas and with the daily pattern of helicopter flying

As camera trap images are stamped with time and date information, activity profiles were prepared for each species captured in the camera traps. The activity profile of each species was presented in the form of a rose diagram where relative frequency (% of total photographs captured) is plotted in a circular plots following four major quarters (0:00, 06:00, 12:00 and 18:00) of a day. A similar rose diagram was prepared for the hour-level frequency of helicopters in Mandakini valley (Figure 23).

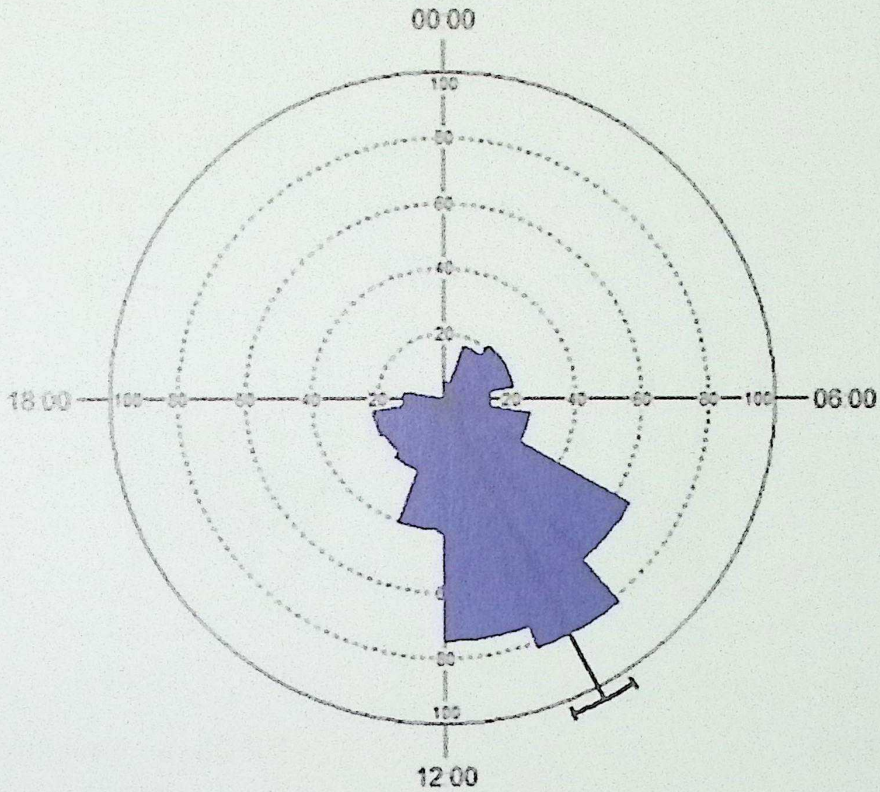


Figure 23 Helicopter flight frequency divided into four quarters of a day in Mandakini valley as observed (n=284) during April-June 2016

From the above diagram (Figure 23), it is evident that most of the flights were operational between 09:00 hrs to 12:00 hrs during the second quarter of a day. In very few instances, there were early morning or pre-dawn flights. Few flights were operated after 14:00, as the weather tends to be inclement after noon, posing difficulties to helicopter operation. The pattern also showed that the peak helicopter operating time and the peak activity period of wild animals in the Himalaya overlap (pre-dawn to 09:00). Following this finding, the activity patterns of frequently captured ungulates (Figure24 a, b, c); carnivores (Figure 25 a, b, c) and Himalayan monal (Figure 26) was compared with the helicopter flight intensity pattern.

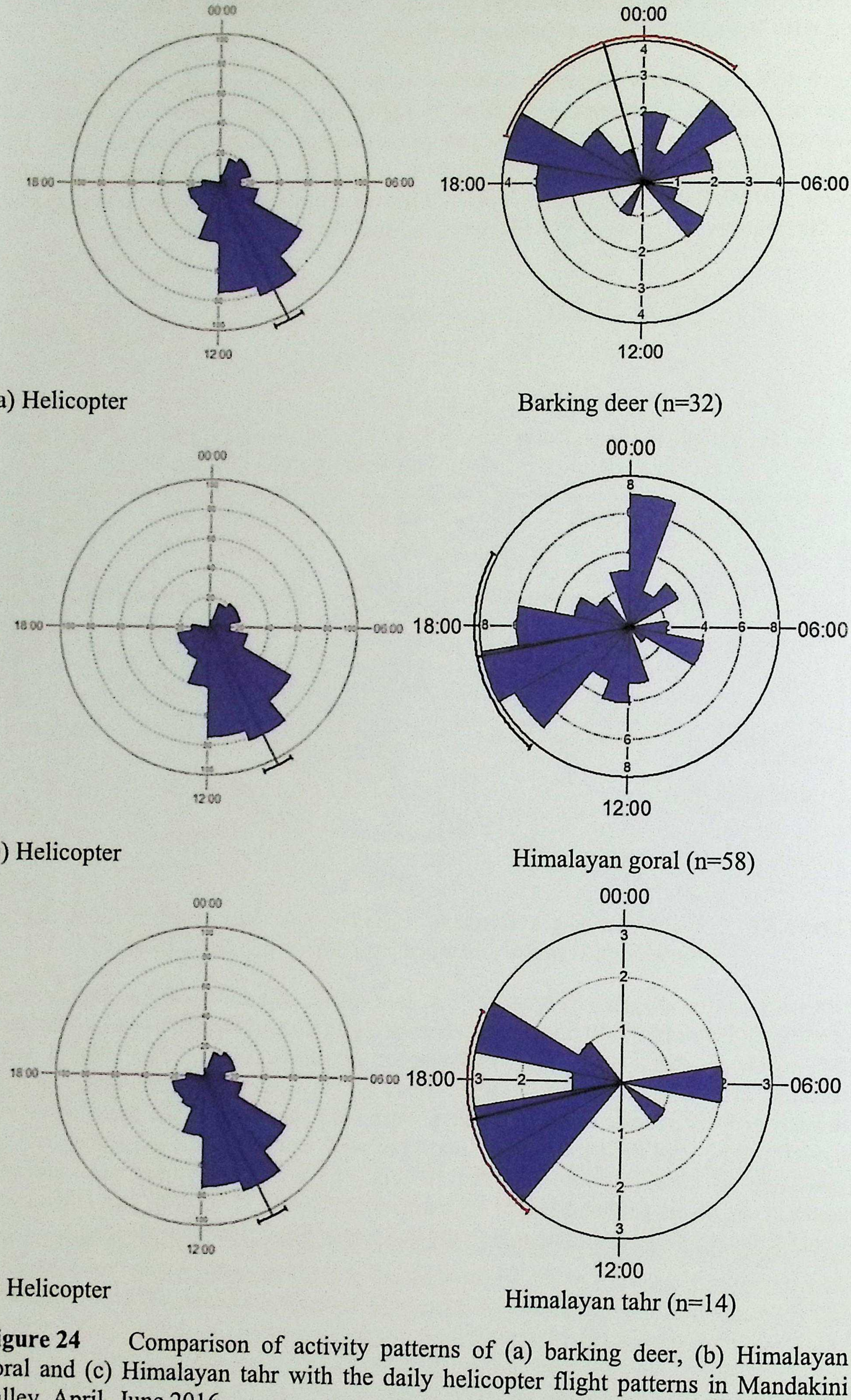


Figure 24 Comparison of activity patterns of (a) barking deer, (b) Himalayan goral and (c) Himalayan tahr with the daily helicopter flight patterns in Mandakini valley, April- June 2016

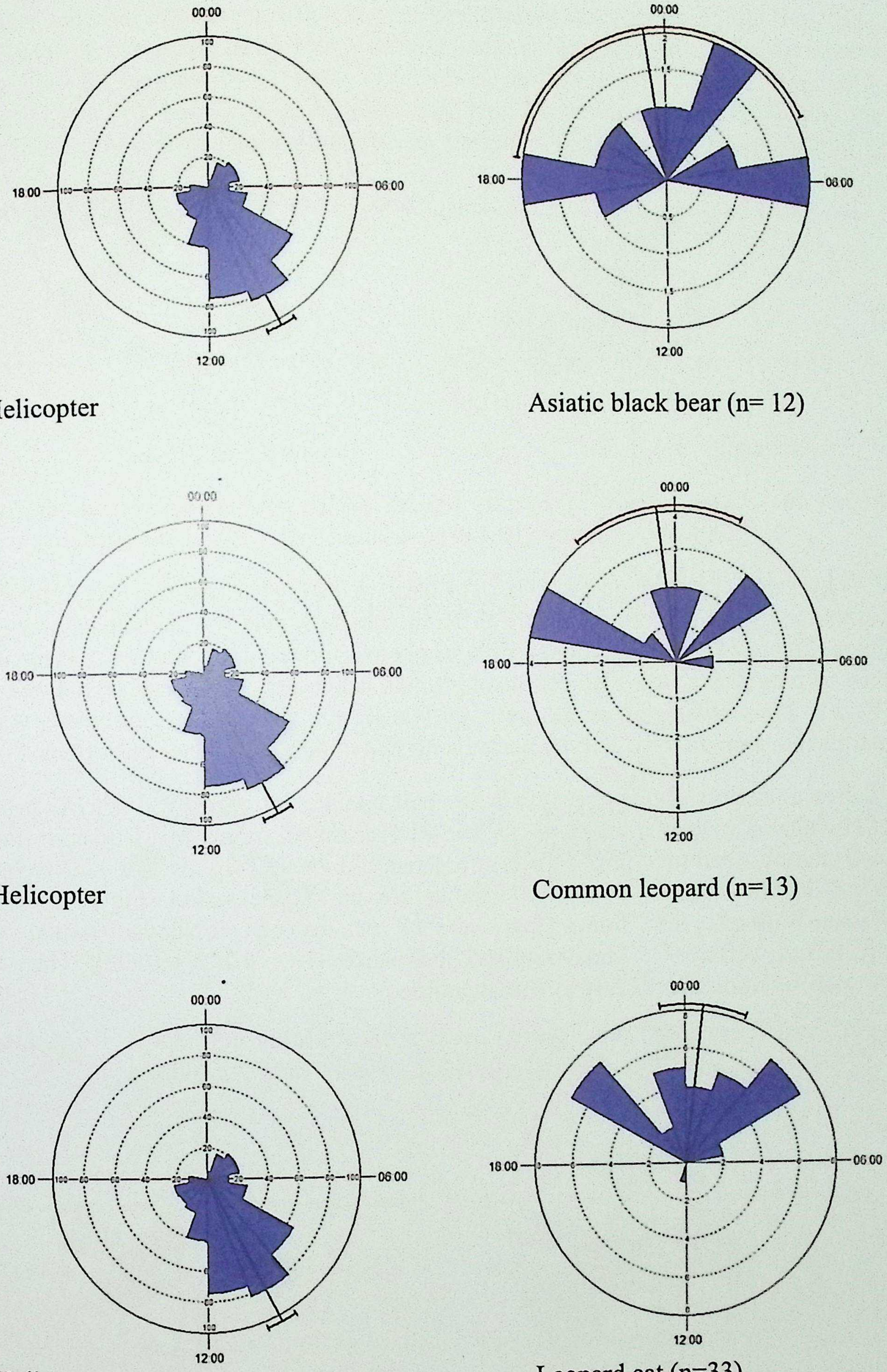
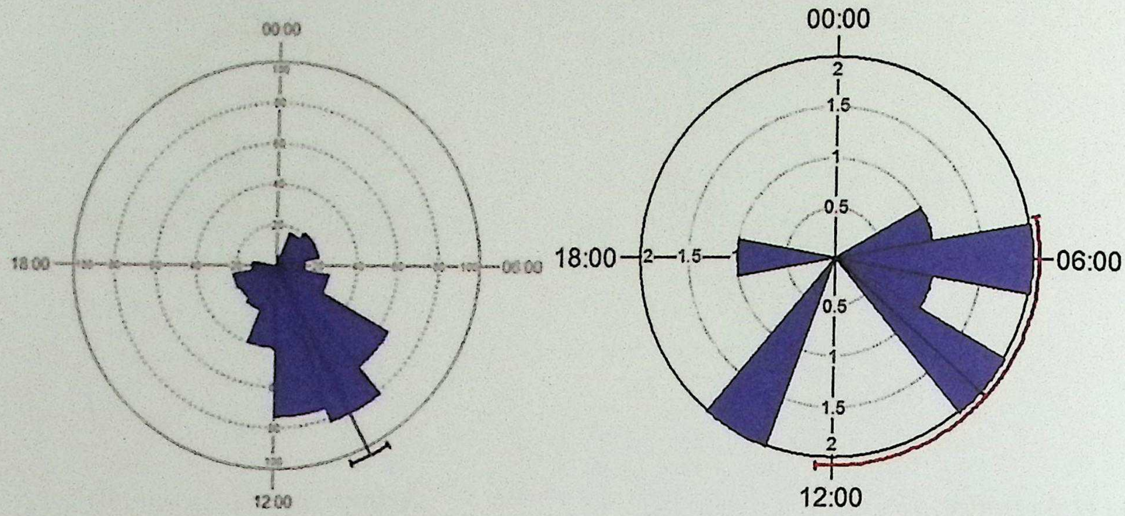


Figure 25 Comparison of activity patterns of (a) Asiatic black bear, (b) common leopard and (c) leopard cat with the daily helicopter flight pattern in Mandakini valley, April- June 2016



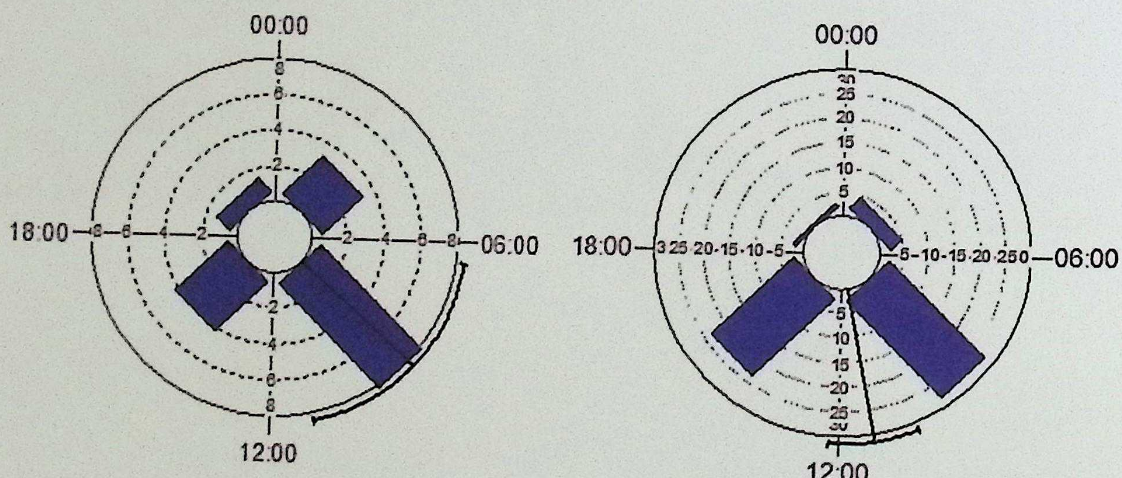
Helicopter

Himalayan Monal (n=9)

Figure 26 Comparison of activity pattern of Himalayan monal with the daily helicopter flight pattern in Mandakini valley, April- June 2016

For frequently captured ungulates such as barking deer, goral and Himalayan tahr, the daily activity peaks are in entirely different quarters than the helicopter operating hours (Figure 24). As the major carnivores photo-captured are nocturnal in behaviour, their activity peaks were also contrasting to the helicopter operational period in a day (Figure 25). However, in the case of Himalayan monal pheasant, there was a marginal overlap in peak activity period with that of peak helicopter operations

Finding a possible overlap between helicopter operational period and activity pattern of Himalayan monal, the activity pattern of Himalayan monal in Mandakini valley (n=9) during April to June 2016 was compared with the activity pattern of Himalayan monal in Shokharakh area (n=54) during the same time-period (Figure 27). The Watson-Williams test found that activity pattern of Himalayan monal was significantly different in Mandakini and Shokharakh ($U^2 = 0.245$, $p<0.02$). The cause for such variations needs further investigations.



Mandakini valley

Shokharakh area

Figure 27 Comparison between the activity pattern of Himalayan monal in Mandakini valley and Shokharakh area, April –June 2016

Activity patterns of some frequently captured species during non-flying and flying seasons were compared using rose diagrams; among the ungulates this analysis was carried out for barking deer (Figure 28), Himalayan tahr (Figure 29) and Himalayan goral (Figure 30); among other wildlife only Himalayan monal (Figure 31) and the most frequently captured animal, the Rhesus macaque, (Figure 32) were considered.

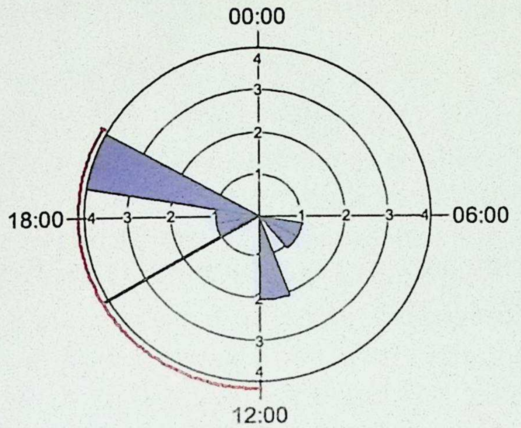


Figure 28 Barking deer activity pattern during – non-flying (n=10) vs. flying (n=22) seasons in Mandakini valley, April –June 2016

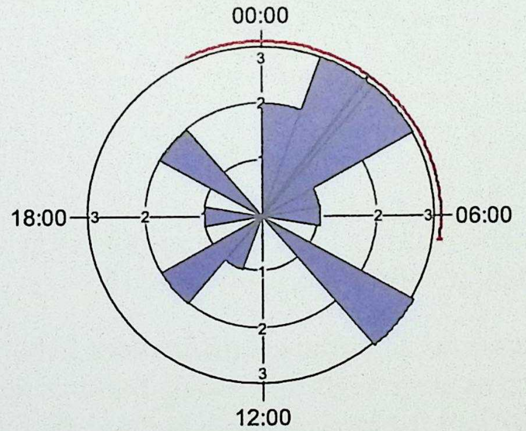


Figure 29 Himalayan goral activity pattern during– non-flying (n=19) vs. flying season (n=58) in Mandakini valley, April –June 2016

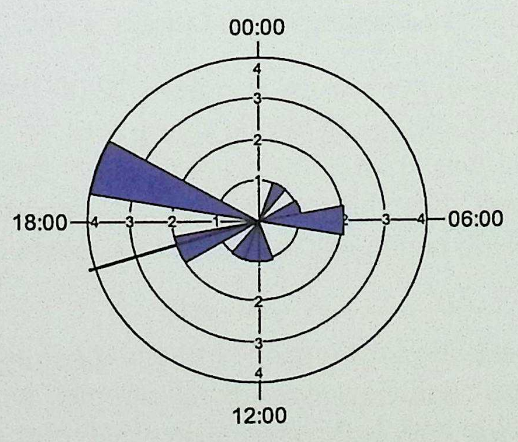


Figure 30 Himalayan Tahr activity pattern during – non-flying (n=13) vs. flying (n=14) seasons in Mandakini valley, April –June 2016

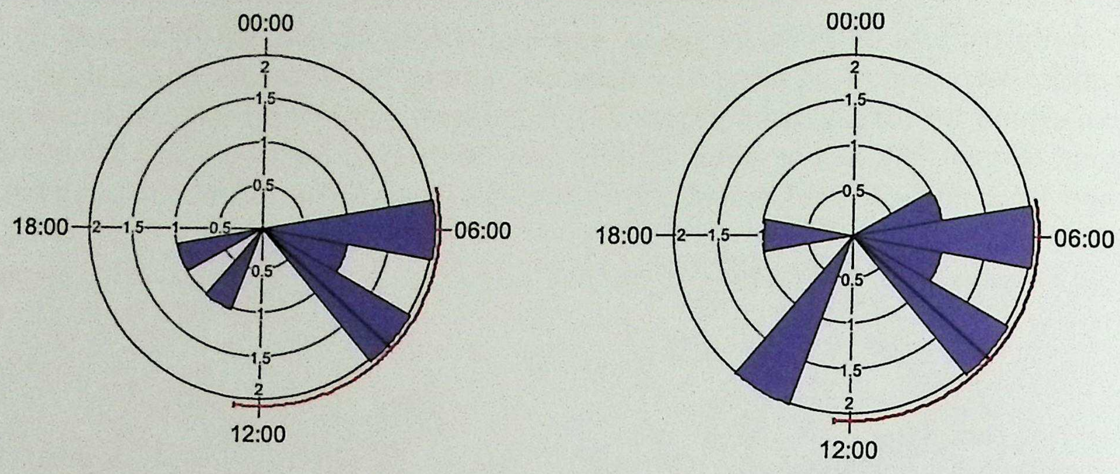


Figure 31 Himalayan Monal activity pattern during– non-flying (n=7) vs. flying (n=9) season in Mandakini valley, April –June 2016

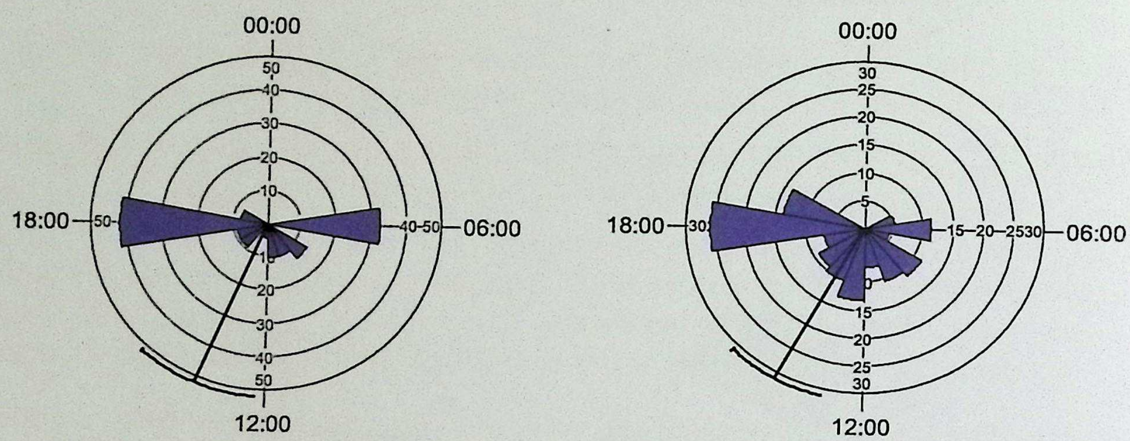


Figure 32 Rhesus Macaque activity pattern during – non-flying (n=141) vs. flying (n=129) season in Mandakini valley, April –June 2016

The Watson-Williams multi-sample test was used to determine if differences between helicopter flying and non-flying activity patterns were significant. For barking deer, goral and rhesus macaque (U^2 = 0.214, 0.189 and 0.17 respectively), the difference was significant ($P<0.05$). For Himalayan tahr and monal, with U^2 0.069 and 0.041 respectively, the difference was not significant. These differences between pre and post flying seasons may also be due to seasonal variations (early and mid-summer) or anthropogenic disturbance levels before and after the opening of Kedarnath shrine.

For barking deer, mean activity peak in the non-flying season was from 12:00 hours to 20:00 hours, which shifted to 21:00 hours to 03:00 hours during flying season. For goral, mean peak activity in non-flying season was from 2300 hours to 06:00 hours, which shifted to 1700 hours in flying season. For rhesus macaques, mean peak activity in non-operating season was around 13:00 hours, which shifted to 15:00 hours in the flying season.

To find if possible changes in activity pattern are due to avoidance of helicopters – by checking for stress in wildlife in the helicopter-affected area– fecal samples were tested for stress hormones, taking Shokharakh and Kaliganga valley samples as control.

Stress hormone levels in carnivores and ungulates of the Kedarnath WS

Over 260 faecal samples were collected from September 2015 to June 2016, and of these, 146 were sent for analysis. Feacal samples were air-dried in the field after collection and placed in brown paper bags, then dried in an oven overnight before being sent to the lab (LaCONES, Centre for Cellular and Molecular Biology, Hyderabad) for hormone extraction and assays, within a month of collection.

To segregate the samples according to the disturbance level, principal component analysis was carries out using noise level, other anthropogenic activities (livestock grazing and human presence) as disturbance variables and elevation, aspect (cool or warm), slope (steep or gentle) and terrain (flat or rugged) as topographical variables. The result (Figure 33) shows that the samples were categorized into three separate clusters. The first one is depicting the high elevation, steep and rugged terrain with high anthropogenic pressure and high noise (the upper Mandakini valley), the second one is from low elevation with high anthropogenic pressure and moderate noise (the lower Mandakini valley) and the third one is from high elevation with minimal anthropogenic pressure and minimal noise (Shokharakh area).

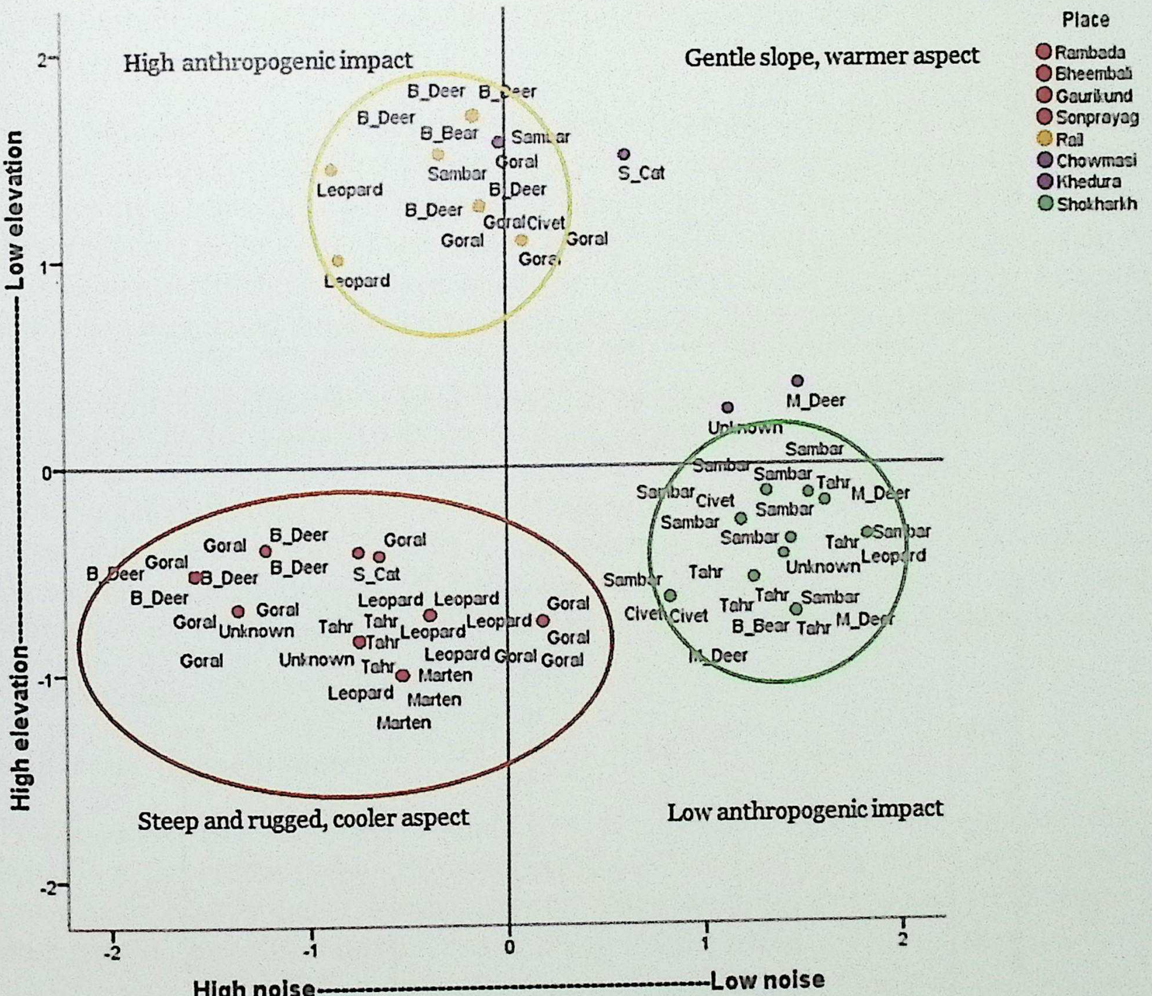


Figure 33 Distribution of collected samples along the two principal components of topographic and disturbance variables of Kedarnath Wildlife Sanctuary. Samples collected from different parts of the Kedarnath Wildlife Sanctuary are shown in different colours (red = upper Mandakini valley, yellow= lower Mandakini valley, purple= Kaliganga valley, green= Shokharakh)

The results of the analysis of stress hormone levels in the fecal samples of the carnivores and ungulates of Kedarnath WS are presented in Figure 34 (for cortisol) Figure 35 (progesterone). Although there are differences in stress hormone levels between different taxa and different individuals, nothing can be concluded at the population level as the sample sizes were too low. The impact of helicopter noise on the stress level of an individual can thus be detected through collection of very large amount of faecal samples and analysis which is beyond the scope of this short duration investigation. The results of progesterone levels showed absence of pregnant females in the samples. The comparison of cortisol levels of a particular taxa within two noise level gradients (very high in Mandakini valley and minimal in Shokharakh area) showed no particular trend.

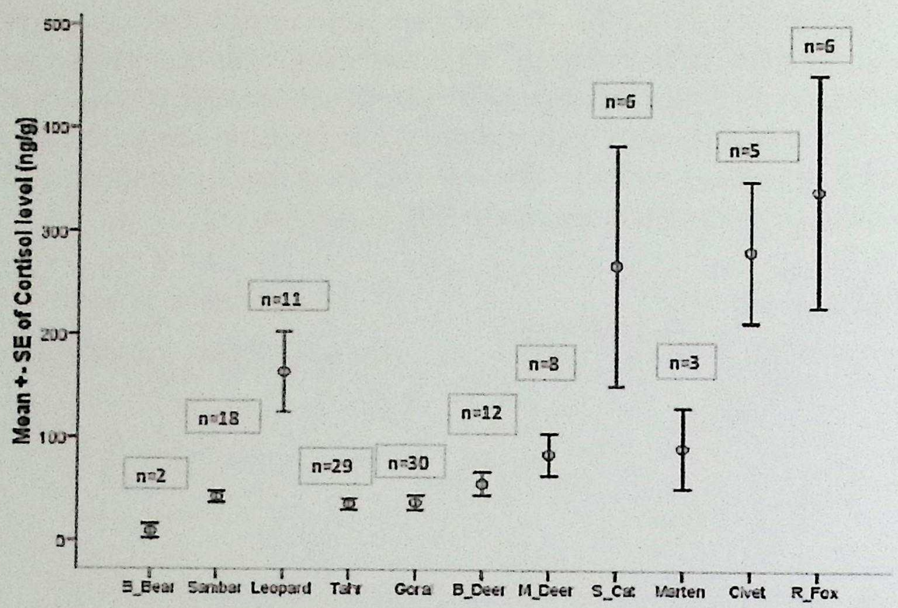


Figure 34 Mean cortisol levels of different species as obtained from faecal samples collected in Kedarnath Wildlife Sanctuary during September 2015 to June 2016

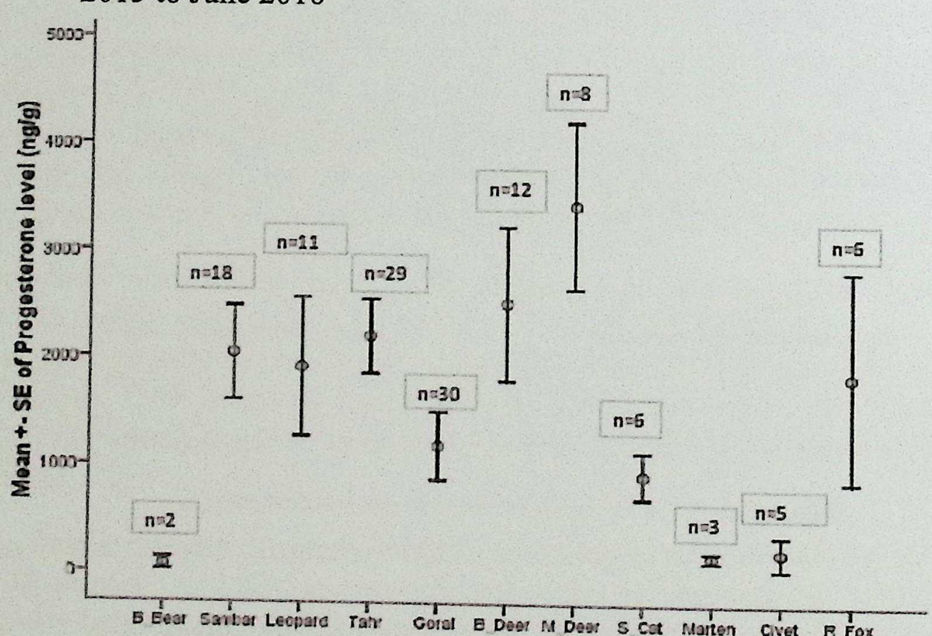


Figure 35 Mean progesterone level of different species as obtained from fecal samples in Kedarnath Wildlife Sanctuary during September 2015 to June 2016

Effects of Noise on Wildlife and mitigation measures as suggested in previous studies

Noise can have several effects on wildlife, which Jannsen (1980) categorised as primary, secondary or tertiary. Primary effects are direct physical auditory changes, such as rupturing of eardrums, masking of auditory signals, where an animal cannot hear important environmental signals, such as mating calls or the approach of a predator or prey, and changes in hearing threshold. Secondary effects of noise disturbance include stress, changes in behaviour, reproductive failure, and changes in the ability to obtain food, shelter or cover. Tertiary effects result from primary and secondary effects, such as decline of a population.

Several studies have investigated the physiological, behavioural and ecological responses of wild animals to aircrafts. Physiological effects could be increased heart rate, damage to eardrums, or inhibition of milk release (Harrington and Veitch, 1992). Behavioural responses range from panic reactions and fleeing to indifference. These reactions appear to be species-specific, and may vary seasonally. Habitat-avoidance has been observed due to aircraft disturbance (McCourt 1974, Krausman 1986). Startle responses or alertness is often seen (Harrington and Veitch 1991, Stockwell *et al* 1991).

Noise can also have a number of ecological effects on wildlife. Animals depend on acoustic signals for a number of natural functions, from communicating, to navigating and finding a mate or food, detecting predators or kin. Noise – especially unnatural anthropogenic noise – can mask these acoustic signals and can act as a barrier to the satisfactory performance of these functions. In addition, noise may also be a stressor, which can be studied through corticosteroid hormone levels in faecal matter or blood.

Escape responses and panic reactions to overflights are perceived as having negative effects on wildlife because they can be energetically "expensive" (Manci *et al*, 1988). This is due to two reasons – feeding animals will tend to stop ingesting food when disturbed, and disturbed animals tend to run or at least move away from the source of disturbance (in this case, aircraft). These decrease energy intake and increase energy expenditure, hence frequent disturbances on wildlife is a burden on their energy supply (Geist, 1978), which can have negative effects on growth and reproduction.

Case Studies

Impact on Herpetofauna

Traffic noise has also been found to have a negative effect on communication behaviour in breeding *Hyla arborea* (Lengagne, 2008). Traffic noises were found to cause a decrease in males' calling activity. Males were not able to adjust the tempo or frequency of the calls in response to traffic noise playbacks.

Similarly, in Thailand, airplane flyby noise and low-frequency motorcycle noise playbacks caused a decrease in calling rate in three species of anurans (Sun *et al.*, 2005).

Impact on birds

Stone, 2000 attempted to find experimental support to the "Niche Hypothesis" (Krause 1987, 1998), which states that anthropogenic noise adversely affects wildlife species. The study tested whether ambient noise played a role in the structure of bird communities in a riparian habitat. It was found that – in areas with similar levels of disturbance and land use – species richness significantly decreased as ambient noise increased, thus supporting the Niche Hypothesis.

The effects of chronic anthropogenic noise on Greater Sage-Grouse at leks was studied (Blickley, 2012a) over three breeding seasons using playbacks of continuous and intermittent noise. Abundance of males at leks was monitored, and it was observed that peak male attendance at leks treated with noise fell significantly, relative to paired controls. This decrease began in the first year of study and continued throughout the study. However, there was limited evidence of effect of the noise playback on males the year after the study ended, indicating possible habituation, and for peak female attendance at the leks. The study concluded that anthropogenic noise caused sage-grouse to avoid leks, and that intermittent noise has a greater effect than continuous noise. Fecal samples of male Sage-Grouse at leks were also collected and corticosteroid metabolites measured. The results, which were published in another paper (Blickley *et al.*, 2012b) found that noise playback has a significant impact on stress levels, with 16.7% higher mean Fecal Corticosteroid Metabolites (FCM) in samples from leks treated with noise than the control leks.

Chronic gas well compressor noise has been found to affect landscape patterns of avian habitat use and nest success (Francis *et al*, 2011), lowering occupancy in noise-affected areas, but increased nest success of gray flycatchers, because of decreased predation by western scrub-jays.

In a five-year study on effect of traffic on birds, light traffic was found to have no significant effect on bird activity nearby (Forman *et al*, 2002), however, heavy traffic on a two-lane highway caused decreased bird presence and breeding for 700m on either side of the road.

Three of seven songbird species were found to have reduced abundance in noisier locations than more quiet ones (Proppe *et al.*, 2013).

However, a study on the Red-Cockaded Woodpecker (Delaney *et al.*, 2000) did not find that military training noises – blank fire and artillery simulators – had an effect on nesting success or productivity. However, flush response increased with a decrease in stimulus distance.

A study on the influence of military training on the abundance and behaviour of raptors did not find any difference in raptor counts between training and non-training day (Schueck, 2001). However, during one intensive training period during breeding season, raptor counts were lower on training days compared to non-training days. Fewer prey capture attempts were observed on training days than on-training days, and lowest raptor counts were associated with firing of artillery, small arms, etc., which implies some correlation between rapid but non-continuous noise and avoidance behaviour in the raptors, compared to continuous noises like that of aircraft.

In a study on waterfowl and the effects of military training, 22 species of waterfowl were monitored in a disturbed area where noise frequently reached 80 dB, and averaged more than 60 dB, and a control site. In the disturbed area, nestling growth and survival rate was found to be significantly lower than that of the control site (Flemming *et al*., 2000).

Conomy (1998) studied whether black ducks and wood ducks habituate to aircraft disturbances. Wild-strain ducks were captured and subjected to actual and simulated activities of jet aircraft. It was observed that the proportion of times the black ducks reacted to the disturbances decreased with time, but remained stable at 5.8% after 17 days. In a second experiment, both duck species were exposed to recordings of jet noises. Black duck reactivity to the noise decreased with time, and no change in time-activity (pre-exposure to noise compared to 24h after first exposure) was observed. However, in contrast, the responses of wood ducks to jet noise did not seem to decrease following the initial exposure to noise.

The behaviour of nesting and loafing herring gulls (*Larus argentatus*) when exposed to supersonic transport, subsonic aircraft and normal colony noises was studied (Burger, 1981). Subsonic aircraft carriers did not seem to have any effect on nesting gulls, but when supersonic transports flew over, more nesting gulls flew away from their nests, and engaged in more fights once they landed, than compared to other conditions. Many eggs were broken during this time, or eaten by intruders.

Helicopters were found to have a greater disturbance effect on waterbirds than aeroplanes (Komenda-Zehnder *et al*, 2003), and this effect increased as the flight altitude decreased. However, the effect of the helicopter on the behaviour of the birds was not significant if it flew at or above 450 m above ground level, and 300m above ground level for aeroplanes.

In a study on the Dassen Island Nature Reserve, an Important Bird Area, birds reacted more strongly to helicopter flights (smaller tourist helicopters and large twin-engine for cargo) when they were directly below the flight paths, or within 250m of the helipads (Nansikombi, 2004). The study thus suggested that helicopter flights be conducted when they were less likely to impact birds on the island. In a study on Emperor Penguin (*Aptenodytes forsteri*) chicks in Antarctica (Giese, 1999), chicks that were exposed to a twin-engine helicopter at 1000 m all became vigilant. Many (69%) either walked or ran less than 10m towards other chicks, and most (83%) displayed flipper-flapping, which might indicate stress. This behaviour was rarely observed in the absence of flights. While the effects were relatively transitory, the paper recommended raising the minimum overflight height to 1500m around breeding localities of the species.

A simulation model was used to assess the impact of helicopter activity on moulting Pacific Black Brant in Alaska (Miller, 1994). It was found that slightly altering the flight route resulted in up to 91% fewer birds experiencing heavy weight loss. The heavier helicopter caused up to 15% more weight loss than did the smaller helicopter. The paper states that weight loss along a given flight line can be reduced by flying at altitudes over 1065 m, flying only when most brant are in their second week of moult, minimizing flight frequency, and avoiding use of larger helicopters when possible.

In a study on King Penguins (Hughes *et al*, 2008), 17 overflights were conducted from heights of 230m to 1768 m above ground level. Due to the overflights, sound levels increased from background levels of 65-69 dB to a maximum mean peak level of 80 dB. According to the study, penguin behaviour changed "significantly" at all altitudes. Pre-overflight behaviour resumed within 15 min of the aircraft passing overhead. Non-incubating birds showed greater response to reduced altitude of overflights than did incubating birds. As the study progressed, the penguins showed reduced response to the overflights, despite later flights being flown at lower altitudes. This suggests some habituation to the aircraft was taking place.

Impact on mammals

Exposure to traffic noise in the prairie dog caused a significant decrease in above-ground activity and foraging and increased vigilance (Shannon, 2014).

In feral horses, running and changes in group size and group composition took place in response to helicopter overflights (Linklater *et al* 2002).

Atlantic walruses on land responded to 27% of 71 helicopter overflights by head-lifting, orienting towards or retreating into the sea (Salter, 1979). The distance of the disturbance and altitude of the aircraft also had an effect on response.

Feral goats surveyed by helicopters were often found to be alert (44%) and in 31% of the observations were observed to move up to 1.5 km in response to the disturbance (Tracey & Fleming, 2007). However, no injuries were observed and no females were observed abandoning their young. The most important factors to influence the extent of alert behaviour or the distance moved were distance from the helicopter and the prior activity.

In North West British Columbia, out of 800 mountain goats, over 80% of observed goats displayed some form of behavioural stress-response to aircraft-based hydroelectric exploration activities, with 33% displaying severe flight response to local rock or plant cover (Foster *et al*, 1983). The responses to the disturbance were statistically independent of time of year, type and vertical orientation of disturbance, and group size. There was a significant correlation between the response and distance of disturbance, geographic area, cover availability, degree of awareness. The mountain goat responses were caused primarily by auditory stimuli, or noise from the aircraft, and secondarily by visual cues. Repeated aerial and ground surveys showed temporary habitat abandonment and changing observability indices in areas with intense exploration activity.

In contrast, a similar study on mountain goats in Alaska found that disturbance reactions were muted in comparison; this may be explained by the topography of the area. The study area in Alaska, having steeper terrain, may have limited the ability of mountain goats to run long distances, compared to those studied in Alberta, which ran over 100m or remained alert for at least 10 minutes (Côté 1996). The proximity of the goats to escape cover may have also reduced the degree of response.

Desert Bighorn Sheep in the Grand Canyon National Park (GCNP) were sensitive to disturbance in the winter, showing a 43% reduction in foraging efficiency, but there was no significant effect seen during the spring (Stockwell, 1991). However, this seasonal change may be because the sheep had migrated further away from the helicopters. A disturbance distance threshold was found to be 250-450 m. While the study did not state the exact number of helicopters flying per day, it quoted another study by Mazzu (1990) which mentioned the number of helicopters flying over designated flight paths, such as the one over the bighorn sampled in this study, to be about 15 per hour during the autumn. To limit the effect of flights on the bighorn, this study suggested restricting helicopters to hours of the day when the sheep were not active, in addition to maintaining a certain flight altitude so as to remain at least 500m away from the sheep.

Dall's sheep directly approached by helicopters or fixed-wing aircraft were more likely to flee, and the more direct the approach the longer the time taken to resume pre-flight behaviour. During indirect approaches by helicopters, sheep close to rocky slopes were less likely to flee than those far away from rocky slope cover (Frid, 2003).

Low-level flight (below 150m) was found to elicit panic behaviour in barren-ground caribou in the Yukon, and individuals were at risk of injuring themselves in their haste to escape (Calef *et al* 1976). However, flights passing by at even very low heights (30 to 60m) did not seem to cause cows to abandon their new-born calves. The paper stated that most injurious reactions by caribou can be avoided if aircraft do not fly below 150m above ground-level. Aircraft would need to fly above 305m to avoid even mild escape responses.

Female caribou with young were found to be most sensitive to aircraft disturbance, and caribou were more disturbed by aircraft during the insect season and post calving than winter (Maier, *et al*. 2001). The paper suggested military aircraft avoid caribou during the post-calving season and that they avoid flying during the cooler periods of the day in the insect season, as that is an important feeding time.

Species such as grizzly bears (McCourt *et al*. 1974), mountain sheep (Bleich *et al*, 1990), and mountain goats (Chadwick, 1973) all have been observed to abandon their habitat in response to small aircraft overflights, even when the overflights were infrequent

One study surgically implanted elk, antelope and bighorn sheep with heart rate and body temperature transmitters (Brown, 2012). These animals were released into large enclosures or the wild (as control) and then subjected to various types of disturbance, such as human foot traffic, fixed wing aircraft, helicopters, and jet aircraft. The study says that these animals habituated to most of the disturbance factors in a short period of time – except for people on foot who entered the enclosures, fixed wing aircraft flying at low elevations and helicopters flying very low and close to the enclosures. The habituation to subsonic and supersonic jet flights appeared to be permanent.

A common criticism for these studies is that the species studied would generally get habituated to frequent disturbance, something which cannot be detected during such short-term studies, covering only a year or two. However, a study by Côté *et al*. 2013 on whether mountain goats (*Oreamnos americanus*) habituated to frequent helicopter overflights over a period of 10 years, found that there was no significant decrease in the percentage of groups which showed a strong behavioural response to overflights, especially when the disturbance was less than 500m away from the mountain goat groups. The paper thus recommended that helicopter flights closer than 1500m to mountain goat groups be avoided.

Other studies have also failed to prove that ungulates habituate to helicopter flights over time (Miller and Gunn 1980; Bleich *et al.* 1990, 1994; Frid 2003).

However, in contrast, a study on desert mule deer concluded they appeared to have habituated to low-flying aircraft (Krausman *et al*, 1986). This lends further credence to the theory that responses and habituation to helicopter disturbance are species-specific.

Effect of Helicopter Noise on Wildlife in Kedarnath WS: A unique case

Few studies on the effects of helicopters on wildlife are in areas with a volume of air traffic comparable with that of Kedarnath WS, where the number of flights per day may be as many as 300 in the peak summer season. In many studies, the number of flights was limited, such as a study on mountain goats (Côté, 2013), where flights numbered about one to ten over a period of ten years. The mountain goats in the study showed no significant habituation to the helicopters over this ten-year period, but this could very well be due to the limited number of flights they were exposed to per day. The numbers of helicopters flying overhead per day in Kedarnath WS are incomparable with any study on helicopter disturbance on wildlife so far. Studies on Desert Bighorn Sheep in the Grand Canyon National Park (Stockwell, 1991 and Mazzu, 1990) mentioned the number of helicopters flying over designated flight paths, to be about 15 per hour during the autumn. This study found no significant change in behaviour on the sheep during the spring, but found some sensitivity to the disturbance in the winter. In Kedarnath WS, it is possible that with the vastly greater number of flights, the animals of the wildlife sanctuary may have become habituated to the disturbance in the recent past, particularly during the last two to three years.

According to an unpublished report by Frid in 1997, mountain goats and mountain sheep disturbance has more impact when it occurs during their bedding period in midday. Low elevation flights near their feeding and escape terrain have marginally less impact in early morning and late evening. However, other ungulates such as moose, elk, caribou and similar Himalayan ungulates such as sambar, barking deer, serow, goral and musk deer as shown in this study, experience less disturbance at midday when they are resting in secure escape cover. These solitary mammals are much more likely to be highly disturbed by flights during early morning and late evening hours.

Specific observations from Kedarnath WS

Previous studies conducted on the effect of helicopters on wildlife are limited in number, and come to no consensus. Nor is there any one protocol followed in the studies, which date as far back as 1973.

Various studies have exposed animals to helicopter flights ranging from 30 m altitude to 1500 m altitude above ground level. However, when it comes to number of flights per day, no other study seems to compare to the number of helicopters flying overhead in the Mandakini valley. Most studies are short term, where a helicopter is flown overhead specifically for the purpose of the study. Where the number of flights has been mentioned, it is generally much lower than the mean number of daily flights in the Kedarnath WS.

Some findings are consistent in studies on the effects of anthropogenic noise – especially helicopter noise – on wildlife. One is that habituation to the disturbance cannot necessarily be predicted, as it is species-specific. The second is that discontinuous noise – like that produced by helicopters – has more of an effect on wildlife than continuous noise. Hence we may infer that helicopters, especially when flying at low elevations and very near wildlife, may cause negative responses in some species. To properly assess what these responses are, more detailed, possibly species-specific studies must be carried out, which investigate all three kinds of possible effects noise may have on a particular species, *viz.*, physiological, behavioural, and ecological.

During this study, Himalayan tahr in the disturbed site (Mandakini Valley) were observed while helicopters flew overhead. In one incident, a single female Himalayan tahr was observed while three helicopters flew overhead. The individual showed no change in behaviour and continued browsing. In another instance, a group of Himalayan tahr (females and sub-adult males) was observed while helicopters flew overhead, and no change in behaviour was observed except for alertness in one or two individuals. When a group of Himalayan tahr in Shokharakh were exposed to a playback of helicopter noise, they showed no change in behaviour. They were also indifferent to sounds of traffic from a road nearby. Moreover, the only instance of a single helicopter flight overhead in Shokharakh, no change in Himalayan tahr behaviour was observed.

Several bird species have been observed and recorded while helicopter overflights were taking place. A black francolin male was indifferent to at least three helicopters flights overhead and continued calling, as did a great barbet and a scarlet finch, on two different occasions. A pair of barn swallows continued building a nest despite helicopter (and human) disturbance. A pair of spot-winged grosbeaks continued feeding despite several helicopters flying overhead in Rail village, which had the highest mean noise level during the period April-June 2016. One nesting Oriental white-eye in Rail village was observed to pause and watch a helicopter while it passed overhead, but no other incidence of behavioural change in birds was recorded during this study.

One interesting observation noted during the course of this study was the difference in animal captures between two camera traps in Rambara which were roughly 400m away from one another, on a trail just off the main pilgrim path to Kedarnath. The first camera, which was under 500m away from the main pilgrim path, captured mostly livestock – cattle and goats – and some humans, along with one or two photos of a wild animal – an Asiatic Black bear. However, the other camera captured no human disturbance – nor was any human disturbance detected there, while signs of lopping and wood collection could be observed near the first camera. In the second camera, which is nearly one kilometre from the main pilgrim path, many different species were captured – Himalayan tahr, common leopard, Asiatic black bear, Himalayan goral, Himalayan serow, Central Himalayan langur, leopard cat, and even musk deer. Both locations suffer a similar amount of disturbance due to helicopters, as the flight path lies just above, but differ in human and livestock presence. This indicates that direct human disturbance has a big negative influence on habitat use by animals.

Conclusions

Based on the findings of this study and a perusal of published information on impacts of aircraft flights on wildlife, the following conclusions are arrived at:

1. All the common wildlife species of Kedarnath WS are present in Mandakini valley. The comparison among the photo-capture rates of different wild animals depicts the consistent use of available habitat in the Mandakini valley, despite a high level of helicopter noise.

2. Some wildlife species altered their activity pattern to either crepuscular or nocturnal. However, in the case of Himalayan monal pheasant, there was a marginal overlap in peak activity period with that of peak helicopter operations.

3. Results of stress hormone studies are inconclusive due to low sample sizes. However, the results can be used as baseline for future comparative studies on similar investigations pertaining to helicopter flight impacts on wildlife.

4. Taking the above three points into consideration, it appears that most of the mammals have adapted to the disturbances in Mandakini valley. However, repeated observations through a long-term monitoring programme is needed to draw stronger conclusions regarding this adaptation hypothesis.

5. There is a high negative correlation between flying height and noise levels and the current levels of noise due to anthropogenic activities and helicopter are above the prescribed limits for Protected Area. Thus, prescribing a minimal flight height would be required to reduce the noise levels.

6. Helicopter sorties ranged from 2 to >300 flights per day in Mandakini Valley. This level of flight intensity is very high and therefore efforts have to be made to maintain the upper limit for number of flights per day to not more than 300/day.

Suggested Mitigation Measures

It is important to consider the implications of anthropogenic noise, especially helicopter noise, within the Wildlife Sanctuary, and to develop methods of mitigation. In the United States of America, the Federal Aviation Administration has been developing rules with the aim to maintain and enhance the "natural quiet" in a protected area, the Grand Canyon National Park. The rules are intended to preserve the "natural quiet" of the park by reducing aircraft noise in the park, so that at least half of the park is free of aircraft noise for 75-100% of the day. Such "silence zones" can also be implemented in India, and subsequently be used as control sites for studies on the effect of noise on wildlife species. In the USA, these rules are being carried out by restricting flight paths, curbing number of flights per day, ensuring some aircraft fly higher, and limiting the number of flights per tourist operator. Similar reforms may be considered and implemented in the Kedarnath WS to protect the "natural quiet" of the wilderness and decrease human disturbance in the WS. Some examples from Indian States are as follows:

1. **Limitation to flight height**: As like the Arunachal Pradesh Civil Aviation Department, the Uttarakhand Civil Aviation Department may consider implementing an altitude limit that is minimum level except for take-off or landing or except when specifically authorised by Director General. An IFR (Instrument Flight Rules) flight shall be flown at a level which is not below the minimum flight altitude established by the state whose territory is overflown, or where no such minimum flight altitude has established.

   A) *Over high terrain or in mountainous area at a level that is at least 600 m (2000ft) above the highest obstacle located within 8 km of the estimated position of the aircraft.*

   Web link of the document: http://www.dgca.nic.in/cars/D9C-C1.pdf

2. **Limitation to noise level:** Following the State Government of Goa that has defined and categorized areas as 'silence zone', the Government of Uttarakhand may consider categorizing some areas as 'silence zone'. Web link of the documents: https://www.goa.gov.in/wp-content/uploads/2016/05/The-Noise-Pollution-Rules-as-ameded-till-11-01-2010.pdf and http://www.envfor.nic.in/downloads/public-information/noise-pollution-rules-en.pdf

   To monitor the noise levels in designated silent zones, there are some state-of the-art technologies and some examples that can be imbibed are as follows:

   1. Use of Laser Distometers: Laser distometers operates on the "time of flight" principle by sending a laser pulse in a narrow beam towards the object and measuring the time taken by the pulse to be reflected off the target and returned to the sender. In this way the speed of the flight and eventually the height can be calculated.

   2. Use of Lidar gun: A Lidar gun sends out a predetermined series of light pulses with a known time interval between each pulse to a target. Through an averaging process the system will able to measure the time of flight between the transmission and reception, resulting in an accurate speed and range.

   3. Automatic Dependent Surveillance – Broadcast (ADS-B): ADS-B is the surveillance technology in which an aircraft determines its position via satellite navigation and periodically broadcasts it, enabling it to be tracked by a ground antenna. Other aircraft to provide situational awareness and allow self-separation can also receive it. By installing the ground structure, the department may enable themselves to monitor the frequency and height of each helicopter service providers.

Long-Term Recommendation:

Use Ropeway as an alternative: To prevent noise pollution and the unaccounted part of air pollution due to very frequent helicopter flying in the highly fragile environment such as Kedarnath WS, the option of mass transportation of pilgrims via passenger ropeways could be considered. Ropeway is a transport mode that emits minimal sound and causes no air pollution. The establishment also requires minimal removal of forest cover. This environment friendly example of pilgrim / tourist transportation is followed in some of the pilgrimage/tourist sites in Uttarakhand and other states of India. This eco-friendly venture can considerably reduce the amount of noise in the Mandakini valley that his home of so many rare, endangered and threatened mammals and other important fauna and flora.

Passenger ropeways can transport large number of pilgrims in an environmentally friendly manner, as this would lead to drastic reduction in the foot falls of pilgrims and pack animals inside the Kedarnath WS. Most importantly, the construction of passenger ropeway in today's world does not require building a motorable road through the Kedarnath WS as all the material and machines could be transported by air using specialized helicopters.

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