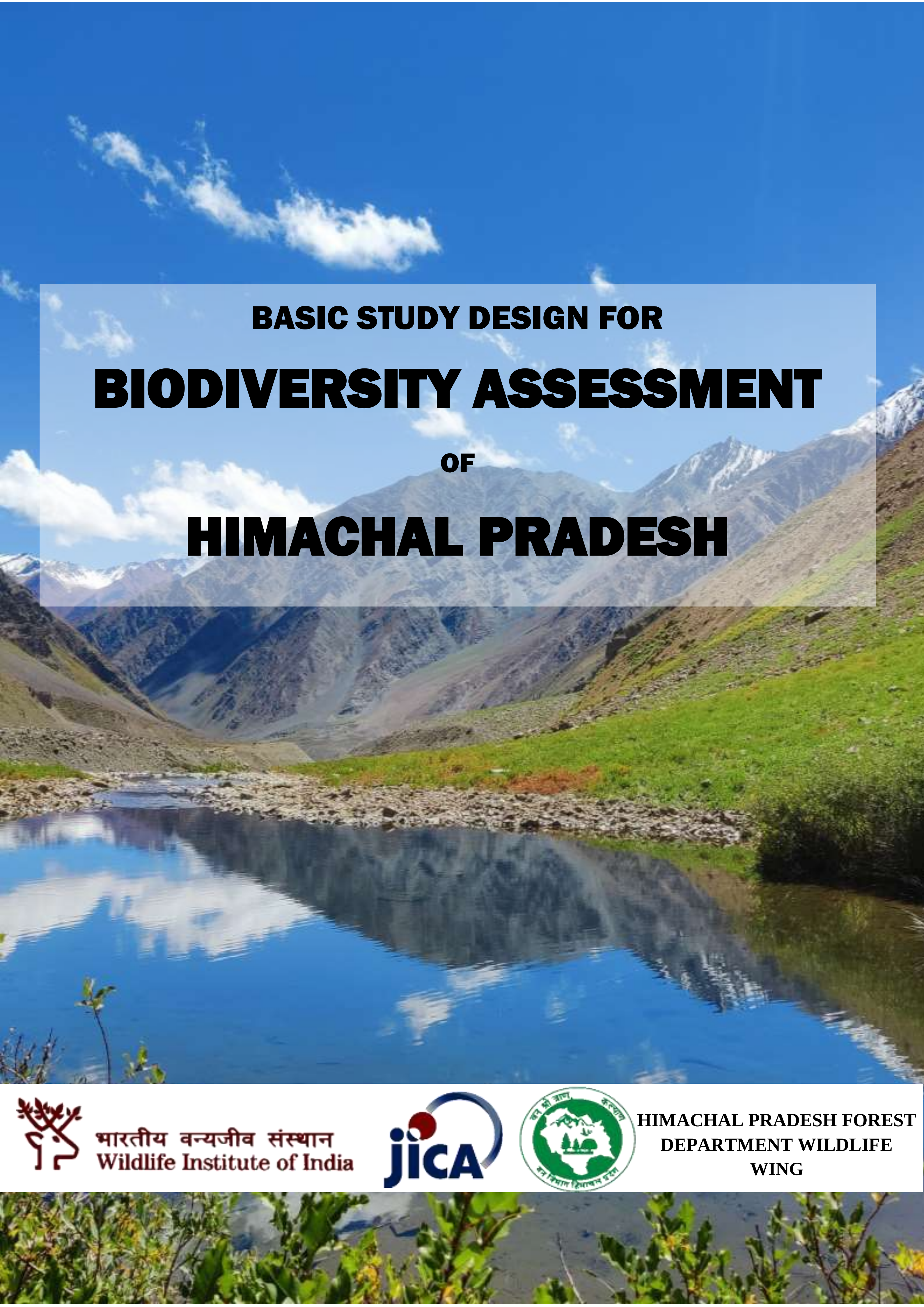

BASIC STUDY DESIGN FOR

BIODIVERSITY ASSESSMENT

OF

HIMACHAL PRADESH

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

JICA

HIMACHAL PRADESH FOREST DEPARTMENT WILDLIFE WING

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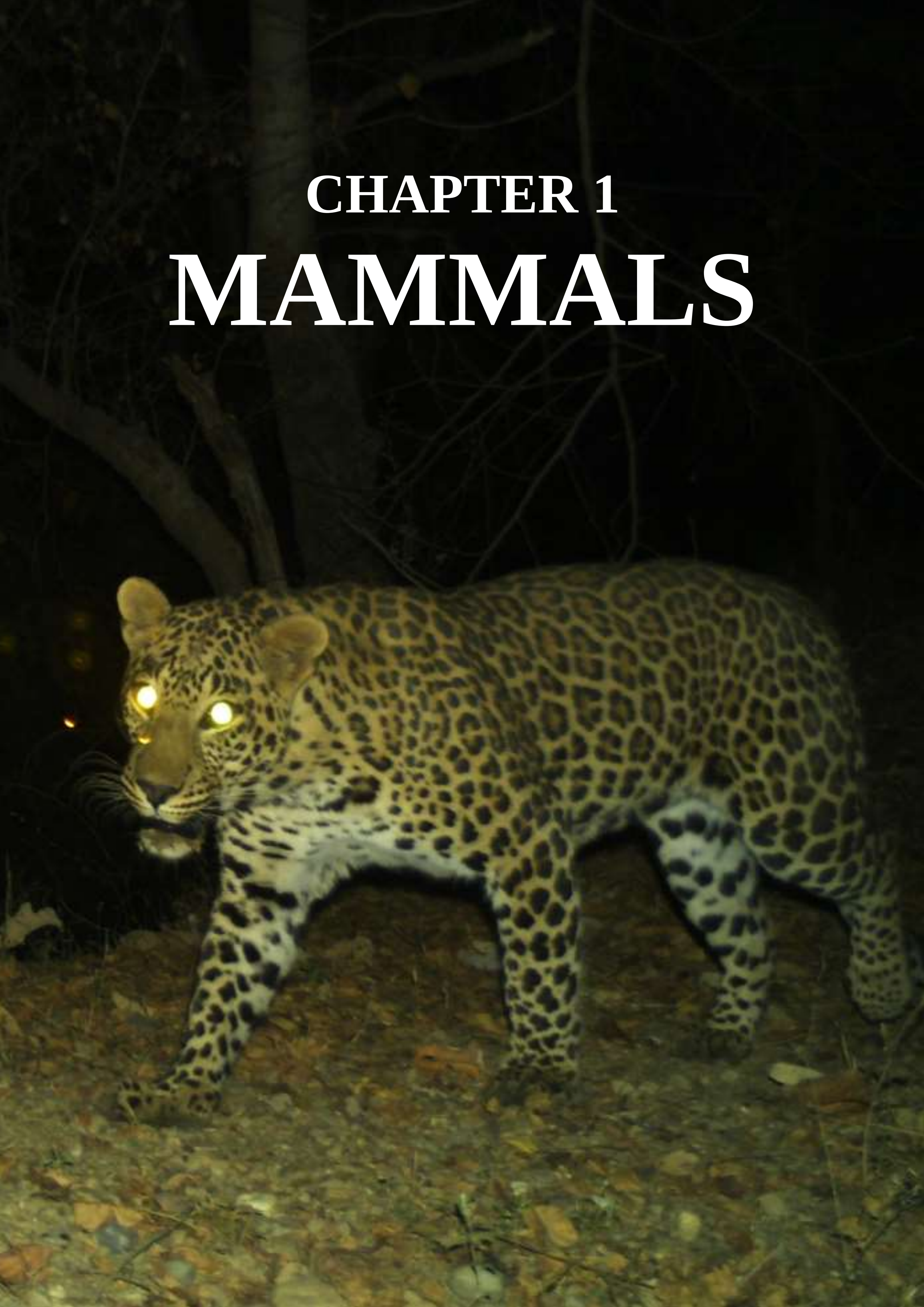
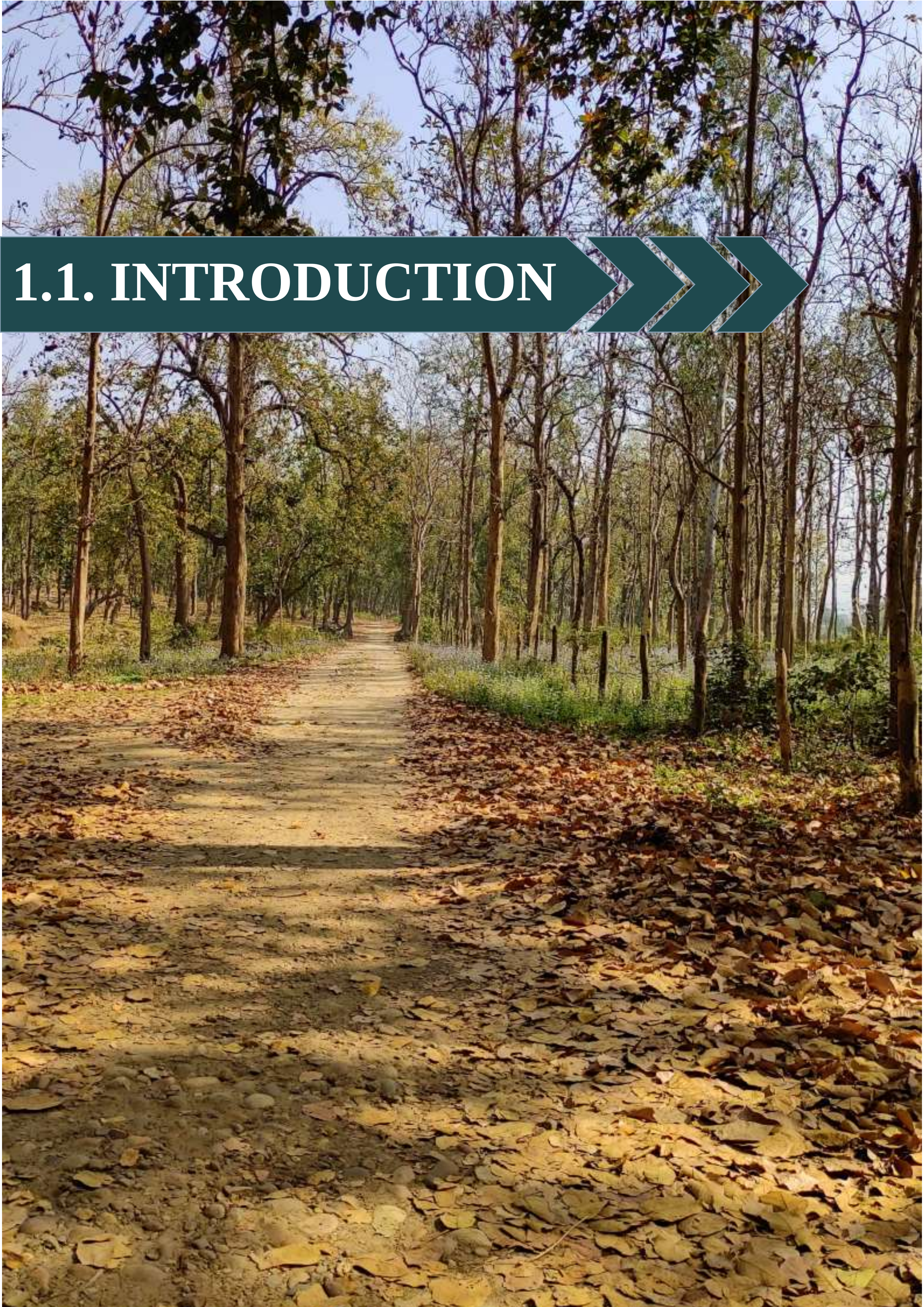
CHAPTER 1
MAMMALS



1.1. INTRODUCTION



INTRODUCTION

Mammals are incredibly adaptable in their behaviour, eco- morphology, life history, and physiology, and as a result are crucial to the optimal functioning of the environment. On a global level, research into the macro ecological mechanisms that underlie the biodiversity patterns of the past and present is still in its early stages. Yet, utilising this knowledge becomes essential in order to stop future biodiversity loss and, eventually, loss of ecosystem services. Unfortunately, efforts to understand the mammalian diversity more clearly are hampered by a lack of data. The fact that there are more known extinct species than there are living species is also crucial to understanding since it suggests an even more fascinating past of mammals. Geographical range sizes, ecological community makeup, species area interactions, and spatial and temporal fluctuations are all intricately intertwined. Fundamentally, the number of species in an area tends to rise with spatial dimensions of the region. The diverse characteristics of the landscape makes it home to a great variety of rare, threatened and endemic species of mammals.

Environmental conditions in the Himalayan valleys range from tropical in the foothills to frigid in the trans-Himalayan region, with vast vegetation cover, and these conditions are excellent for the colonisation of a variety of unique mammalian species in along with generalist ones. Himachal Pradesh is home to around 27% of all the mammalian species in India (Sharma and Saikia 2009), which constitutes a significant portion of the country's vertebrate diversity (Chakraborty et al. 2005, Saikia et al. 2004). Since the state of Himachal Pradesh includes two bio-geographic zones, namely zones 1 and 2, which are further divided into zones A and B (Roberts 1977), and that the mountainous areas provide a distinctive habitat for both herbivores and carnivores, state's mammalian fauna is an amalgamation of Palearctic and Oriental elements. However, the state has reached a critical stage due to its development plans, and the fast-expanding anthropogenic activities have overexploited and even ravaged natural ecosystems and there is a need for surveys and long-term monitoring of the wildlife. Additionally, the existence of some endemic and restricted-range taxa found in the area is threatened (Negi et al. 2015).

For the purpose of creating conservation and management strategies, research on the diversity and distribution of mammals is essential (Augugliaro et al. 2019). Camera trapping has recently emerged as one of the most popular survey techniques for studying the mammalian species in a landscape as it makes it possible to collect information on the majority of the medium- to large-sized mammals that exist there (Rowcliffe and Carbone 2008; Burton et al. 2015). The estimation of the population of animals using the capture-recapture model is both highly advantageous (Carbone et al. 2002) and accurate (Jennelle et al. 2002). However, because this technique of estimation relies on recognising specific types of difficult-to-distinguish animal species, it cannot be used (Liu et al. 2013). A novel approach for estimating the size of the wildlife population of unidentified individuals with photographic rates was proposed by Carbone et al. in 2001, and this approach was later found to be precise (Carbone et al. 2002).

In order to scan elusive and rare mammalian species for wildlife monitoring, camera traps have proven to be a revolutionary tool. They provide tremendous potential for advanced ecological understanding and better conservation of these species. The reliability of the interpretation one establishes from the camera trap, though, is crucial for any survey method. According to Sollmann (2018), it depends on the right study design, data collection, and analysis methods. According to Liu et al. (2013), long-term camera trapping could be used to examine the current state as well as any changes or alterations in animal species diversity, relative abundance, wildlife population estimates, and activity patterns.

This chapter covers an attempt to use camera trapping and line transect to assess the ecology of the mammalian species in Himachal Pradesh's Simbalbara National Park (SNP), Churdhar Wildlife Sanctuary (ChWLS), Pin Valley National Park, and Chandratal Wildlife Sanctuary (CWLS).

1.2. LITERATURE REVIEW

1.1. LITERATURE REVIEW

A significant portion of the rich and diverse range of biological diversity that inhabits the Himalayas is represented by the mammalian fauna, and according to Ghosh (1996), the Himalayas are home to around 65% of the 372 mammalian species present in India. Snow leopards (*Uncia uncia*) and Asiatic ibex (*Capra sibrica*) are among the animals that live in the cold, desert portions of the state. Musk deer (*Moschus* sp.), Himalayan tahrs (*Hemitragus jemlahicus*), and brown bears (*Ursus arctos*) are among the mammals that live in the more temperate regions of the state. Sambar (*Rusa unicolor*), barking deer (*Muntiacus muntjac*), wild pig (*Sus scrofa*), goral (*Naemorhedus goral*), and Leopard (*Panthera pardus*) are all abundant in the region's lower regions (Mahar et al. 2011).

In most biological groups, carnivores are at the top of the food chain, and they certainly play a crucial role in maintaining the vital equilibrium of different ecosystems (Terbourgh et al. 1999). Despite being a region of cliffs and ridges, the Himalayas of the state are home to a variety of mammalian carnivores, including charismatic species like the snow leopards, who are most frequently seen in the more arid, non-forested tracts between 3200 m and 5200 m. The species can be found as low as 2700 m, and according to recent studies, they may occasionally exploit the lower forest tracts (3200 m). Snow leopards mostly hunt Asiatic ibex (*Capra sibirica*) and bharal (*Pseudois nayaur*) (Lyngdoh et al. 2014; Schaller 1977). The Himalayan brown bear is biologically distinct from the forest-dwelling black bear because it is predominantly restricted to the rolling uplands and alpine meadows above timberline (Schaller 1977). It can be found in some watersheds outside of Himachal Pradesh's 13 PAs (Singh et al. 1990; Green 1993). It was referred to as "fairly common" by survey respondents in Great Himalayan NP, Kais WLS, Tundah WLS, and Kugti WLS. In PAs like Kanawar WLS, Sangla WLS, and Rupi Bhaba WLS, it is "fairly uncommon". The Malana Valley, Hamta Pass, Solang Valley, Bara Bangal, Parbati Valley, Ropa Valley, Kaksthal, Manali, Pooh and Lingti, and Ensa valleys (Lahul and Spiti) were among the respondents' reports of Himalayan brown bear sightings outside the PAs. However, it is "fairly common" in Bara Bangal, Ropa (Kinnaur District), and Ensa (Spiti District) (Sathyakumar, 2001). Asiatic black bears in Himachal Pradesh are present in and near 21 PAs (Singh et al. 1990, Gaston& Garson 1992, Green 1993). Outside of PAs, Asiatic black bears occur in the forested areas of Pangi (Chenab catchment) and Bharmaur valleys (Ravi catchment in Chamba District; Dhauladhar range (Beas catchment), Bara Bangal, Chota-Bangal, and Bir in Kangra District; Parbati Valley, Pandrabis, Bashleo Pass (Sutlej catchment), and Solang and Jagatsukh valleys in Kullu District; upper catchments of Bata and Giri in Solan and Shimla Districts; catchments of Sutlej and Yamuna, Pandrabis, Shimla Ridge, Karsog, Shali, Kandyali, Hatu, and Moral Kanda areas in Shimla District; and the Ropa valley, and Kalpa and Kaksthal areas in Kinnaur District) (Sathyakumar 2001).

The state's fauna is also composed largely of ungulates, which serve as the primary source of food for large carnivores. They have been known of modifying their behaviour in response to seasonal changes, habitat variances, and disturbance factors. According to Sathyakumar and Bashir (2010), their behaviour may be a sensitive indicator of the management, protection, and quality of the environment. The region is home to a total of 19 ungulate species from the four families Moschidae, Cervidae, Bovidae, and Equidae. (Schaller 1977; Bhatnagar 1993). In the Indian Himalaya and Trans Himalaya, cliff and pasture-dominated regions between 3200m and 5200m asl are thought to be the habitats of blue sheep and ibex (Ghoshal 2017). These two species are two of the snow leopard's main prey. Beyond a few pockets of relatively small areas (such as Hemis National Park in Ladakh, Spiti in Himachal Pradesh, and Prek Chu catchment in Kanchendzonga Biosphere Reserve, Sikkim), the distribution and conservation status of the snow leopard and its main prey (blue sheep and Asiatic ibex) remain poorly understood despite nearly three decades of ongoing research and conservation efforts. According to Bhatnagar et al. (2016), such places only make up around 4% of the possible habitat for snow leopards in India.

On the southern side of the Greater Himalayas, in India, the musk deer inhabits forested areas between 2500 m and the tree line. 3200m to 4300m asl in different Himalayan regions. The musk deer is well adapted to living in alpine, sub-alpine, and upper temperate habitats (>2500 m), unlike other ungulates of the Himalayas, which must migrate to lower elevations in the winter (Sathyakumar et al. 1992). According to Gaston et al. (1983), the species can be found in the state's western Himalayas. The diversity of mammalian species of Himachal Pradesh has mainly contributed by Hinton & Lindsay (1926), Pocock (1939, 1941), Ellerman& Morrison-Scott (1951), Singh et al. (1990), Julka et al. (1999), Chakraborty et al. (2005), Saikia et al. (2011), Saikia & Boro (2013) and Sharma & Sidhu 2016. Sharma et al. (2017) recorded common leopard, snow leopard, leopard cat, Eurasian lynx, masked palm civet, Indian grey mongoose, golden jackal, red fox, brown bear, Asiatic black bear, common otter, stone marten, yellow-throated marten, Siberian weasel, wild pig, Himalayan musk deer, Himalayan serow, Himalayan tahr, Himalayan goral, blue sheep, barking deer, rhesus macaque, Himalayan langur, red giant flying squirrel, Royle's mountain vole, Indian crested porcupine, Himalayan field mouse, common house rat, little Indian field mouse, house mouse, Rufous-tailed hare and

Indian Royle's pika in GHNP (Great Himalayan National Park).To our surprise, Snow leopard, Indian wolf, red fox, musk deer, Siberian ibex, Himalayan tahr, blue sheep, Nayan, yak, vole, and Himalayan marmot were recently discovered in Chandertal Wildlife Sanctuary in a study by Singh & Thakur (2019).

1.3. MATERIALS AND METHODS

1.2. MATERIALS AND METHODS

1.2.1. Before planning the survey

It was crucial to fully understand the approach we utilize during the survey period, which can only be done with an in-depth understanding of the elevation, habitats, species, and vegetation structure of the research area. Furthermore, it was also important that we know the distinction between surveys and censuses. In contrast to a census of species, which provides an absolute number of species, a survey of species abundance yields an estimate or an index of population size (Thompson et. al., 1998). Survey is defined to be the first descriptive step in the series of increasingly complicated study designs aimed at more advanced ecological questions, but are rarely designed to explain 'why' and 'how' the ecological processes occur. Two other important factors that follows are surveillance (repeatedly surveying to measure changes) and monitoring (entails setting targets) (Greenwood and Robinson, 2006).

Carnivores, sometimes have large home range sizes, which directly points out that we carry out research at larger area extent. Smaller the geographic area of the survey area, or the size of sampling units, more likely the model assumptions will be violated. So we carefully determined our final goals and specific objectives, the type of data that we need, and the survey methods (sampling) expected to provide reliable inferences most efficiently (MacKenzie and Royle, 2005). We also contemplated a proper combination of adequate sampling and efficient field methods to accommodate imperfect detections.

We divided the entire study according to few details, knowing that the objectives come first, which will further drive our survey design and fieldwork. Sampling details included a thorough understanding of study areas, our sampling units, characteristics of the habitats and selection criteria's. For survey protocols, we strictly focused on detection methods, sampling seasons and survey durations depending on the areas. Precision of the estimates was our prime focus considering statistics.

Establishing goals and objectives: Different objectives require different sampling designs, different types of data, and different resources because our ability to make inferences and how accurate and reliable the parameter estimates will be, solely depends on the behavior of target species, its density, distribution and the logistical constraints of the survey (MacDonald, 2004).

Survey Data: We targeted detection of individual animals (i.e. capture histories) and applied well known and operationally efficient models to infer demographic states. **Designs, methods and protocols:** Given the pertinent conditions and constraints (i.e. target population, study area, logistical constraints), we narrowed down to the most efficient combination of optimal sampling design and survey method, also understanding "where, how, how much, and how often to sample".

After delineating the boundaries of survey population and further deciding about how to divide the space into meaningful sampling units, we carefully developed the protocol, detailing which field techniques and under which conditions should they be employed to detect individuals in the sampling units. Answering the 'which' and 'how' questions (Yoccoz et al, 2001) requires critical, realistic, a priori assessment of available resources including time, trained personnel and standard equipment. Sampling methods, in particular were chosen to ensure reasonably high detection rates, which would further likely translate into detection probabilities and sample sizes adequate for analysis and modelling procedures required to produce results and finally, meet the objectives.

Statistically formalizing survey objectives: The conceptual framework of the survey design, sampling design and sampling methods were related explicitly to specific analytical methods, which required rendering in statistical terms of why, what and how questions (Royle, 2008). We formalized *a priori* this relationship (the dependency) between the sample data and the population state (e.g. the abundance, occurrence), so that the sampling methods produce data that meets the assumptions of the chosen statistical analysis. **Key issues:** Making clear definitions about our target population and each mammal species, spatial extent of the survey, strong attributes to measure, proper/ideal probabilistic sampling/cluster sampling and stratification, and tackling system variability were few key issues while this survey was designed.

1.2.2. Field Sampling Design

Camera traps were used to capture images of mammals in some of Himachal Pradesh's Protected Areas (PAs), including Simbalbara National Park (SNP), Churdhar Wildlife Sanctuary (ChWLS), Pin Valley National Park (PVNP), and Chandratal Wildlife Sanctuary (CWLS). Following Marinho et al. (2018), camera-trap locations were chosen without bait based on their accessibility, topographical characteristics, animal routes, and nallahs (seasonal drainages) with carnivore signs. A single Cuddeback X-ChangeTM colour model with motion sensors (Cuddeback, Green Bay, WI, USA) was placed at each location, and a 2 second time lag was set between animal detections. At 30-45 cm above the ground, cameras were mounted to trees. At least twice a month, camera traps were checked, including the replacement of memory cards and batteries. Following the completion of each camera-trapping session, images were checked for animal detections. Mammals were identified with the help of literature

(Jerdon 1874, Prater 1965, Jerdan 1984, Tritsch 2001, Menon 2014, Grewal & Chakravarty 2017). Prior to further analysis, all camera station data from each sampling period was combined. Each camera's required trapping effort (measured in camera-days) was computed from the time it was mounted until it was removed, if the camera still had images left, or until the time and date labelled on the last photographed. The sum of all cameras' camera days within a sampling period was used to determine the total amount of trapping effort.

1.2.3. Camera-trapping

A total of 31 camera traps were deployed in a grid-based approach (grid size: 1 km^2) during two sampling blocks: March 2021-April 2021 (n=17) and April 2021-May 2021 (n=14) (Figure 1.1).

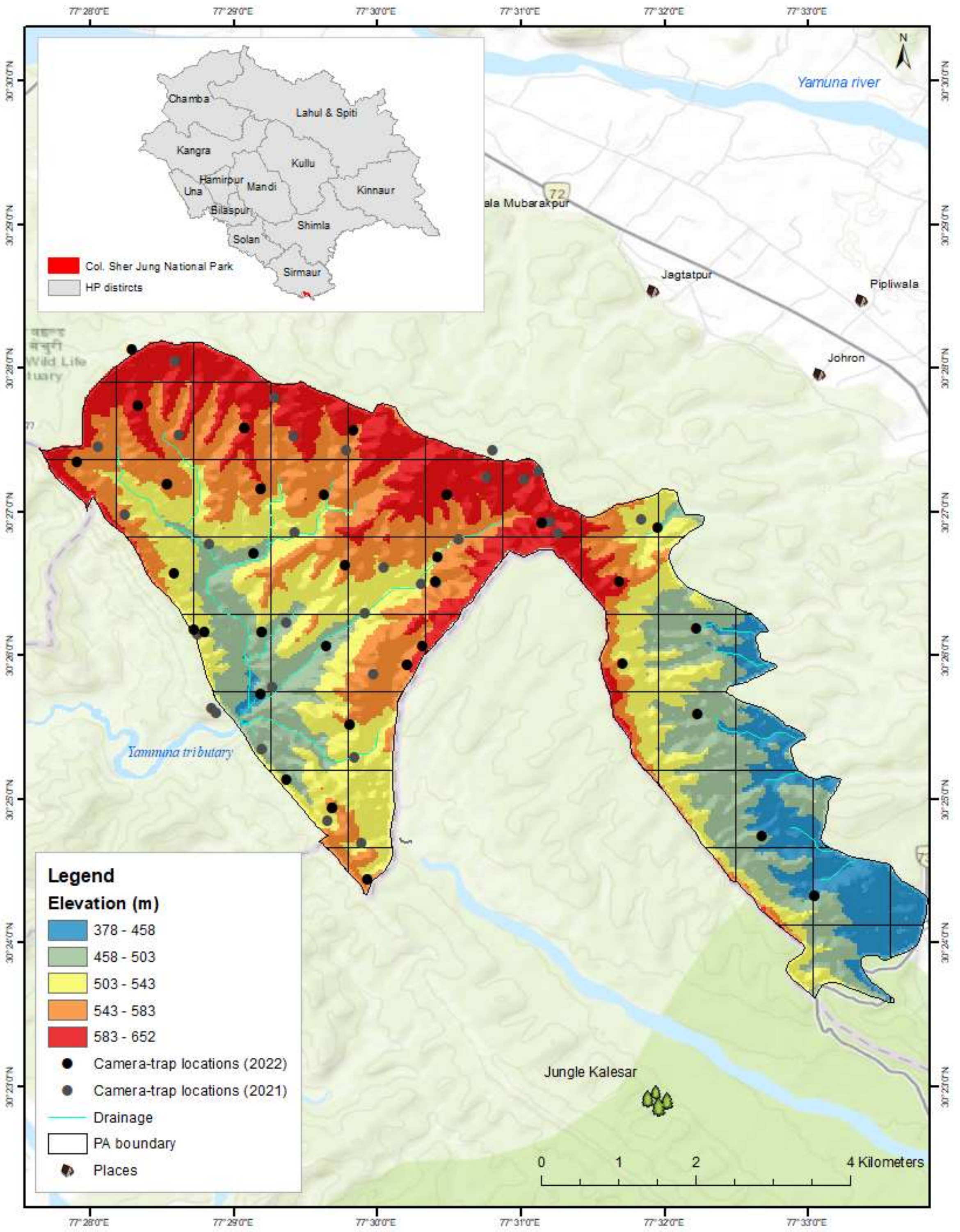


Figure 1.1: Map of Col. Sher Jung National Park showing camera trap locations during the year 2021 and 2022

Churdhar Wildlife Sanctuary (ChWLS): A total of 31 camera traps were deployed in a gridbased approach (grid size: 1 km^2) during October 2021-December 2021 and July-September, 2022 (Figure 1.2).

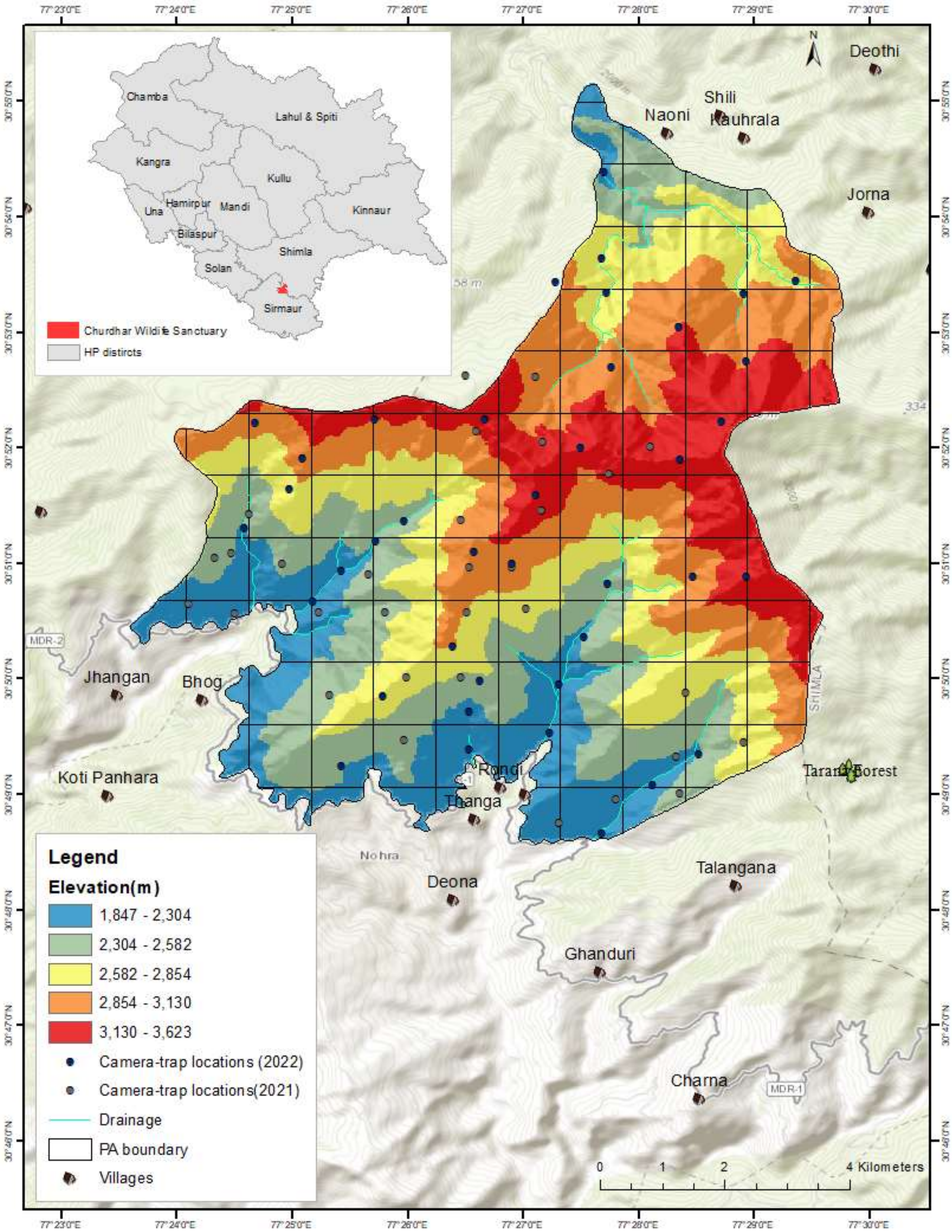


Figure 1.2: Map of Churdhar Wildlife Sanctuary showing camera trap locations during the year 2021 and 2022

Chandratal Wildlife Sanctuary (CWLS): A total of 20 camera traps were deployed in a grid-based approach (grid size: 1 km^2) during September 2021-October 2021 (Figure 1.3).

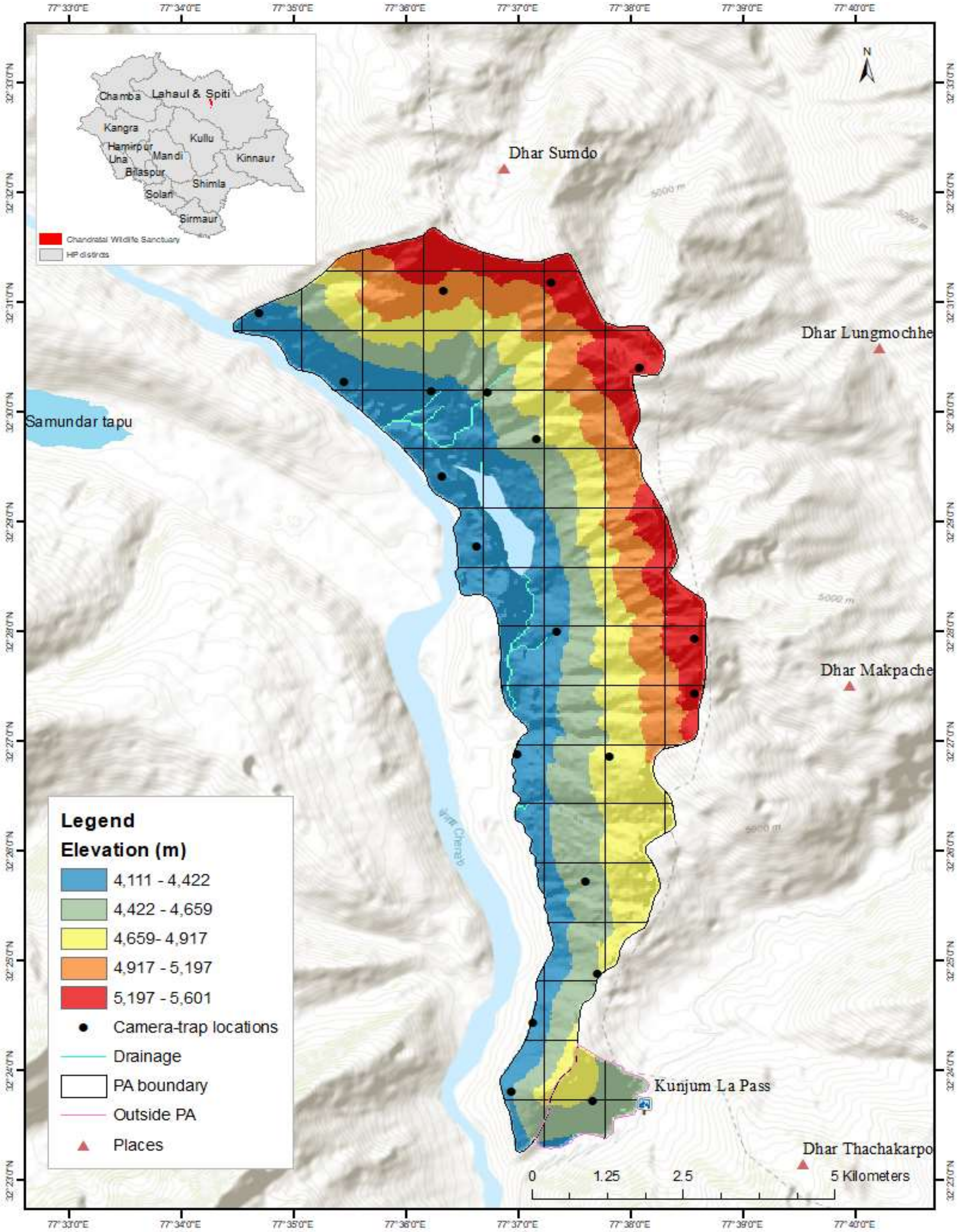


Figure 1.3: Map of Chandratal Wildlife Sanctuary showing camera trap locations during the year 2021 and 2022

Pin Valley National Park: A total of 75 camera traps were deployed in a grid- based approach (grid size: 1 km^2) during September 2021-October 2021 (Figure 1.4).

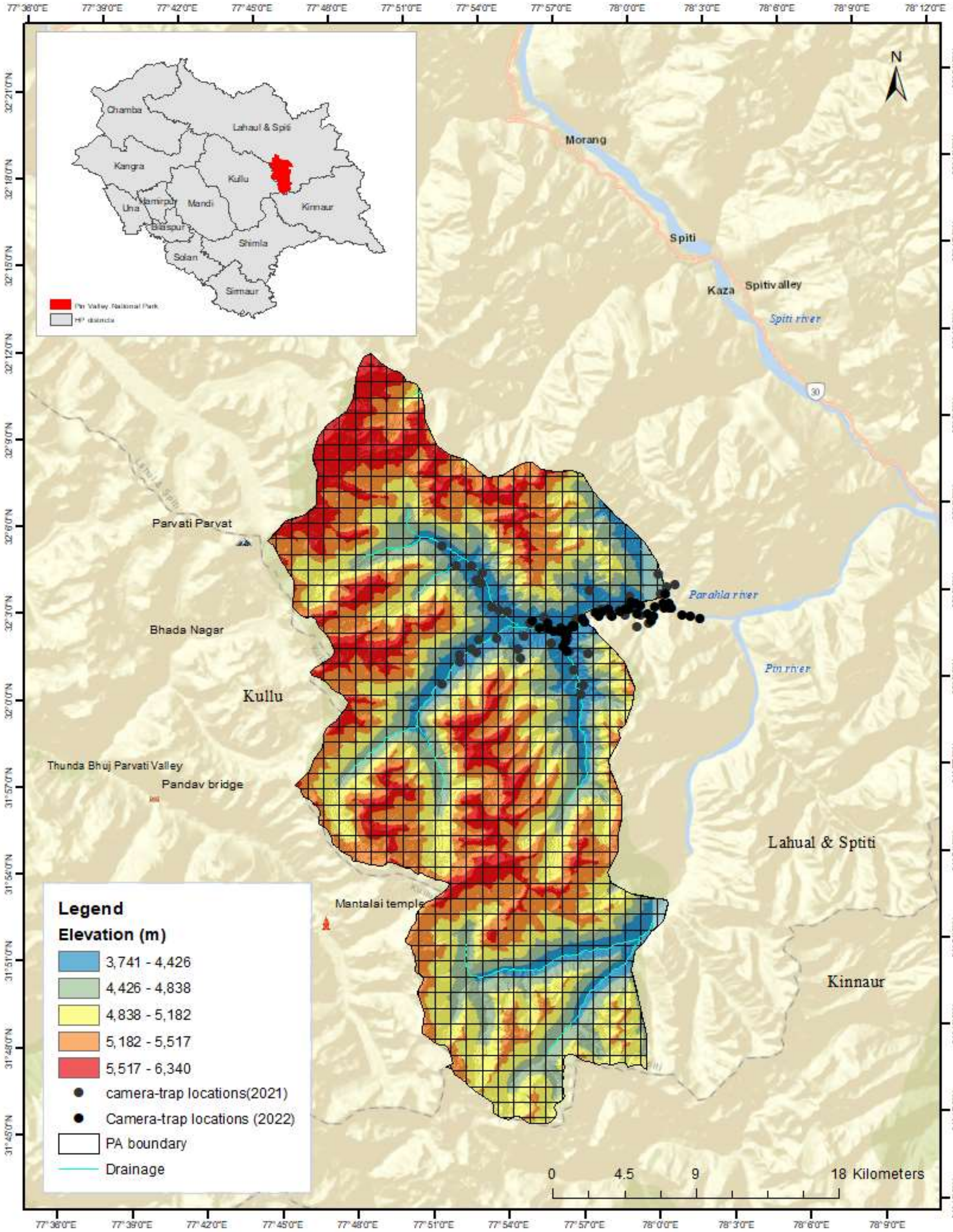


Figure 1.4: Map Pin Valley National Park showing camera trap locations during the year 2021 and 2022

1.2.4. Species richness and RAI_1 / ER / Photo capture rates

Species richness was estimated as the total number of species detected during the study period. RAI1 (Relative Abundance Index) was calculated as a total number of independent photographs for each species divided by total trap nights and multiplied by 100 (Carbone et al. 2001). The criteria to determine a photographic event (a species occurrence) were (1) consecutive photographs of the same species within 0.5 hours (30 minutes) were counted as one species occurrence, (2) the stamped time of the first photograph of these consecutive photographs was taken as the species-occurrence time. After 30 minutes, additional photos of the same species were considered another occurrence event, and (3) different identifiable individuals were treated as a separate occurrence even though they appeared in the same photograph, or the photographs were taken within 30 minutes (O'Brien et al. 2003). The analysis was carried out in a windows-based MS office excel worksheet using the data analysis tool.

$RAI_1 = (A/N) \times 100$ (O'Brien et al. 2003)

Where A is independent photo captures, and N is trap nights.

1.2.5. Trap Effort

To understand the time required to detect mammals if they are present at a sampling location, we calculated RAI_2 (the number of trap nights required to get a single photograph of the species) and RAI_3 (the number of trap nights required to get a first photograph of the species) (Jenks et al. 2011). RAI_2 was calculated by dividing total trap nights by the number of independent photos of each species. RAI_3 was calculated through frequency distribution of nights to the first detection of each photo-captured species. All analysis was carried out in a windows-based MS office excel worksheet using the data analysis tool.

$RAI_2 = (N/A)$ (Jenks et al. 2011)

Where A is independent photo captures, and N is trap nights.

Furthermore, to quantify the optimal number of camera stations and days (i.e., how many locations and days needed to be sampled to capture most of the mammalian species of SNP), we plotted mammal species detected against sample locations and days and fitted a hyperbola curve. We created this species accumulation curve (SAC) for all mammals pooled across camera stations and days to evaluate the sampling quality and survey effort needed for determining species richness. To eliminate the order in which data was recorded, we randomised the data 100 times using the vegan package (Oksanen et al. 2018) with R software v. 3.5.2 (R Core Team 2018).

1.2.6. Density estimation of identifiable individuals

Camera traps have been used to estimate tiger, leopard, and clouded leopard's densities in various landscapes (Borah et al. 2013, Singh & Macdonald 2017). In the study area, leopards and leopard cats were distinguished by their natural body and face markings with distinctive patterns, which enables the identification of individual animals. Since a single camera trap was deployed at each location, both flanks of all the captured individuals were not obtained. Therefore, only one flank was used with the maximum number of photographs. Individual detection histories were created using binary format (detection or non-detection of the individual), along with other trap-specific details such as spatial coordinates of the trap, time, and date. Camera stations were treated as "proximity detectors", allowing the animal to be detected at multiple traps on any given occasion. We used spatially explicit capture-recapture (SECR) methods to estimate density using a maximum-likelihood-based approach (Efford et al. 2009). These methods eliminate the subjectivity of calculating an effective trap area to estimate density (Borchers & Efford 2008, Royle & Young 2008). We defined the state space for each site by adding a 5 and 25 km buffer for leopard cat and leopard, respectively, to the outermost coordinates of the two trapping grids. (Mizutani et al. 1998, Chen et al. 2016).

1.2.7. Density estimation using camera-trap distance sampling

The distance between the animal and the camera at snapshot moments is calculated in distance sampling with camera traps to ensure that animal movement does not bias the distribution of detection distances (Howe et al. 2017). We thus defined a finite set of snapshot moments (2 seconds apart) within the sampling period (as suggested in Howe et al. 2017) for a total number of nine camera traps (n=9). The radial distance between each animal and the camera trap was estimated using a regression equation developed from the field calibration for each snapshot moment when the species was captured. This calibration was done for ten camera traps for distance sampling. In this equation, the dependent variable was the ratio of the actual height of an individual to its height in the photograph, and the explanatory variable was the distance at which the individual was photo captured. The information on actual heights for different species was obtained by comparing the camera-trap photos of the species with the calibration pole height. We received information on actual heights for different species by comparing the camera-trap photos of the species with the calibration pole height. For Chital Deer (*Axis axis)* and Sambar deer (*Rusa unicolor)*, nine, eight, six and five comparable photographs of adult males, adult females, sub-adults, and fawns, respectively, were identified from the camera trap data. Density was estimated following the equation for camera-trap point transects (Howe et al. 2017).

We estimate D as:

$$\hat{D} = \frac{\sum_{k=1}^{K} n_k}{\pi w^2 \sum_{k=1}^{K} e_k \hat{P}_k} \quad \text{(Howe et al. 2017)}$$

Where n_k is the number of observations of animals at a point $_k$ (camera-trap location), e_k is the temporal effort and P_k is the estimated probability of obtaining an image of an animal that is within θ degrees (angle covered by the camera's field of view), K is the total number of camera-trap locations and w (truncation distance) in front of the camera at a snapshot of the moment. The effort at a point k was measured as $e_k = \theta\ T_k/2\ \pi t$ where $\theta/2\pi$ describes the fraction of a circle covered by a camera, T_k is the period of camera deployment (in seconds), and t is the unit of time used to determine a finite set of snapshot moments within T_k (also in seconds). We defined the period of camera deployment as the time the target species was expected to be active during the sampling period. We use the distances r_i to model the detection function and estimate P_k.

Distance data were censored accordingly and modelled with two different setups, 'user-manual' and 'empirical'. For the 'user-manual' setup, θ was assumed to be 42° (0.733 radians). For the 'empirical' setup, θ was estimated empirically: θ was assessed by walking in front of the camera, perpendicularly to the midline of the field of view, and measuring the distance from the operator to the midline that triggered the sensor, using the camera in setup mode. This procedure was repeated 3-4 times (walking five times from the left and five times from the right); the angle of view was calculated using basic trigonometric formulas and was used as an estimate for realised θ. We used the point transect distance sampling method in Distance (Thomas et al. 2010) for all analyses, where $e_k = \theta\ T_k/2\ \pi t$ is used to calculate the survey effort. For the analysis in Distance, we modelled the detection by using the same functions as Howe et al. 2017: half normal with 0, 1 or 2 Hermite polynomial adjustment terms; hazard rate with 0, 1 or 2 cosine adjustments; uniform with 1 or 2 cosine adjustments. Adjustment terms were constrained, where necessary, to ensure the detection function was monotonically decreasing. We selected candidate models of the detection function by comparing AIC values, acknowledging the potential for overfitting because many observations were not independent.

1.2.8. Line transect sampling

Line transects were also used to determine the ungulate density (Karanth et al. 2004; Ramesh et al. 2009). The terrain of undulating and dry riverbeds and mixed and Sal-dominated forests were covered during the survey on foot, while every animal visually detected was recorded (Karanth et al. 2002). A total of eight (n=8) were covered in the landscape, and each transect was repeated six times resulting in a total effort of approximately 58 km of transects. The perpendicular distance (x) of an animal from the transect was then calculated using a range finder (Inesis, Telemeter, 900) and a compass to determine the sighting angle (θ); and the radial distance was then calculated via the equation $x = r \sin \theta$ (Thomas et al. 2002). The method assumes that every animal on the transect path will be detected; thus, the animal detection probability is a declining function of perpendicular distance from the transect (Thomas et al.2002).

The detection metric is then fitted to the data to estimate the proportion of the population detected, which can then be used to estimate species population abundance with the standard estimator of the form:

$$N = \frac{nA}{2wLPa} \text{ (Thomas et al. 2002)}$$

where N is abundance, A is the total survey area, n is the number of animals counted, w is the approximate distance view on each side of the transect, L is the length of the transect, and P_a is the detection probability of each animal. We used the statistical software package DISTANCE (Thomas et al. 2001) to fit the models and estimate species abundance. It employs the models described here and considers size bias associated with the increased probability of detecting larger animal groups.

1.2.9. Species Distribution Models

We initially considered a total of 48 variables representing the main factors that are considered important range determinants for mammalian species which were encountered from our camera trapping sessions: topography, climate and human impact (unique combinations after variable correlations separately for each species. The topographic and climatic variables were specifically selected because the occurrence of mammalian species has been reported to be associated with mountainous areas, cold low variability in annual water discharge rate and high precipitation. The climate and topography variables were extracted from the WorldClim data base at 30″ (~1-km) resolution according to the duration of the study period (http://www.worldclim.org). Human impact was represented by the human footprint, an estimate of human influence based on population density, land transformation, accessibility and infrastructure data. We converted all predictor variables to their means (except for altitude, which was converted to its standard deviation and range) for each 1 km×1 km grid cell.

The main modelling method used was MAXENT, a machine-learning method that estimates a species' distribution across a study area by calculating the probability distribution of maximum entropy subject to the constraint that the expected value of each feature under this estimated distribution should match its empirical average. The MAXENT method is among the best-performing modelling approaches for presence-only occurrence data. We implemented MAXENT using version 3.2.1 (http://www.cs.princeton.edu/~schapire/maxent/). We used default values for the convergence threshold (10^{-5}), maximum number of iterations (500) and the newly introduced logistic output format. The logistic output can be interpreted as an estimate of the probability of presence (ranging from 0–1), conditioned on the environmental variables in each grid cell.

1.2.10. Conservation Status

We identified the conservation status of recorded mammals based on the IUCN (International Union for the Conservation of Nature) Red List criteria, viz. Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT) and Least Concern (LC) (IUCN 2020) and the Indian Wildlife Protection Act (WPA), 1972 schedules viz I, II, III and IV (Anonymous 2006).

1.4. RESULTS

1.5. COL. SHER JUNG NATIONAL PARK

1.5. Simbalbara National Park (SNP)

1.5.1. Species richness and RAI_1 / ER / Photo capture rates

We recorded 17 mammals (6 carnivores and 11 non-carnivores or herbivores) with 3529 independent records over the whole sampling period of 1912 trap nights (Table 1.1). The independent records (n) and relative abundance index (RAI1) for the photo-captured species ranging from Golden Jackal (n=1, RAI1=0.06) to Common Leopard (n=69, RAI1=3.23) for carnivores, and from Nilgai (n=17 RAI1=0.82) to Sambar (n=1078, RAI1=53.19) for herbivores (Figure 1.5). Using the Encounter Rate (ER) of all the identified species in the landscape, the species occurrence maps have been digitised in the GIS environment (Appendix II). A total of 20 mammalian species (Large, medium, and small-sized) were recorded in the SNP, out of which 15 were photo-captured in the camera traps, and five were observed via direct sighting during the field survey (Table 1.2).

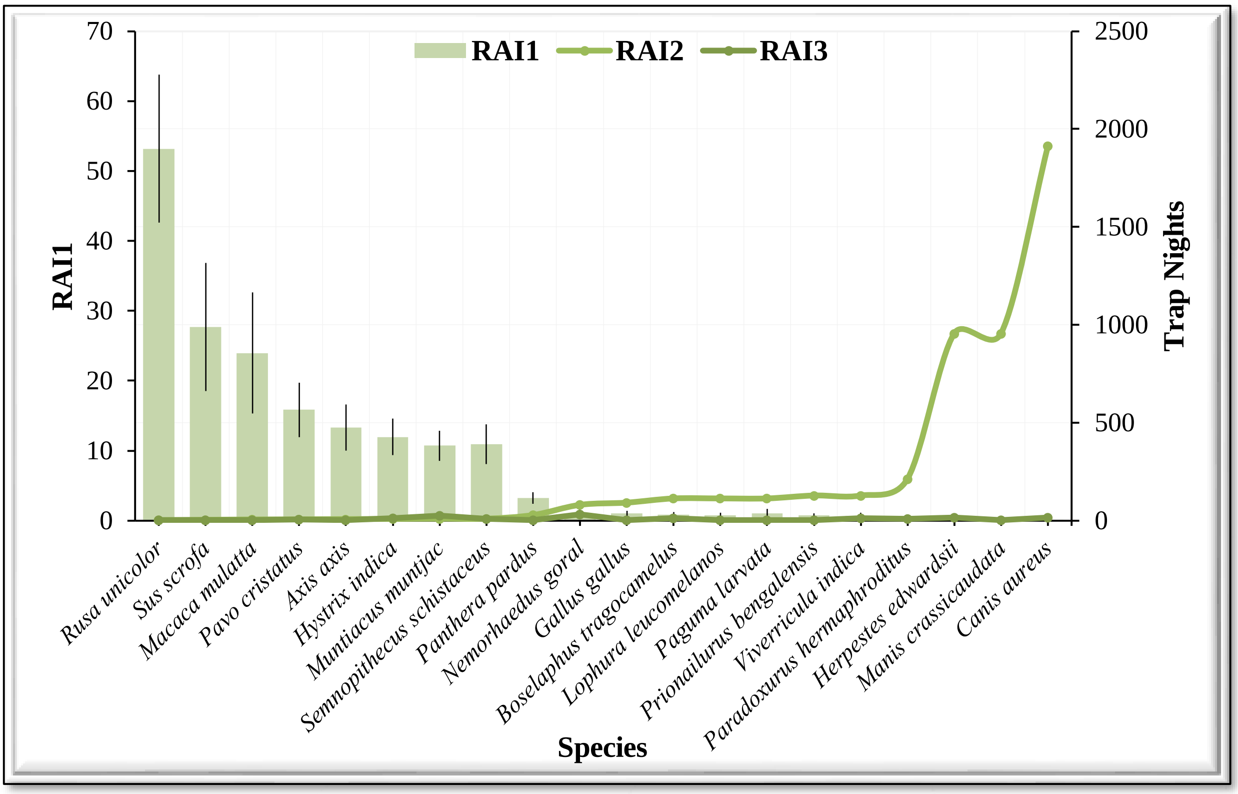


Figure 1.5: RAI1 (Relative Abundance Index), RAI2 (minimum time, i.e., trap nights required to detect single photograph), and RAI3 (Average day to first photographic detection) of photo-captured mammals in SNP. RAI1 = (Independent photographs / trap nights) × 100. RAI2 = Trap nights / independent photographs. RAI3 was calculated through frequency distribution of nights to the first detection of photo-captured species**.**

Table 1.1: A checklist of mammals of SNP, showing independent records (n), RAI1 (Relative Abundance Index), RAI2 (trap nights required to detect single photograph), RAI3 (average day to first photographic detection), and conservation status. RAI1 = (Independent photographs / trap nights) × 100. RAI2 = Trap nights / independent photographs. RAI3 was calculated through frequency distribution of nights to the first detection of photo-captured species. Abbreviations used are n = Independent Captures, IUCN = International Union for Conservation of Nature, LC = Least Concern, VU = Vulnerable, NT = Near Threatened, WPA = Wildlife Protection Act, 1972.

Species	n	RAI1	RAI2	RAI3	IUCN	WPA, 1972
Carnivores						
Masked or Himalayan Palm Civet *Paguma larvata*	17	1.07	112.47	3	LC	Sch II
Small Indian Civet *Viverricula indica*	15	0.69	127.47	11	LC	Sch II
Common Palm Civet *Paradoxurus hemaphroditus*	9	0.43	212.44	9	LC	Sch II
Golden Jackal *Canis aureus*	1	0.06	1912.00	14	LC	Sch II
Leopard Cat *Prionailurus bengalensis*	15	0.77	127.47	3	LC	Sch I
Common Leopard *Panthera pardus*	69	3.23	27.71	4	VU	Sch I
Grey Mongoose *Herpestes edwardsii*	2	0.08	956.00	14	LC	Sch II
Herbivore						
Blue Bull or Nilgai *Boselaphus tragocamelus*	17	0.83	112.47	13	LC	Sch III
Sambar *Rusa unicolor*	1078	53.19	1.77	2	VU	Sch III
Himalayan Brown Goral *Nemorhaedus goral*	24	1.07	79.67	31	NT	Sch III
Indian or Red Muntjac *Muntiacus muntjak*	215	10.70	8.89	24	LC	Sch III
Spotted Deer *Axis axis*	279	13.29	6.85	2	LC	Sch III
Indian Crested Porcupine *Hystrix indica*	246	11.95	7.77	13	LC	Sch IV
Omnivore						
Himalayan Langur *Semnopithecus schistaceus*	213	10.96	8.98	8	LC	Sch II
Rhesus Macaque *Macaca mulatta*	391	23.97	4.89	2	LC	Sch II

Indian Wild Pig *Sus scrofa*	565	27.66	3.38	1	LC	Sch II
Insectivore						
Indian Pangolin *Manis crassicaudata*	2	0.08	956.00	2	EN	Sch I

Table 1.2: A checklist of mammals identified through direct and indirect methods in SNP.

S. R. No.	Species	Direct Sighting	Camera-trap Image	Scat / Pellets / Dung	Pugmark / Hoof marks	Scrape marks	Call	Remarks
1	Leopard		✔	✔	✔	✔		
2	Sambar	✔	✔	✔	✔	✔	✔	
3	Chital	✔	✔	✔	✔	✔	✔	
4	Barking Deer	✔	✔	✔	✔	✔	✔	
5	Wild Pig	✔	✔	✔	✔	✔		
6	Himalayan Goral	✔	✔	✔				
7	Indian Crested Porcupine	✔	✔			✔		Porcupine quill was observed.
8	Masked Palm civet		✔					
9	Small Indian Civet		✔					
10	Asian Palm Civet		✔	✔				
11	Leopard Cat		✔					
12	Golden Jackal		✔					
13	Himalayan Langur	✔	✔	✔	✔		✔	
14	Rhesus Macaque	✔	✔	✔	✔		✔	
15	Yellow-throated Marten	✔						
16	Asiatic Elephant	✔		✔	✔		✔	
17	Nilgai		✔					
18	House shrew	✔			✔			
19	House mouse	✔						
20	Common Indian Field mouse	✔						

1.5.2. Trap effort

Two carnivore species, i.e., Golden Jackal (RAI2=1912) and Grey mongoose (RAI3=956), and one Insectivore, i.e., Indian Pangolin (RAI2=956), took the highest number of trap nights for a single detection. Rhesus Macaque (RAI3=1), Indian Crested Porcupine (RAI3=1), and Barking Deer (RAI3=1) took only one trap night to detect for the first time, whereas 25 trap nights were required for the first detection of Himalayan Goral (RAI3=31). In herbivore species, Sambar (*Rusa unicolor*), took the least number of trap nights for a single detection. Thus the relative abundance for the species was observed to be the highest, followed by rhesus macaque (*Macaca mulatta*) and wild Pig (*Sus scrofa*). The relative abundance of major carnivore species, i.e., leopard (*Panthera pardus*) and jackal (*Canis aureus*), has been low. Among the carnivore species, i.e., Golden Jackal took the highest number of trap nights for a single detection, and no sighting or direct/indirect signs of the species were observed in the field during the survey. The species accumulation curve (SAC) indicated that the mammal community was adequately sampled after the deployment of approximately 19 camera stations and 45 days (Figure 1.6).

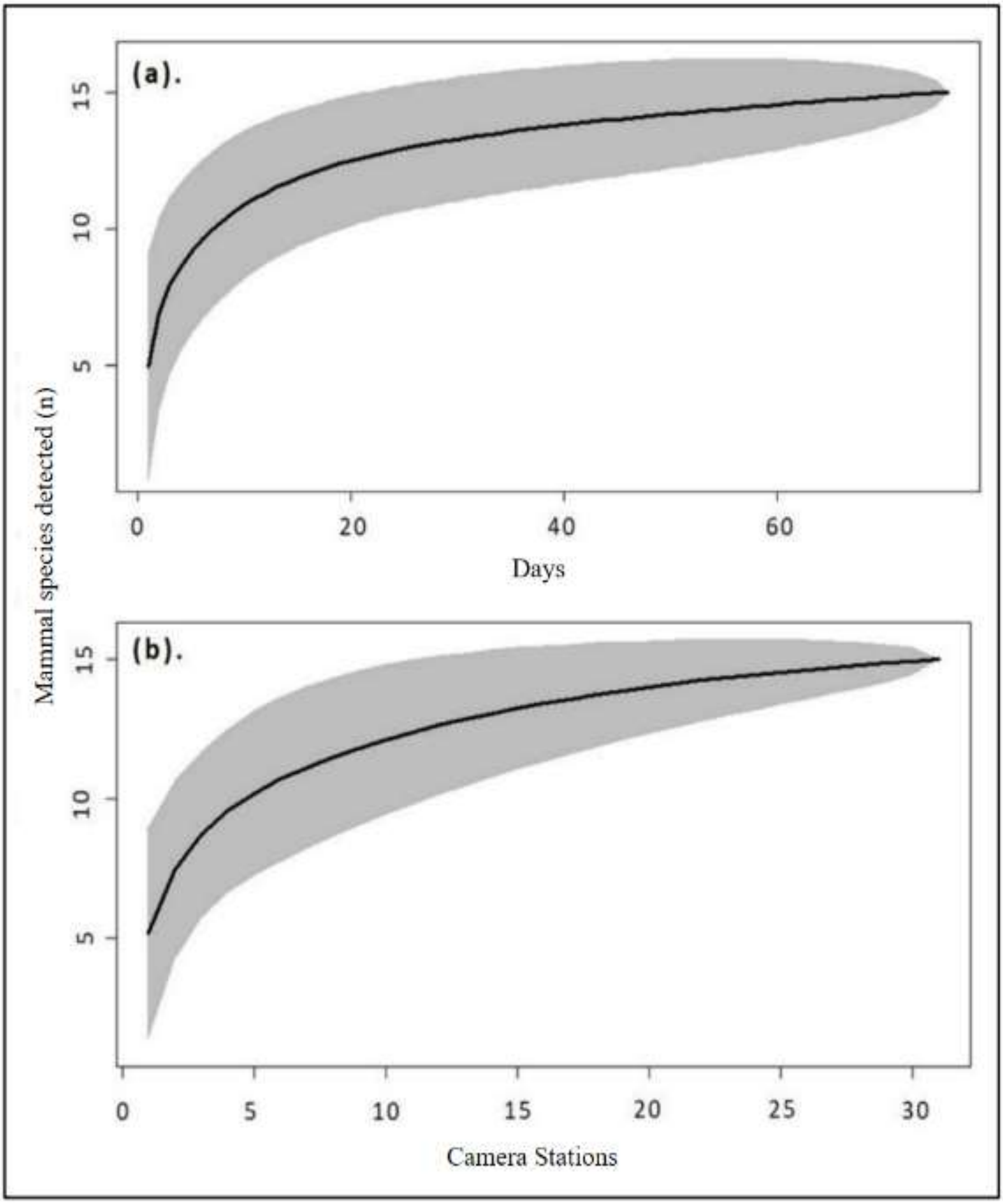


Figure 1.6: Species accumulation curve for mammals estimated using the R package vegan (Oksanen et al. 2018), depicting the relationship to the number of mammal species (n=17) detected over (a) 76 days, and (b) 31 camera stations in SNP. The black line indicates the modelled species accumulation curve, and the shaded area indicates 95 % confidence interval

1.5.3. Density estimation of identifiable individuals

In SNP, two species of identifiable mammals were recorded: leopard *Panthera pardus* and leopard cat *Prionailurus bengalensis*. The rosette markings on the species were used to identify different individuals (Harihar et al. 2009, Selvan et al. 2014). However, due to the meagre capture-recapture rate, the density could not be estimated using the spatially explicit capture-recapture (SECR) method. For leopards, eight and six images of right and left flanks, respectively, and for leopard cats, five and three images of right and left flanks, respectively, were obtained through camera trapping. As only a single camera trap was deployed at each location, both flanks of all the captured individuals were not obtained. Therefore, we utilised the photographs of the highest number of flanks for the species and identified seven individuals of leopard and four individuals of leopard cats in the landscape.

1.5.4. Density estimation of unidentifiable individuals

28 camera traps (CTs) took 620 snapshots of sambar. Similarly, 14 CTs took 217 photographs of spotted deer, 21 CTs captured 125 pictures of barking deer, 21 CTs captured 289 photos of wild boar, 19 CTs captured 45 snapshots of rhesus macaque, and 11 CTs captured 57 images of Himalayan langur. Half normal model with Hermite polynomial adjustments fit the best for all the species except for sambar and rhesus macaque, for which uniform cosine adjustments were used. We found the highest ungulate density for sambar (5.3 ± SE 1.0 individuals/km^2) and the lowest for wild boar (2.1 ± SE 0.7 individuals/km^2) (Table 1.3; Figs 1.7, 1.8).

Table 1.3: The table shows models and functions for calibrating density by camera trap distance sampling (CTDS) method for SNP.

Species	CV	95% CI	Function
Spotted Deer *Axis axis*	0.34	2.35-9.42	Half-normal / Hermite
Sambar *Rusa unicolor*	0.18	3.65-7.96	Uniform / Cosine
Barking Deer *Muntiacus muntjac*	0.29	1.97-6.32	Half-normal / Hermite
Wild Pig *Sus scrofa*	0.36	0.96-4.77	Half-normal / Hermite
Rhesus Macaque *Macaca mulatta*	0.47	0.48-3.51	Uniform / Cosine
Himalayan Langur *Semnopithecus schistaceus*	0.48	0.47-3.12	Half-normal / Hermite

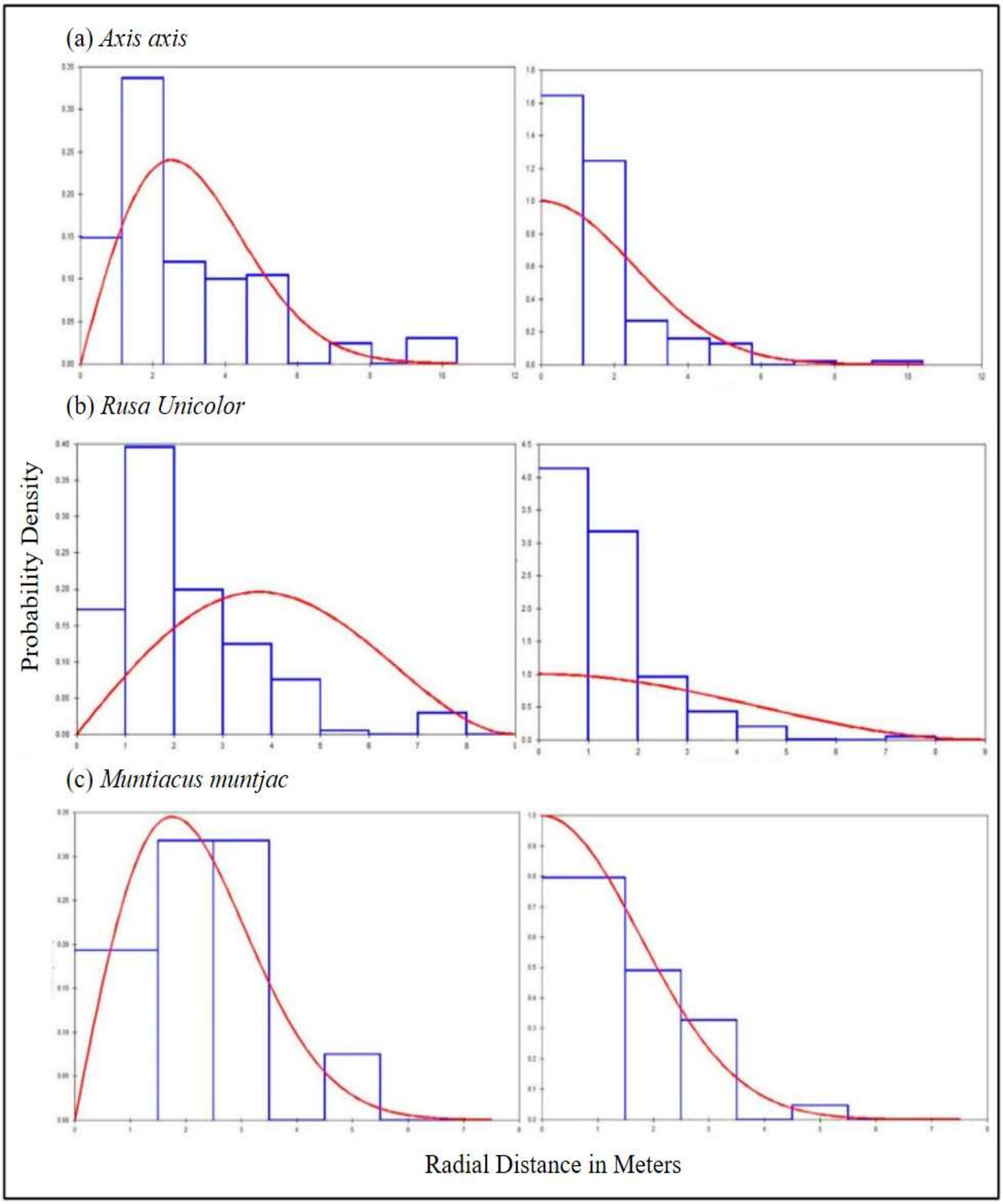


Figure 1.7: The detection probability and probability density for the models selected for estimating density by the CTDS method for SNP. The bars show the data distribution, and the line represents the model fit. The bars' heights are scaled to cover the same total area as the area under the line to show how well the detection function fits the data.

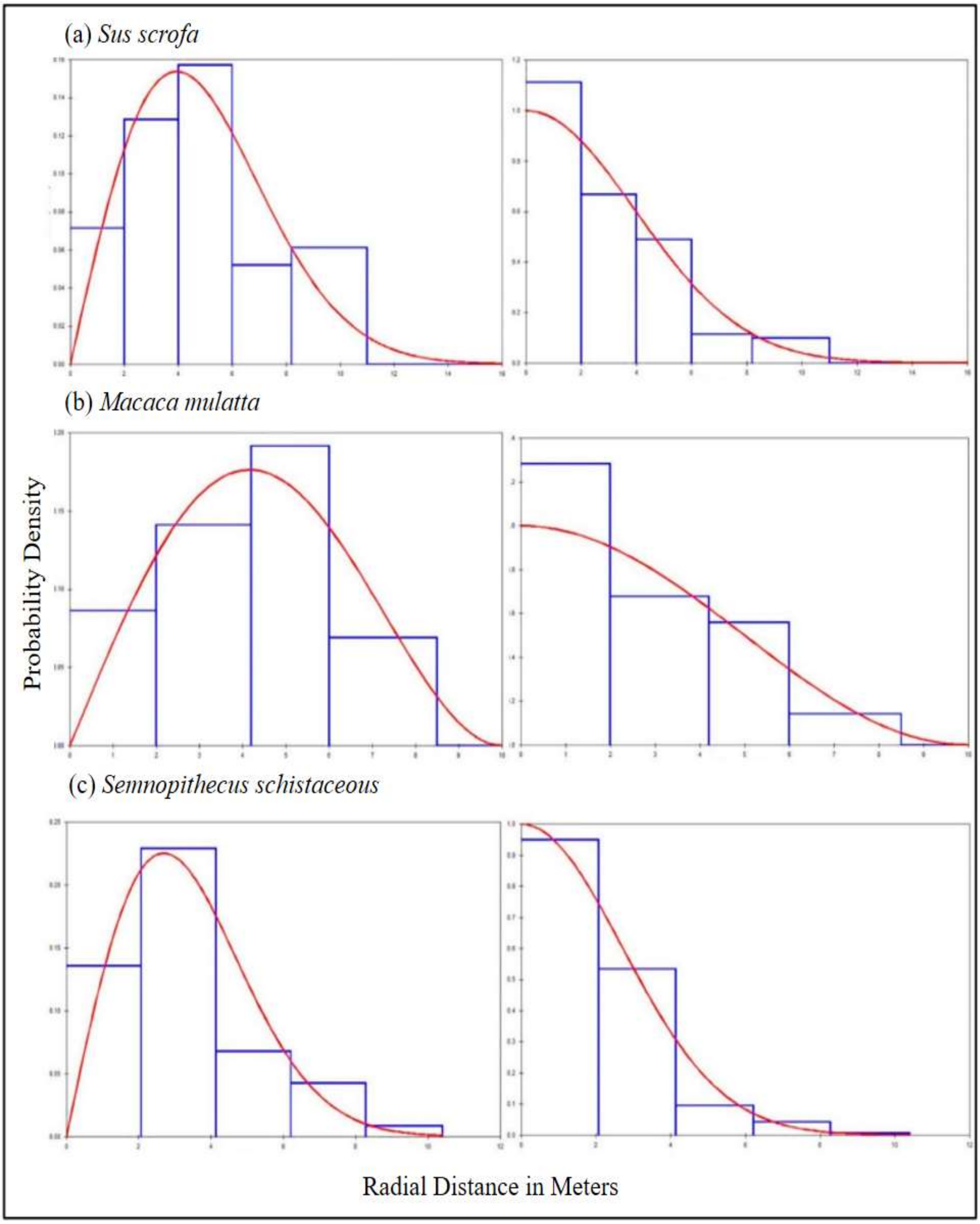


Figure 1.8: The detection probability and probability density for the models selected for estimating density by the CTDS method for SNP. The bars show the data distribution, and the line represents the model fit. The bars' heights are scaled to cover the same total area as the area under the line to show how well the detection function fits the data.

1.5.5. Line Transect Sampling

During the line transect survey, ungulates, primates and Galliformes were encountered, and analysis was carried out for each species. Ungulate density in the landscape was highest for *Rusa unicolor* (5.6 ± SE 2.1 individuals/km^2) and lowest for *Muntiacus muntjac* (3.2 ± SE 1.5 individuals/km^2). Among primates and Galliformes, the highest density was recorded for *Macaca mulatta* (17.1 ± SE 6.9 individuals/km^2) and *Gallus gallus* (16.4 ± SE 6.9 individuals/km^2) (Table 1.4; Figures 1.9, 1.10). Also the diel activity overlap was calculated for leopard and other species (Figure 1.11). The occurrence hotspots were also plotted for all species (Figure 1.12).

Table 1.4: Densities of various species in SNP, estimated via field survey using line-transect distance sampling (LTDS) method followed by analysis in DISTANCE software**.**

Species	Density (individual/km^2)	CV	95% CI	AIC Value	p-value	Model
Chital deer *Axis axis*	4.1 (±2.3)	0.56	1.43-11.64	36.9	0.87	Half-normal / Simple polynomial
Sambar deer *Rusa unicolor*	5.6 (±2.1)	0.34	3.21-12.79	27.88	0.91	Half-normal / Cosine
Barking Deer *Muntiacus muntjac*	3.2 (±1.5)	0.48	1.29-8.18	24.54	0.94	Half-normal / Cosine
Wild Pig *Sus scrofa*	4.7 (±2.4)	0.51	1.8-12.54	20.31	0.84	Negative exponential / Simple polynomial
Ungulates	17.0 (±4.9)	0.28	9.72-29.92	111.31	0.97	Negative exponential / Simple polynomial
Rhesus macaque *Macaca mulatta*	17.1 (±6.9)	0.40	7.85-37.36	153.44	0.85	Uniform / Cosine
Himalayan langur *Semnopithecus schistaceus*	10.7 (±5.1)	0.41	4.29-26.64	56.65	0.78	Half-normal / Simple polynomial
Primates	23.0 (±7.6)	0.33	12.15-43.77	324.90	0.96	Negative exponential / Cosine
Indian Peafowl *Pavo cristatus*	13.2 (±5.9)	0.44	5.66-31.11	87.03	0.86	Uniform / Simple polynomial
Red jungle fowl *Gallus gallus*	16.4 (±6.9)	0.42	7.35-37.00	114.02	0.93	Uniform / Simple polynomial
Galliformes	27.47 (±9.3)	0.34	14.25-52.96	138.7	0.81	Negative exponential / Simple polynomial

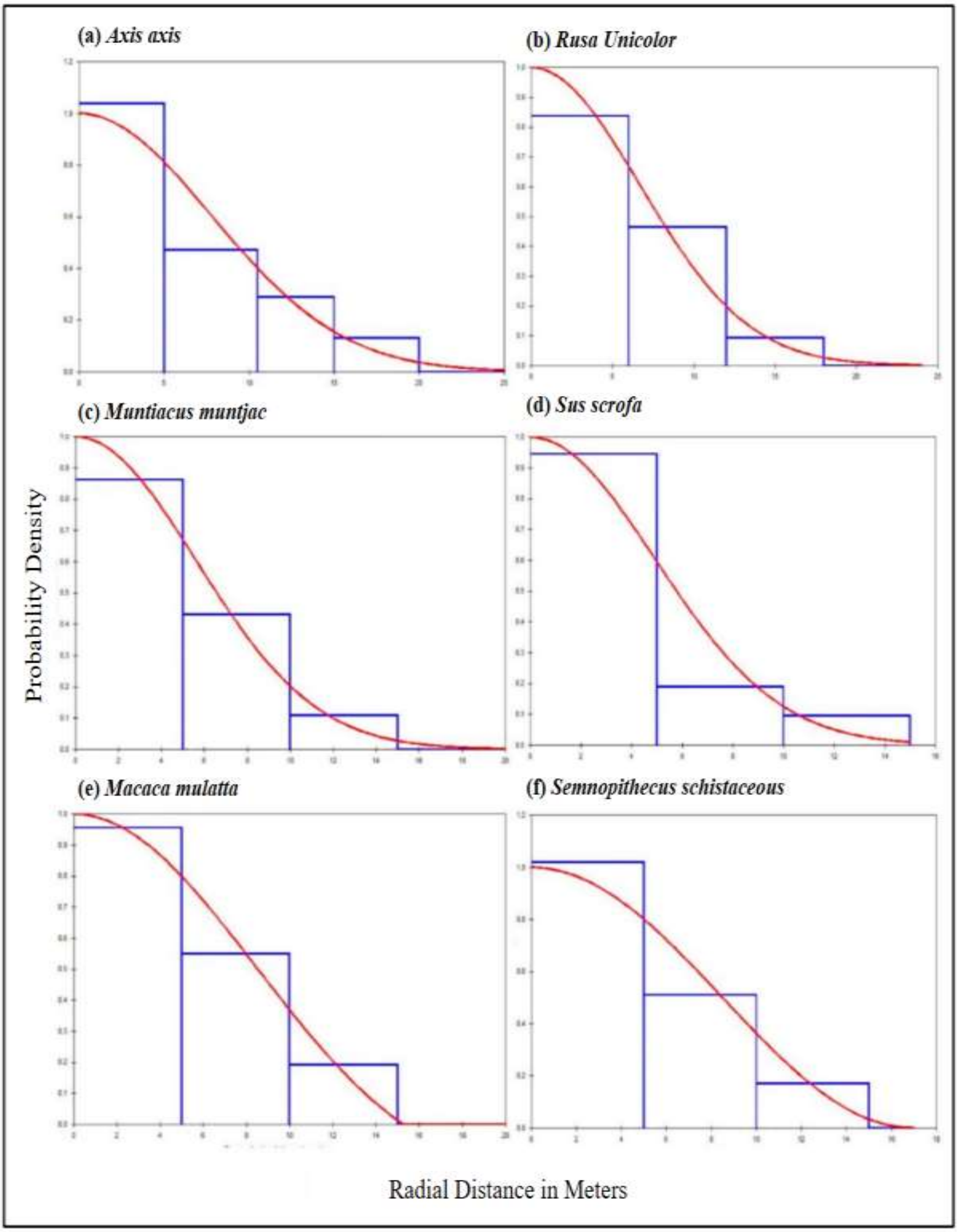


Figure 1.9: The detection probability for the models selected for estimating density by the LTDS method for SNP. The bars show the data distribution, and the line represents the model fit. The bars' heights are scaled to cover the same total area as the area under the line to show how well the detection function fits the data

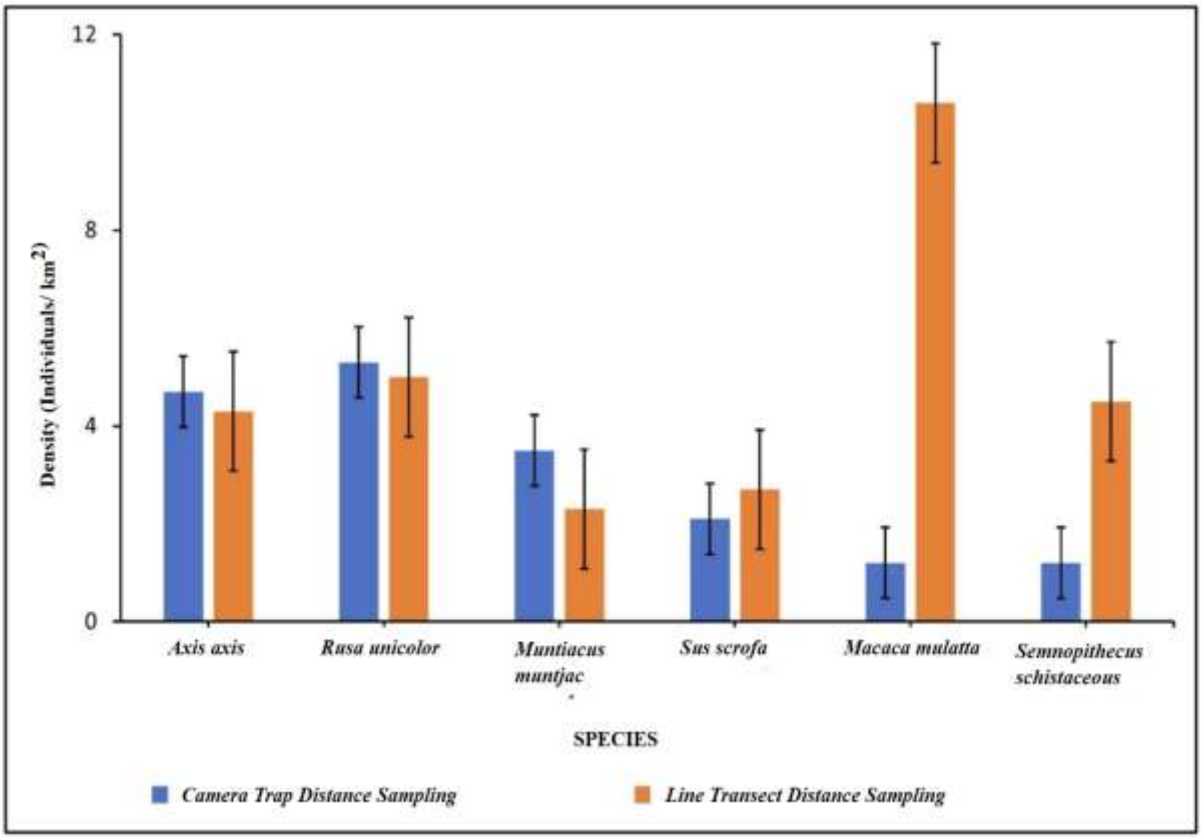


Figure 1.10: The bar graph compares densities estimated for ungulates and primates using two methods, i.e., camera-trap distance sampling and line transect distance sampling, in SNP.

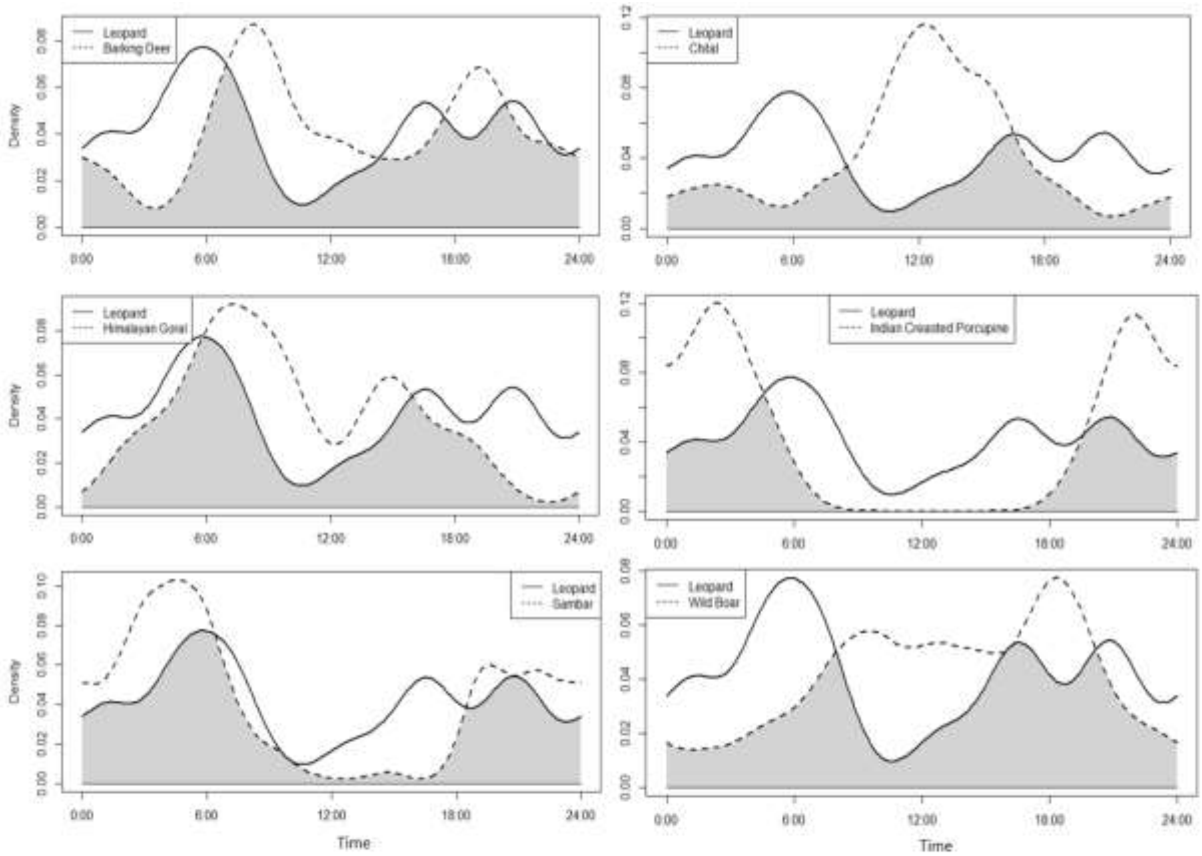


Figure 1.11: Temporal Patterns of Common Leopard with small and large prey species in SNP.

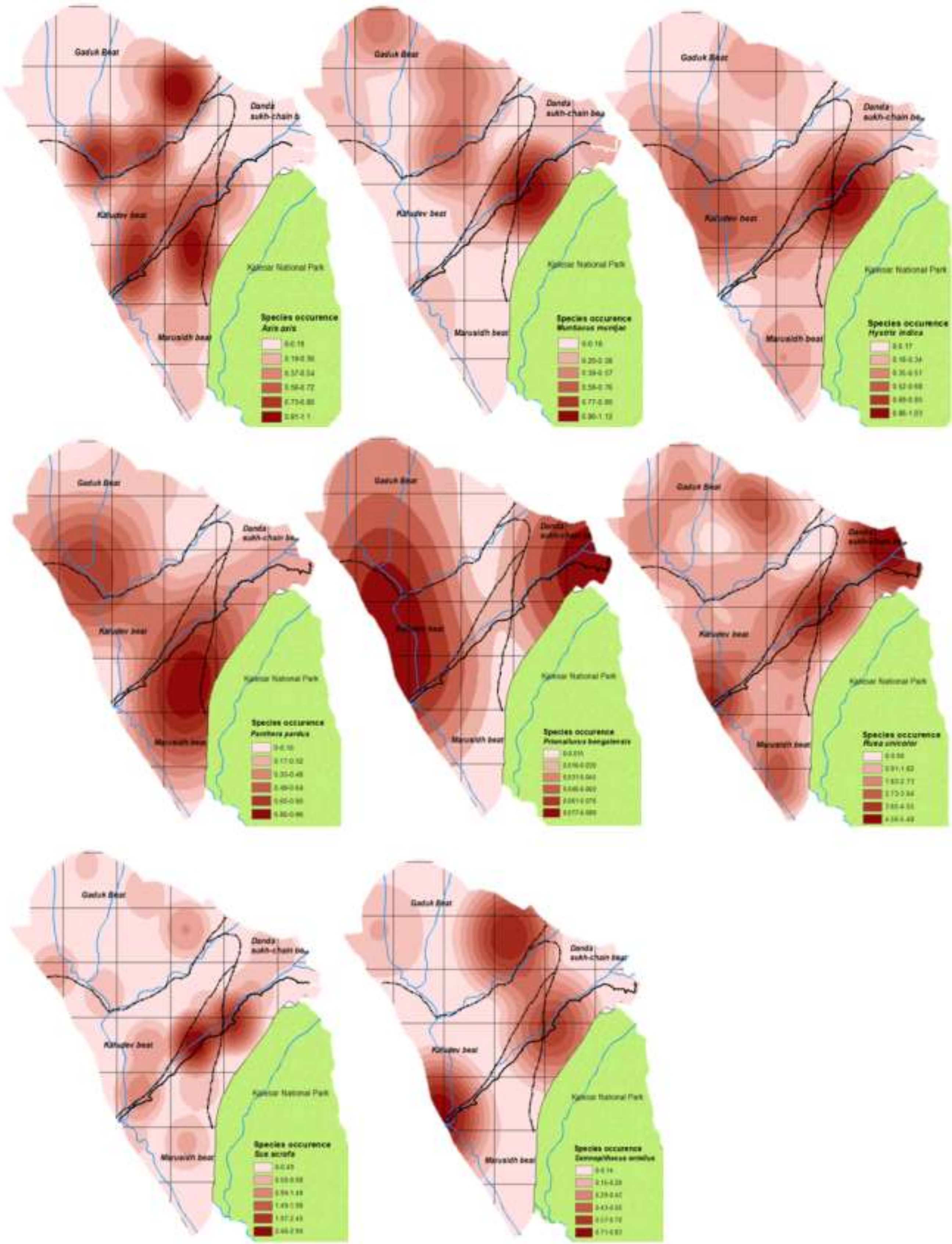
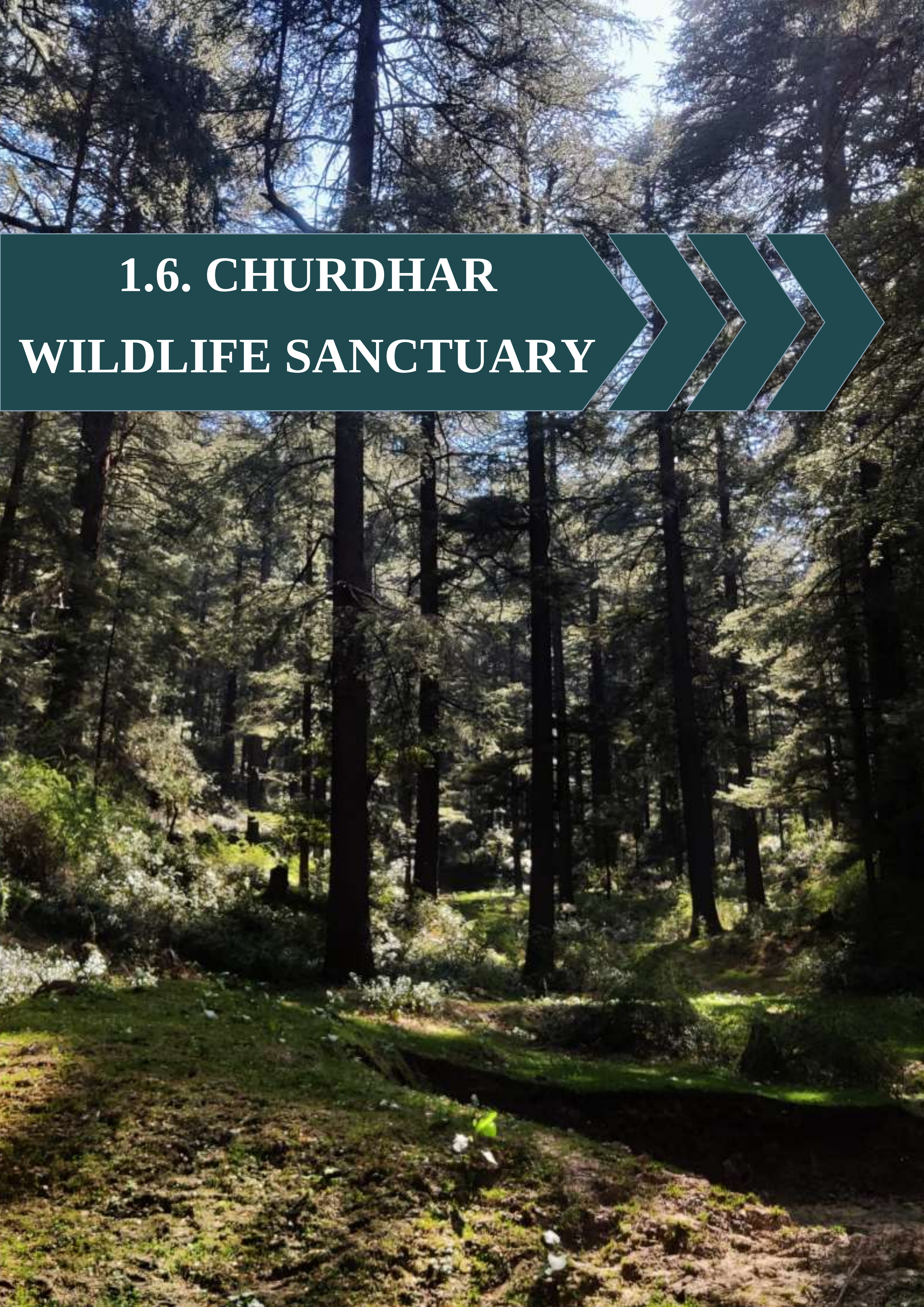


Figure 1.12: Occurrence Hotspots of mammalian fauna in Col. Sher Jung National Park

1.5.6. Conservation Status

Of the species photo-captured, we categorised two (common leopard and sambar) as Vulnerable (VU), one (Himalayan Goral) as Near Threatened (NT) and the rest 13 as least concern by the IUCN Red List of threatened species. All mammal species were recorded with protected status under different Schedules of the Indian Wildlife Protection Act (WPA), 1972. We recorded two species with schedule I (part I), six species with schedule II (part I), six species with schedule III, and one species with schedule IV under the WPA, 1972

1.6. CHURDHAR WILDLIFE SANCTUARY



1.6. CHURDHAR WILDLIFE SANCTUARY (CHWLS)

To study seasonal variation in detection probability and probable densities, camera trapping sessions were conducted in two different seasons i.e. winters and late summers. Here, we present our results separately so that there is proper understanding of animal presence and their detection rates seasonally. This would further help policy makers/ stakeholders for management implications based on seasonal variation in animal movements, their abundance and densities.

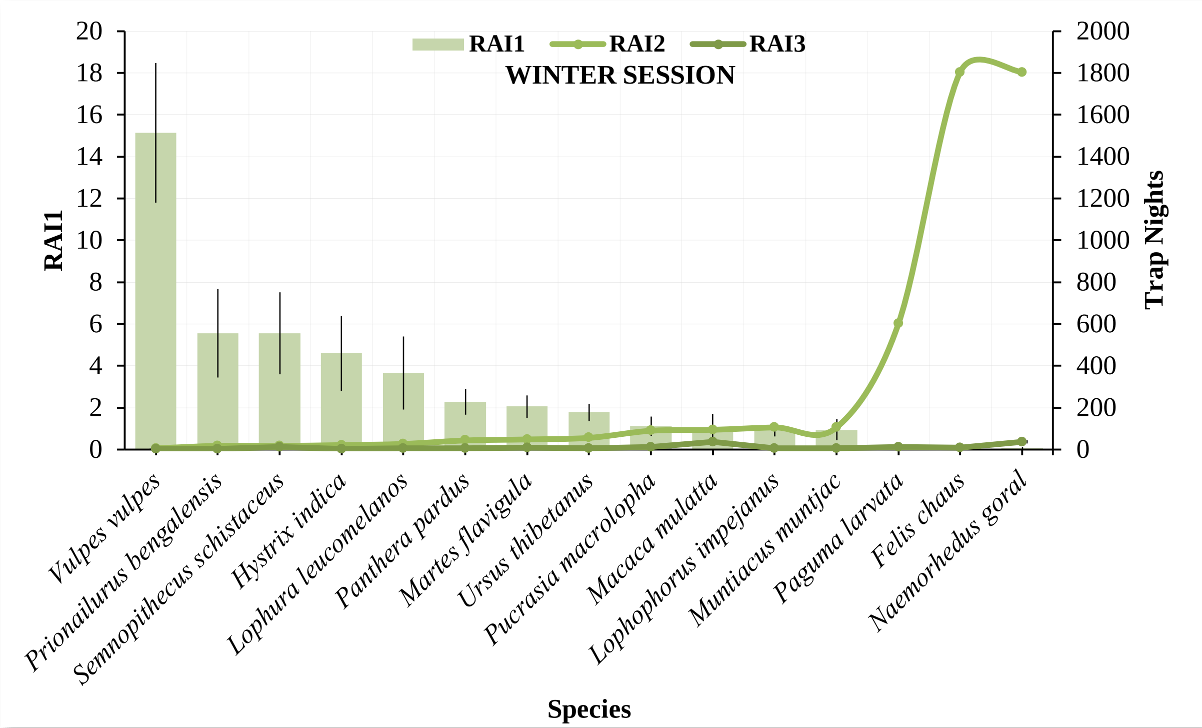
1.6.1. Species richness and RAI1 / ER / Photo capture rates

We recorded 12 mammals (7 carnivores and 5 non-carnivores or herbivores) with 769 independent records over the sampling period of 1804 trap nights (Table 1.5). The independent records (n) and relative abundance index (RAI1) for the photo-captured species ranging from Jungle Cat (n=1, RAI1=0.04) to Red Fox (n=274, RAI1=14.08) for carnivores, and from Himalayan Goral (n=1, RAI1=0.05) to Himalayan Langur (n=100, RAI1=5.34) for herbivores (Figure1.13).

Table 1.5: A checklist of mammals of ChWLS photo captured during winter session (a) and late-summer session (b), showing independent records (n), RAI1 (Relative Abundance Index), RAI2 (trap nights required to detect single photograph), RAI3 (average day to first photographic detection), and conservation status. RAI1 = (Independent photographs / trap nights) × 100. RAI2 = Trap nights / independent photographs. RAI3 was calculated through frequency distribution of nights to the first detection of photo-captured species. Abbreviations used are n = Independent Captures, IUCN = International Union for Conservation of Nature, LC = Least Concern, VU = Vulnerable, NT = Near Threatened, WPA = Wildlife Protection Act, 1972.

Species	n	RAI_1	RAI_2	RAI_3	IUCN	WPA, 1972
Carnivores						
Leopard *Panthera pardus*	44	2.29 (±0.66)	41	6	VU	Sch I
Asiatic Black Bear *Ursus thibetanus*	32	1.7 (±0.42)	56	7	VU	Sch II
Red Fox *Vulpes vulpes*	274	14.08 (±3.33)	7	1	LC	Sch II
Jungle Cat *Felis chaus*	1	0.04 (±0.04)	1804	10	LC	Sch II
Leopard Cat *Prionailurus bengalensis*	99	5.31 (±2.08)	18	4	LC	Sch I
Masked Palm Civet *Paguma larvata*	3	0.15 (±0.11)	601	11	LC	Sch II
Yellow throated marten *Martes flavigula*	40	2.09 (±0.57)	45	9	LC	Sch II
Herbivores						
Himalayan Goral *Nemorhaedus goral*	1	0.05 (±0.05)	1804	36	NT	Sch III
Barking Deer *Muntiacus muntjac*	19	1.03 (±0.58)	95	5	LC	Sch III
Rhesus Macaque *Macaca mulatta*	68	3.59 (±3.02)	27	36	LC	Sch II
Himalayan Langur *Semnopithecus schistaceus*	100	5.34 (±1.97)	18	12	LC	Sch II
Indian Crested Porcupine *Hystrix indica*	88	4.73 (±1.92)	21	4	LC	Sch IV

Species	n	RAI_1	RAI_2	RAI_3	IUCN	WPA, 1972
Carnivores						
Jungle Cat *Felis chaus*	52	3.42 (±1.59)	29	9	LC	Sch II
Leopard *Panthera pardus*	25	1.64 (± 0.70)	61	9	VU	Sch I
Leopard Cat *Prionailurus bengalensis*	18	1.18 (± 0.50)	84	10	LC	Sch I
Yellow-throated Marten *Martes flavigula*	31	2.04 (± 0.95)	49	10	LC	Sch II
Asiatic Black Bear *Ursus thibetanus*	10	0.65 (± 0.21)	152	9	VU	Sch II
Red Fox *Vulpes vulpes*	206	13.57 (± 3.45)	7	2	LC	Sch II
Masked Palm Civet *Paguma larvata*	9	0.59 (±0.24)	169	6	LC	Sch II
Herbivores						
Indian Crested Porcupine *Hystrix indica*	25	1.64 (± 0.58)	61	5	LC	Sch IV
Rhesus Macaque *Macaca mulatta*	36	2.37 (± 0.58)	42	2	LC	Sch II
Barking Deer *Muntiacus muntjac*	3	0.19 (± 0.11)	506	17	LC	Sch III
Himalayan Goral *Naemorhedus goral*	5	0.32 (± 0.30)	304	9	NT	Sch III
Himalayan Langur *Semnopithecus schistaceus*	102	6.71 (± 2.67)	15	3	LC	Sch II



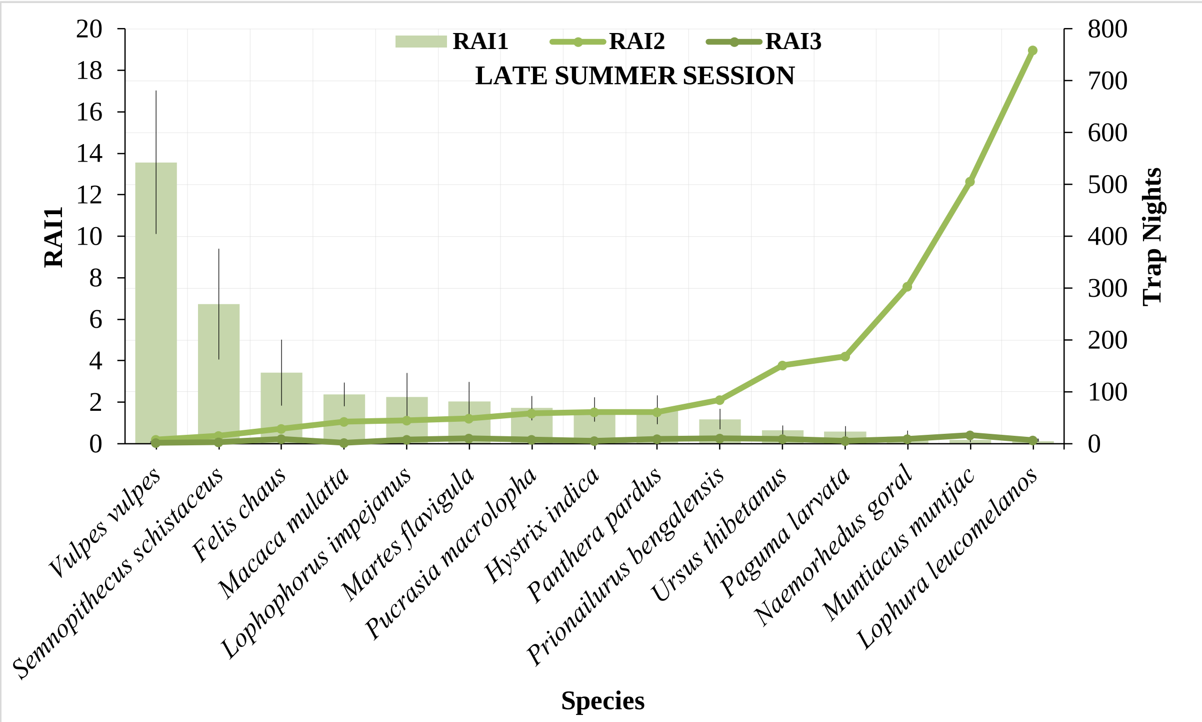


Figure 1.13: A and _B. RAI1 (Relative Abundance Index), RAI2 (minimum time, i.e., trap nights required to detect single photograph), and RAI3 (Average day to first photographic detection) of photo-captured mammals in ChWLS during winter session. RAI1 = (Independent photographs / trap nights) × 100. RAI2 = Trap nights / independent photographs. RAI3 was calculated through frequency distribution of nights to the first detection of photo-captured species.

1.6.2. Trap effort

Jungle Cat (RAI2=1804) and Himalayan Goral (RAI2=1804) took the highest number of trap nights for a single detection. Red Fox (RAI3=1) took only one trap night to detect for the first time. The first detection of Himalayan Goral and Rhesus Macaque required a trapping effort of 36 nights. The species accumulation curve (SAC) indicated the mammal community was adequately sampled after deploying approximately 20 camera stations and 40 days (Figure 1.14).

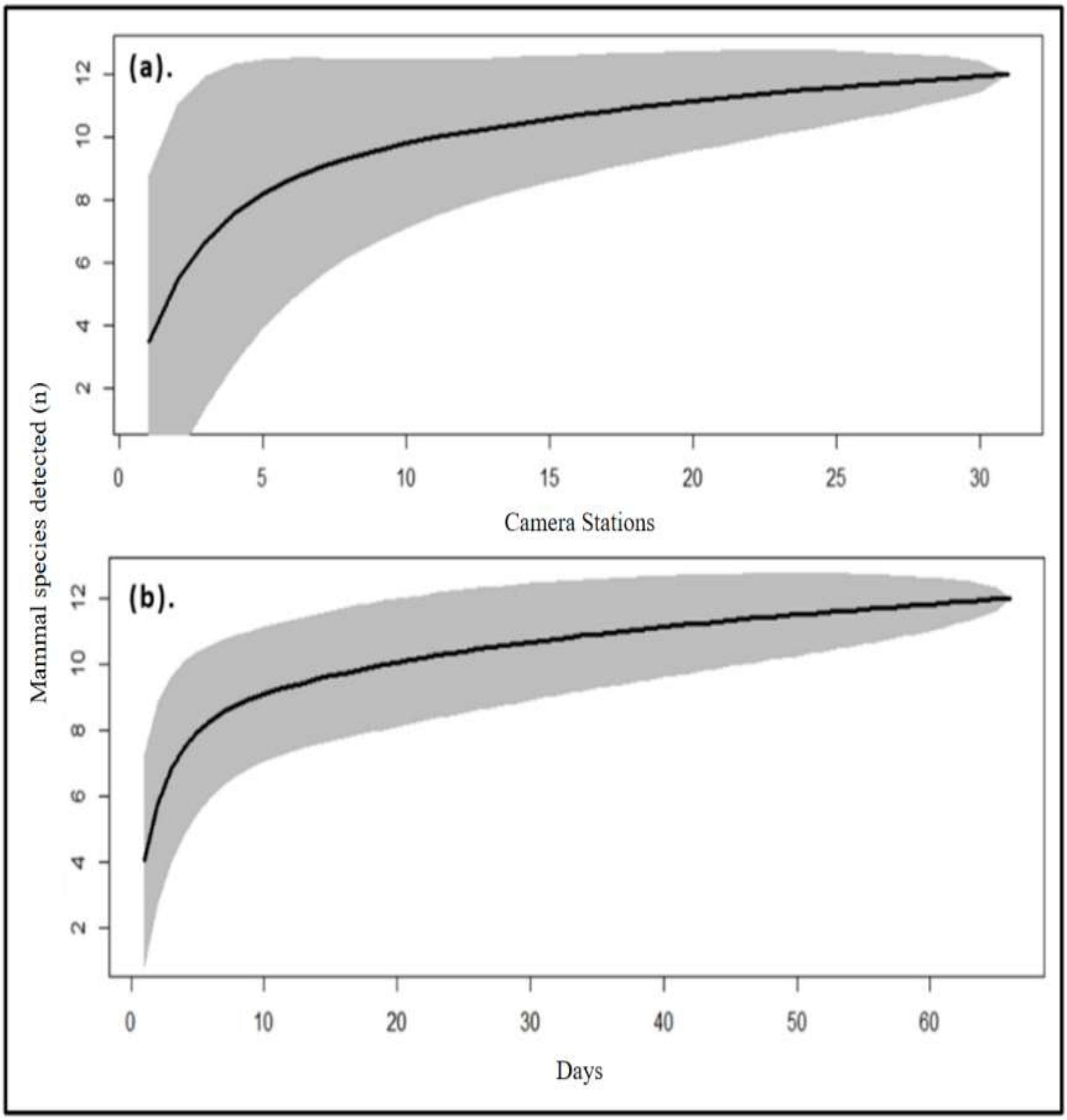


Figure 1.14: Species accumulation curve for mammals estimated using the R package vegan (Oksanen et al. 2018), depicting the relationship to the number of mammal species (n=12) detected over (a) 31 camera stations, and (b) 67 days in ChWLS. The black line indicates the modelled species accumulation curve, and the shaded area indicates 95 % confidence interval.

1.6.3. Density estimation of identifiable individuals

We recorded 20 (right flank) and 18 (left flank) photographs for leopard, and 54 (right flank) and 38 (left flank) photos for leopard cat. The density of leopard and leopard cat as estimated by the SECR method were 11.2 ± SE 4.92 and 58.82 ± SE 13.73 individuals/100 km^2, respectively

1.6.4. Density estimation of unidentifiable individuals

25 CTs captured 274 snapshots of red fox, 14 CTs took 32 pictures of Asiatic black bear, 9 CTs captured 19 photos of barking deer, 7 CTs captured 40 images of yellow-throated marten, 9 CTs took 88 pictures of Indian crested porcupine, and 10 CTs took 100 photographs of Himalayan langur. Uniform model with cosine adjustments best fit for all the species except for Indian crested porcupine and Himalayan langur, for which half-normal Hermite adjustments were used. Density was highest for langur (3.8 ± SE 1.5 individuals/km^2) and lowest for Asiatic black bear (0.5 ± SE 0.2 individuals/km^2) (Table 1.6; Figure 1.15, 1.16, 1.17). Temporal overlap of common leopard with other species was also evaluated (Figure 1.18)

Table 1.6: A table shows models and functions used for calibrating density by the camera trap distance sampling (CTDS) method for ChWLS**.**

Species	CV	95% CI	Function
Asiatic Black bear *Ursus thibetanus*	0.48	0.16-1.48	Uniform / Cosine
Red fox *Vulpes vulpes*	0.34	0.77-3.32	Uniform / Cosine
Yellow throated marten *Martes flavigula*	0.34	0.88-3.54	Uniform / Cosine
Barking Deer *Muntiacus muntjac*	0.44	0.47-13.46	Uniform / Cosine
Indian crested porcupine *Hystrix indica*	0.38	0.64-2.90	Half-normal / hermite
Himalayan Langur *Semnopithecus schistaceus*	0.4	1.69-8.89	Half-normal / hermite

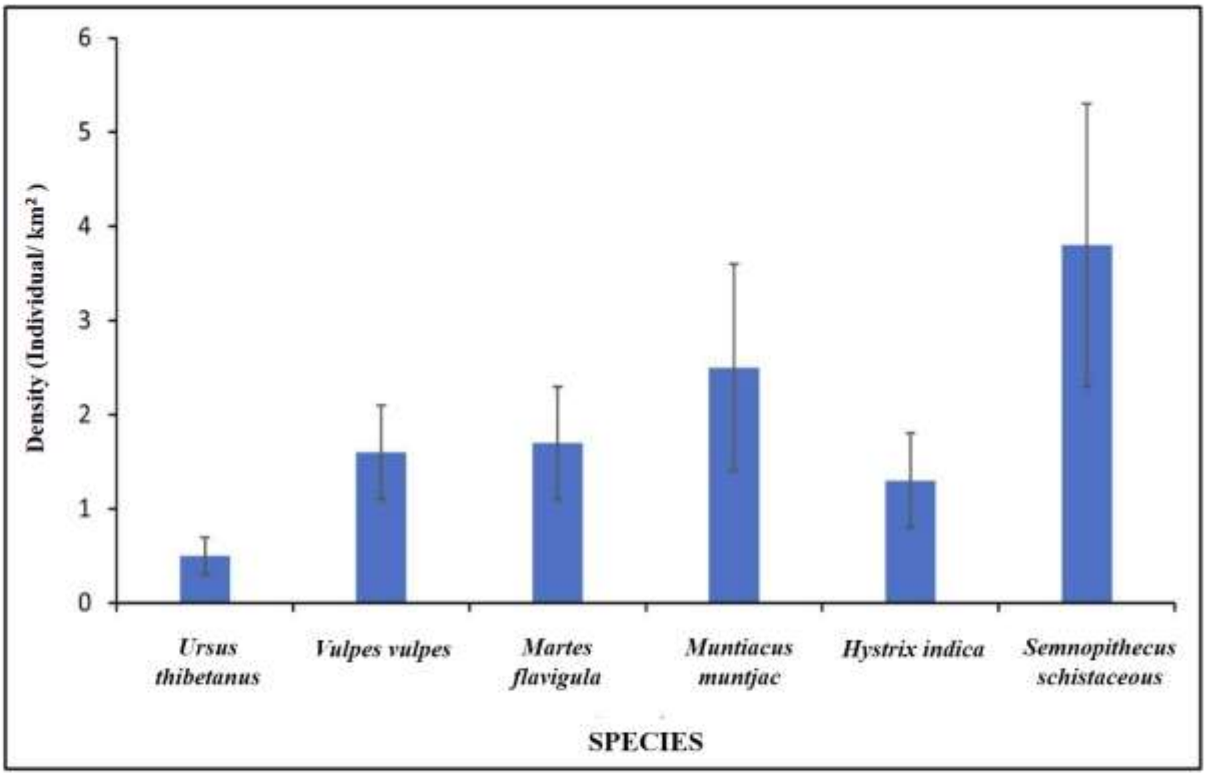


Figure 1.15: The bar graph compares densities estimated for mammalian species using the CTDS method in ChWLS.

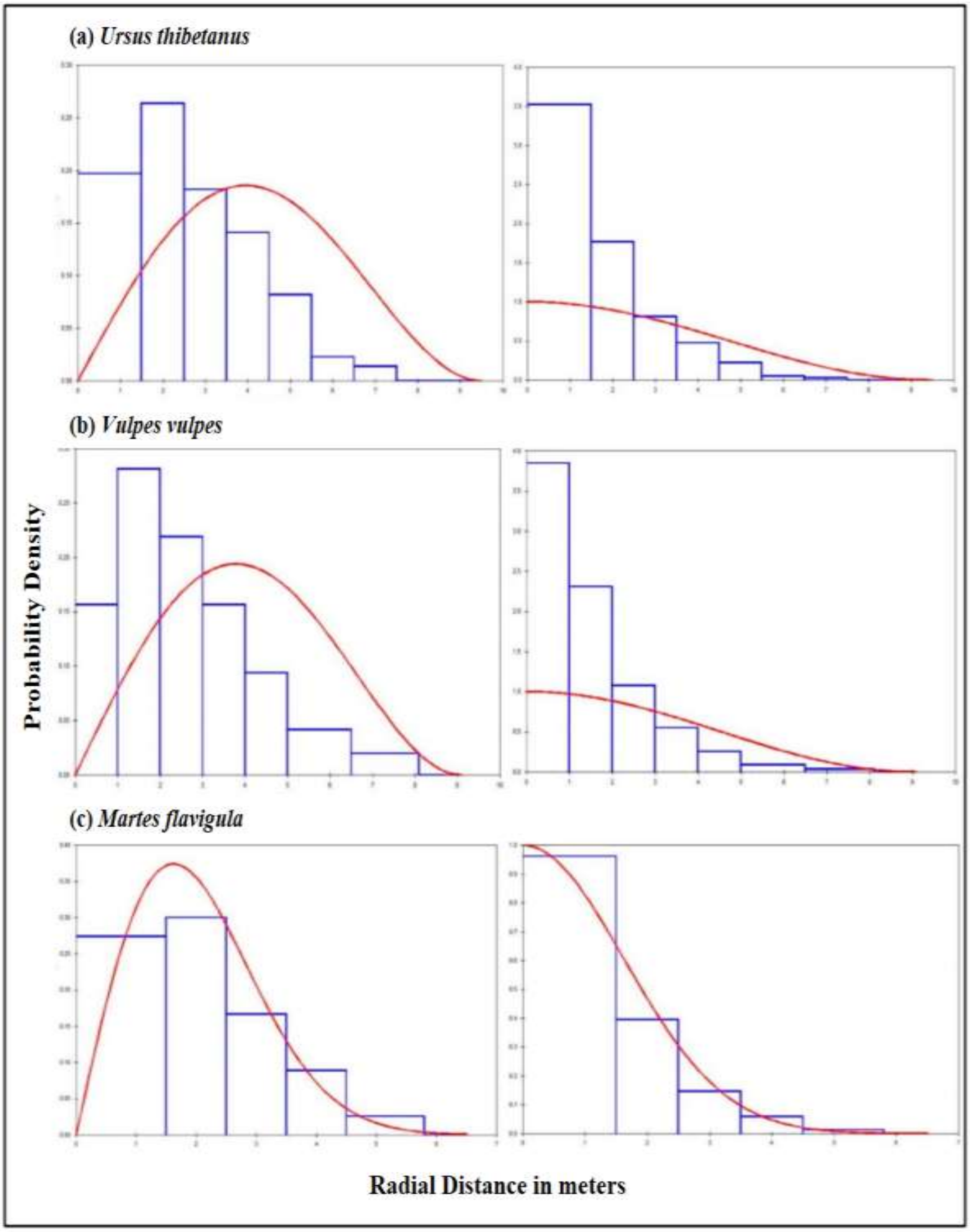


Figure 1.16: The detection probability and probability density for the models selected for estimating density by the CTDS method for ChWLS. The bars show the data distribution, and the line represents the model fit. The bars' heights are scaled to cover the same total area as the area under the line to show how well the detection function fits the data.

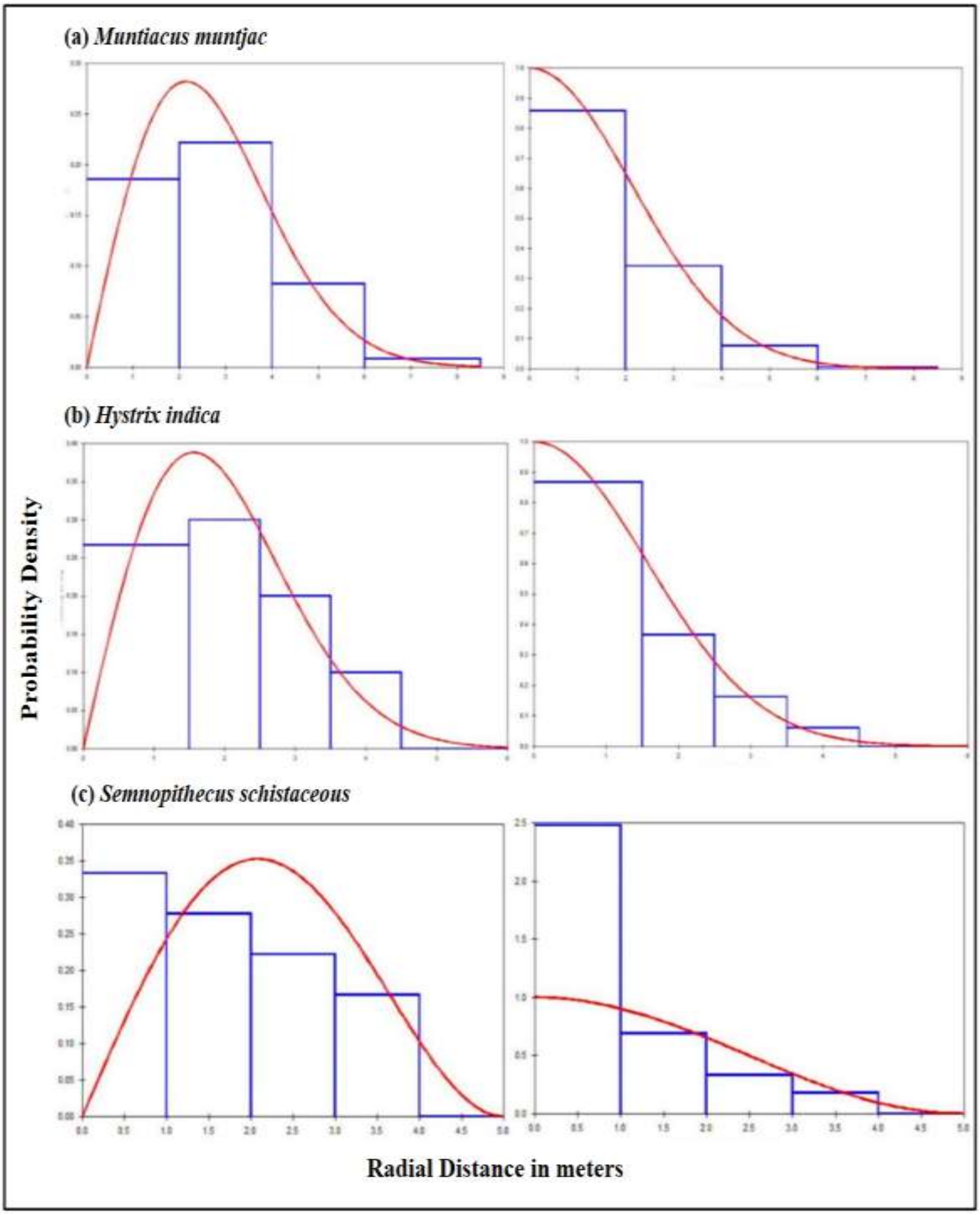


Figure 1.17: The detection probability and probability density for the models selected for estimating density by the CTDS method for CWLS. The bars show the data distribution, and the line represents the model fit. The bars' heights are scaled to cover the same total area as the area under the line to show how well the detection function fits the data.

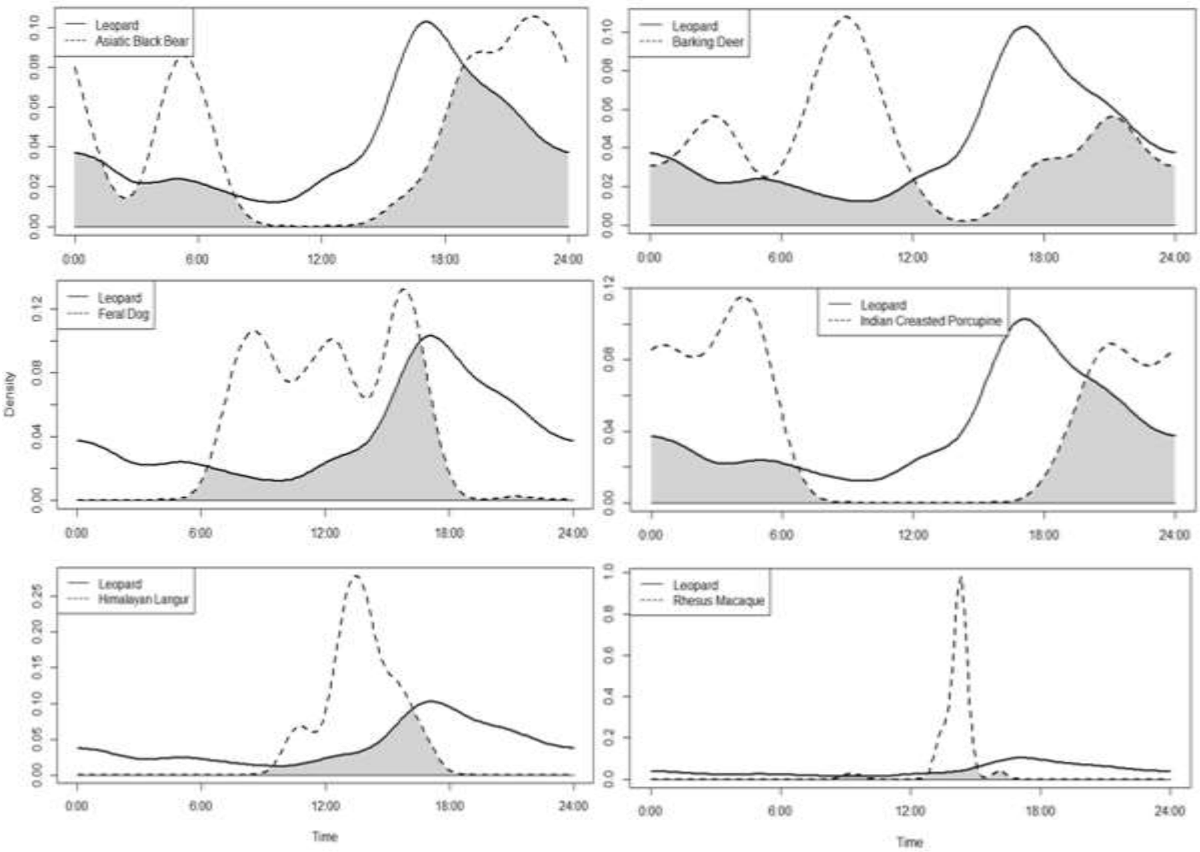


Figure 1.18: Temporal interactions of Common leopard with other mammalian species found in the Churdhar Wildlife Sanctuary

1.7. CHANDRATAL WILDLIFE SANCTUARY

1.7. Chandratal Wildlife Sanctuary (CWLS)

1.7.1. Species richness and RAI1 / ER / Photo capture rates

We recorded 6 mammals (4 carnivores and 2 non-carnivores or herbivores) with 85 independent records over the sampling period of 529 trap nights (Table 1.7). The independent records (n) and relative abundance index (RAI1) for the photo-captured species ranging from Stone Marten (n=1, RAI1=0.18) to Red Fox (n=57, RAI1=10.84) for carnivores and from Siberian Ibex (n=3, RAI1=0.54) to Royle's Pika (n=12, RAI1=2.17) for herbivores (Figure 1.19).

Table 1.7: A checklist of mammals of CWLS, showing independent records (n), RAI1 (Relative Abundance Index), RAI2 (trap nights required to detect single photograph), RAI3 (average day to first photographic detection), and conservation status. RAI1 = (Independent photographs / trap nights) × 100. RAI2 = Trap nights / independent photographs. RAI3 was calculated through frequency distribution of nights to the first detection of photo-captured species. Abbreviations used are n = Independent Captures, IUCN = International Union for Conservation of Nature, LC = Least Concern, VU = Vulnerable, EN = Endangered, WPA = Wildlife Protection Act, 1972.

Species	n	RAI_1	RAI_2	RAI_3	IUCN	WPA, 1972
Carnivores						
Snow Leopard *Panthera uncia*	1	0.20 (±0.26)	529	29	EN	Sch I
Wolf *Canis lupus*	11	2.07 (±0.89)	48	15	LC	Sch I
Red Fox *Vulpes vulpes*	57	10.84 (±3.49)	9	3	LC	Sch II
Stone Marten *Martes foina*	1	0.18 (±0.18)	529	21	VU	Sch I
Herbivores						
Siberian Ibex *Capra sibirica*	3	0.54 (±0.54)	176	35	LC	Sch I
Royle's Pika *Ochotona roylei*	12	2.17 (±1.18)	44	5	LC	Sch IV

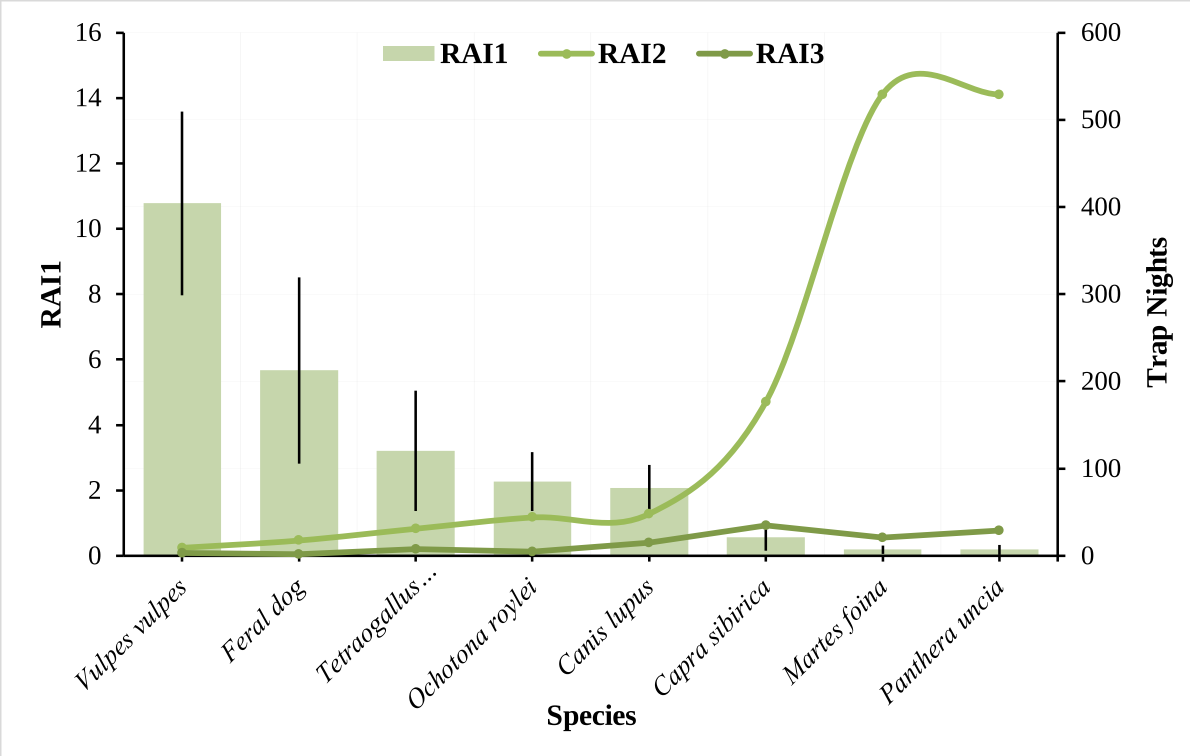


Figure 1.19: RAI_1 (Relative Abundance Index), RAI_2 (minimum time, i.e., trap nights required to detect single photograph), and RAI_3 (Average day to first photographic detection) of photo-captured mammals in CWLS. RAI_1 = (Independent photographs / trap nights) × 100. RAI_2 = Trap nights / independent photographs. RAI3was calculated through frequency distribution of nights to the first detection of photo-captured species.

1.7.2. Trap effort

Two carnivore species, i.e., Snow Leopard (RAI2=529) and Stone Marten (RAI3=529), and one herbivore, i.e., Siberian Ibex (RAI2=176), took the highest number of trap nights for a single detection. Red Fox (RAI3=3) and Royle's Pika (RAI3=5) took only one trap night to detect for the first time, whereas 35 trap nights were required for the first detection of Siberian Ibex (RAI3=35). The species accumulation curve (SAC) indicated that the mammal community was adequately sampled after deploying approximately 20 camera stations and 38 days (Figure 1.20). Temporal interactions within mammal species was also observed (Figure 1.21).

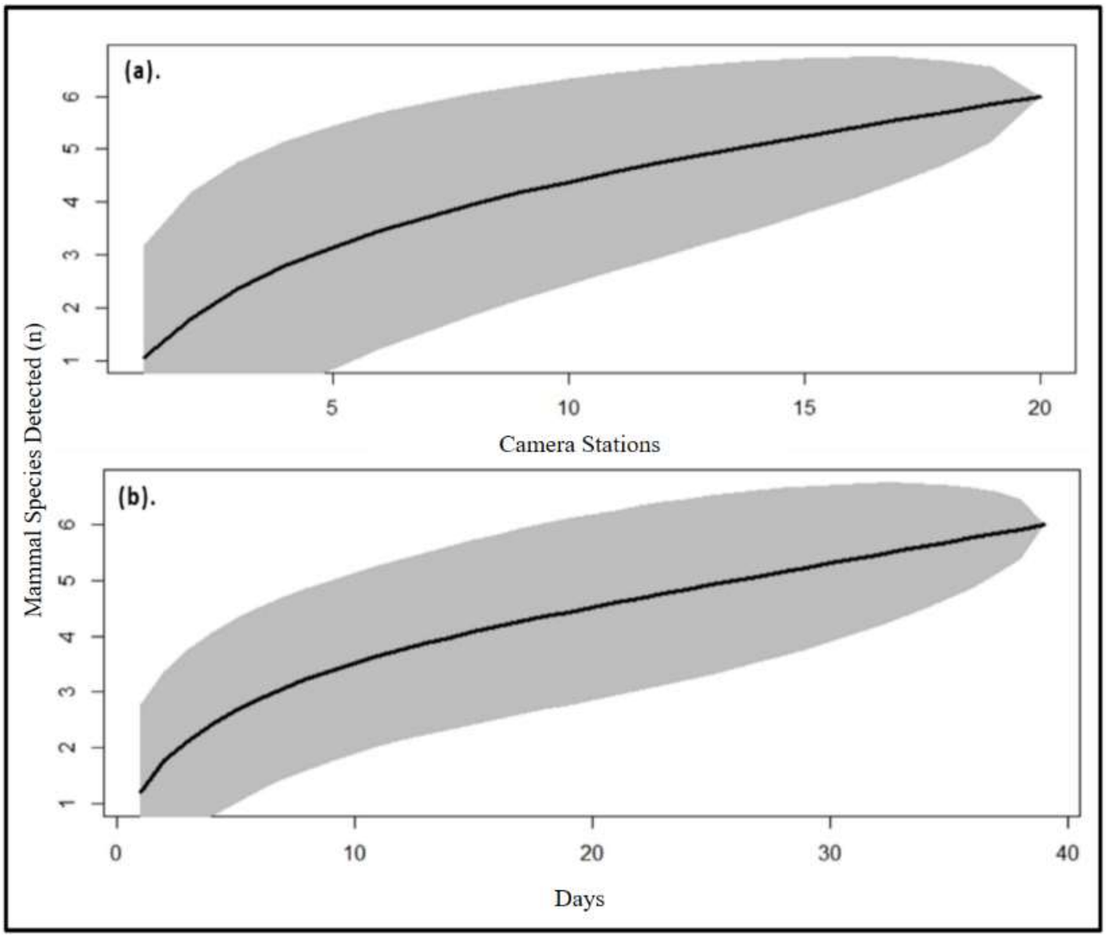


Figure 1.20: Species accumulation curve for mammals estimated using the R package vegan (Oksanen et al. 2018), depicting the relationship to the number of mammal species (n=6) detected over (a) 20 camera stations and (b) 38 trap nights in CWLS. The black line indicates the modelled species accumulation curve, and the shaded area indicates 95 % confidence interval**.**

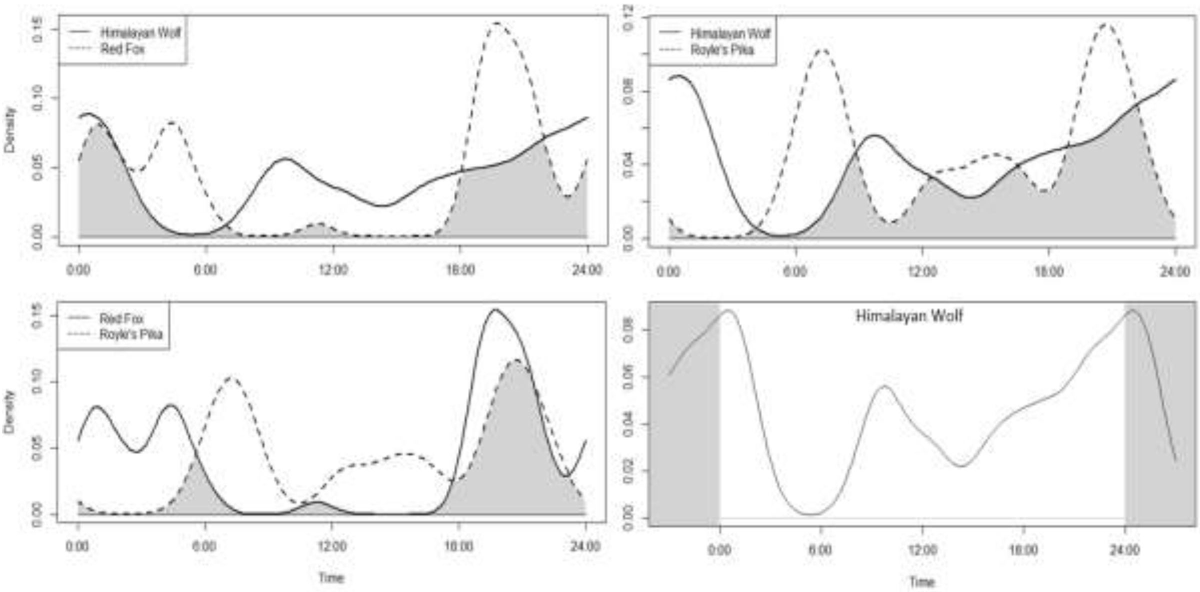


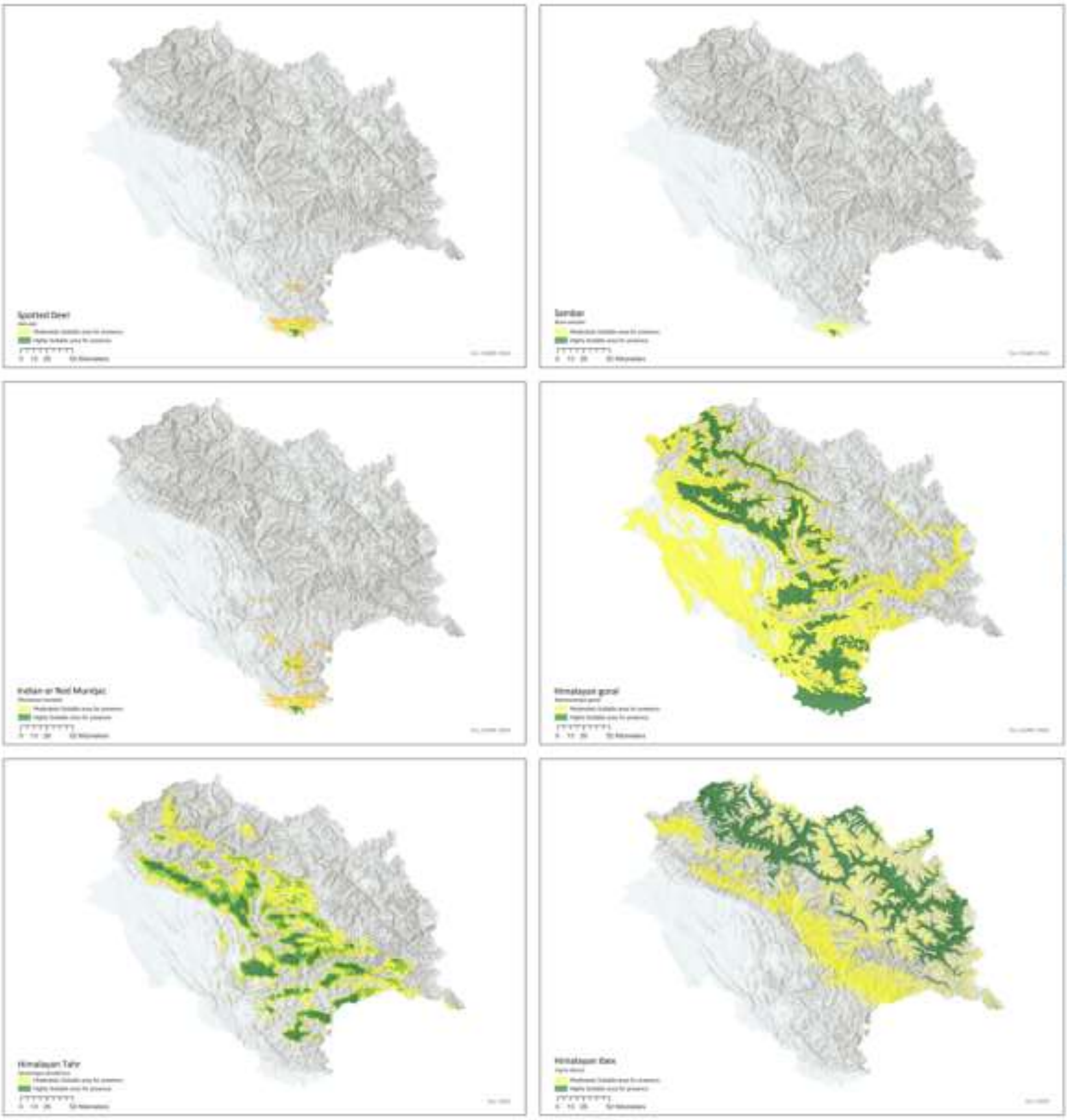
Figure 1.21: Temporal interactions within mammal species observed in Chandratal Wildlife Sanctuary

1.7.3. Conservation status

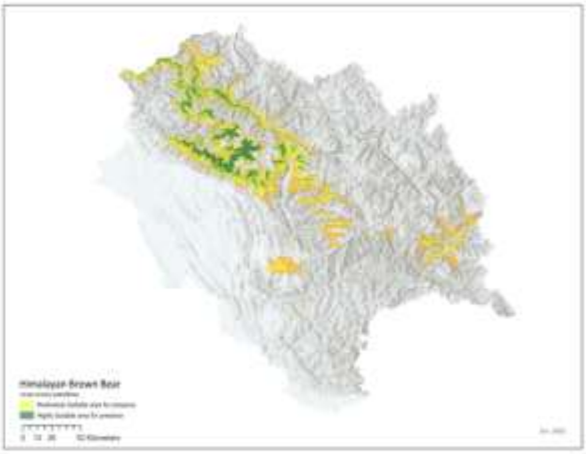
Of the species photo-captured, we categorised one (snow leopard) as Endangered (EN), one (stone marten) as Vulnerable (VU), and the rest four as least concern by the IUCN Red List of threatened species. All mammal species were recorded with protected status under different Schedules of the Indian Wildlife Protection Act (WPA), 1972. We recorded four species with schedule I (part I), one with schedule II (part I), and one with schedule IV under the WPA, 1972.

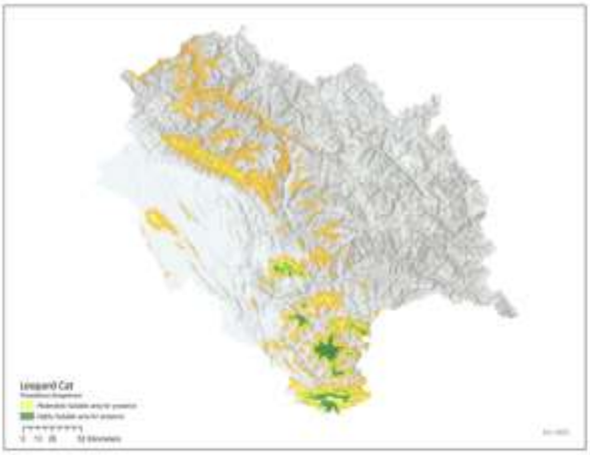
1.8. Species Distribution Modelling

Out of the 32 species of mammals found in our study areas, we generated species distribution maps for 18 species of mammals which were frequently captured in our camera traps. The moderate and highly suitable areas for presence of these species belonging to the Family *Bovidae* (*Axis Axis, Rusa Unicolor, Muntiacus muntjac, Naemorhedus goral, Hemitragus jemlahicus and Capra sibrica),* Family *Ursidae* (*Ursus thibetanus* and *Ursus arctos isabellinus*), Family *Felidae* (*Prionailurus bengalensis, Panthera pardus and Uncia uncia*), Family *Canidae* (*Vulpes culpes and Canis lupus chanco*) and Family *Mustelidae* (*Mustela altaica, Mustela sibrica, Martes flavigula* and *Martes foina*), and *Paguma larvata* separately.

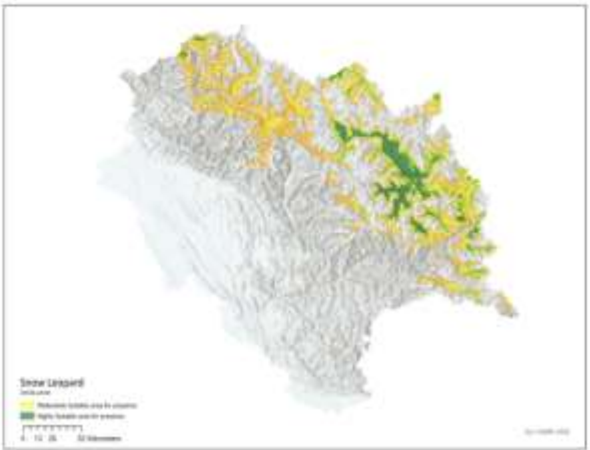



Asiatic Black Bear


Himalayan Brown Bear

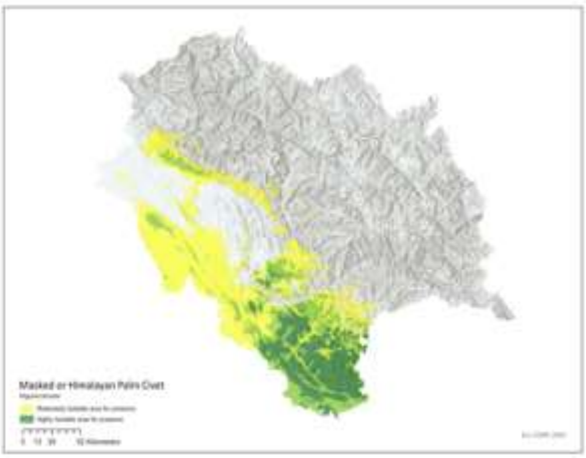

Leopard Cat

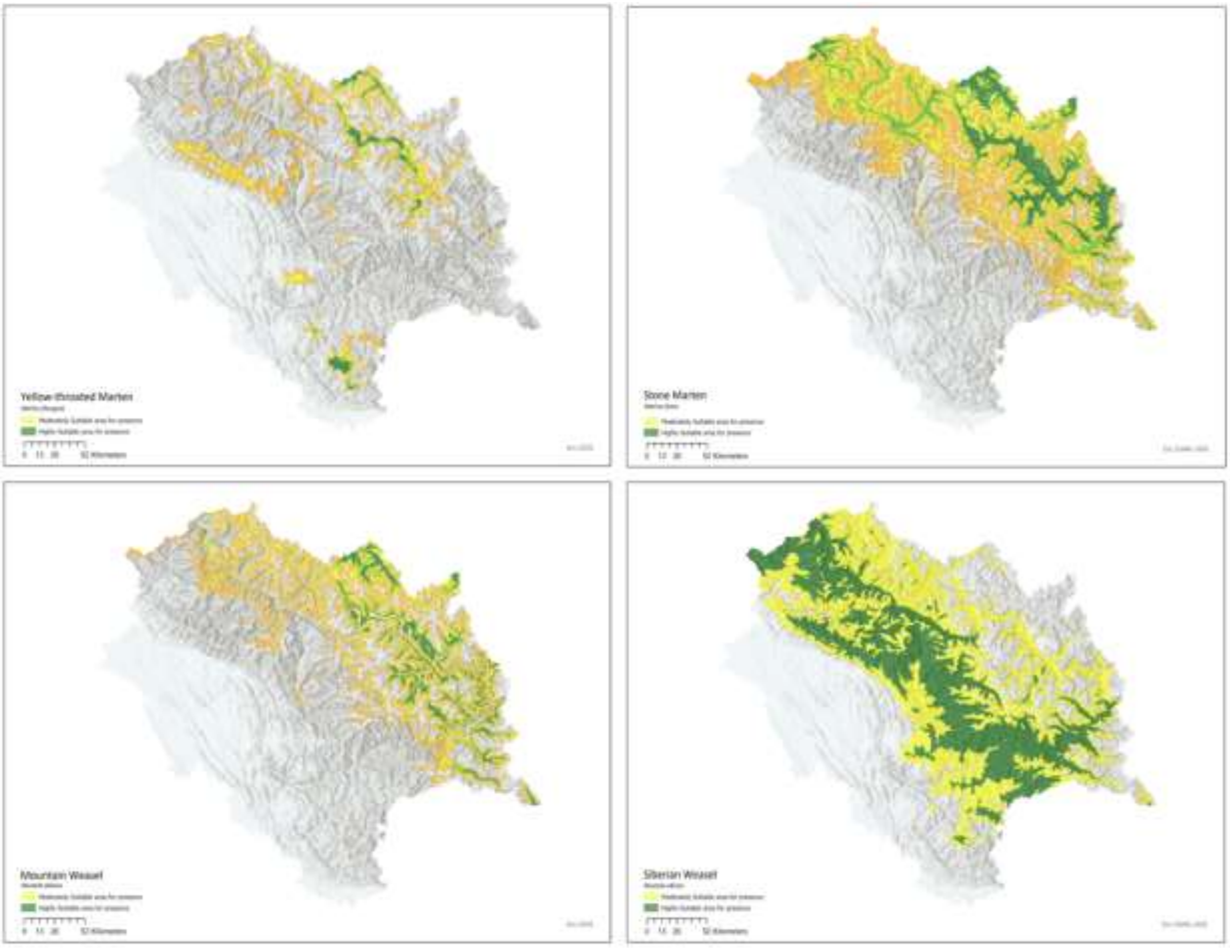

Common Leopard


Snow Leopard


Red Fox


Tibetan Grey Wolf


Masked or Himalayan Palm Civet


Yellow-throated Marten
Stone Marten
Mountain Weasel
Siberian Weasel

1.9. DISCUSSION

Discussion

To monitor the success of conservation activities in various areas of National Park, baseline data on abundance and species richness are crucial for several species of concern. This study explored a broad description of species richness, relative abundance index, and threat status of mammalian fauna SNP. The study confirms 20 mammalian species belonging to 6 orders, 12 families and 19 genera, out of which 15 species were photographed in strictly forested habitats. Our findings indicate that SNP supports a diversity of mammalian fauna of which 4 (20 %) are threatened species (IUCN 2020). Although our camera-trapping survey under-represented species groups such as rodents, and grassland species; direct observational records confirm the presence of one species of Elephantidae, i.e., Elephant *Elephas maximus* (EN), one species of Mustelidae, i.e., Yellow throated marten *Martes flavigula* (LC); and two species of Muridae, i.e., Common Indian field mouse *Mus booduga* (LC) & House mouse *Mus musculus* (LC), and one species of Soricidae, i.e., House shrew *Suncus murinus* (LC).

The mammal species richness (n=20) observed in this study is almost similar when compared with previous study conducted in Simbalbara WLS by Sharma & Saikia, 2009. They recorded 21 species of mammals from Simbalbara WLS of which rodents, shrews and bats are represented by 6 species, using the method of direct and/or opportunistic sightings however, leopard cat (*Prionailurus bengalensis*), Asian palm civet (*Paradoxurus hermaphrodites*), yellow throated marten (*Martes flavigula*) masked palm civet (*Paguma larvata*) and small Indian civet (*Vivericula indica*) as reported in our study were not present in the study conducted by Sharma & Saikia, 2009. As we conducted camera-trapping more intensively (grid-size: 1 km^2) to photo-capture all mammals, i.e., small, medium, and large. Our study had successfully recorded majority of mammalian fauna using camera-traps alone, which shows that our methodology was efficient at sampling the species in the region. The analysis of distance sampling methods (Camera-trap point transect & line transect) highest and lowest density among the ungulates is that of *Rusa unicolor* and *Muntiacus muntjac;* and among all the mammals, including primates, highest density in the landscape has been represented by that of *Macaca mulatta.*

Although Simbalbara N.P. provides connectivity with the Kalesar National Park (KNP) of Haryana, an area which is known to harbour decent population of Nilgai (*Boselaphus tragocamelus*) in the grasslands and fringes of the forests (Sharma et al. 2013), no signs of the species or direct sightings of Nilgai (*Boselaphus tragocamelus*) occurred during the field survey. However, the camera trap did record the presence of the species in the landscape; among the herbivores, Nilgai took the highest number of trap nights for a single detection.

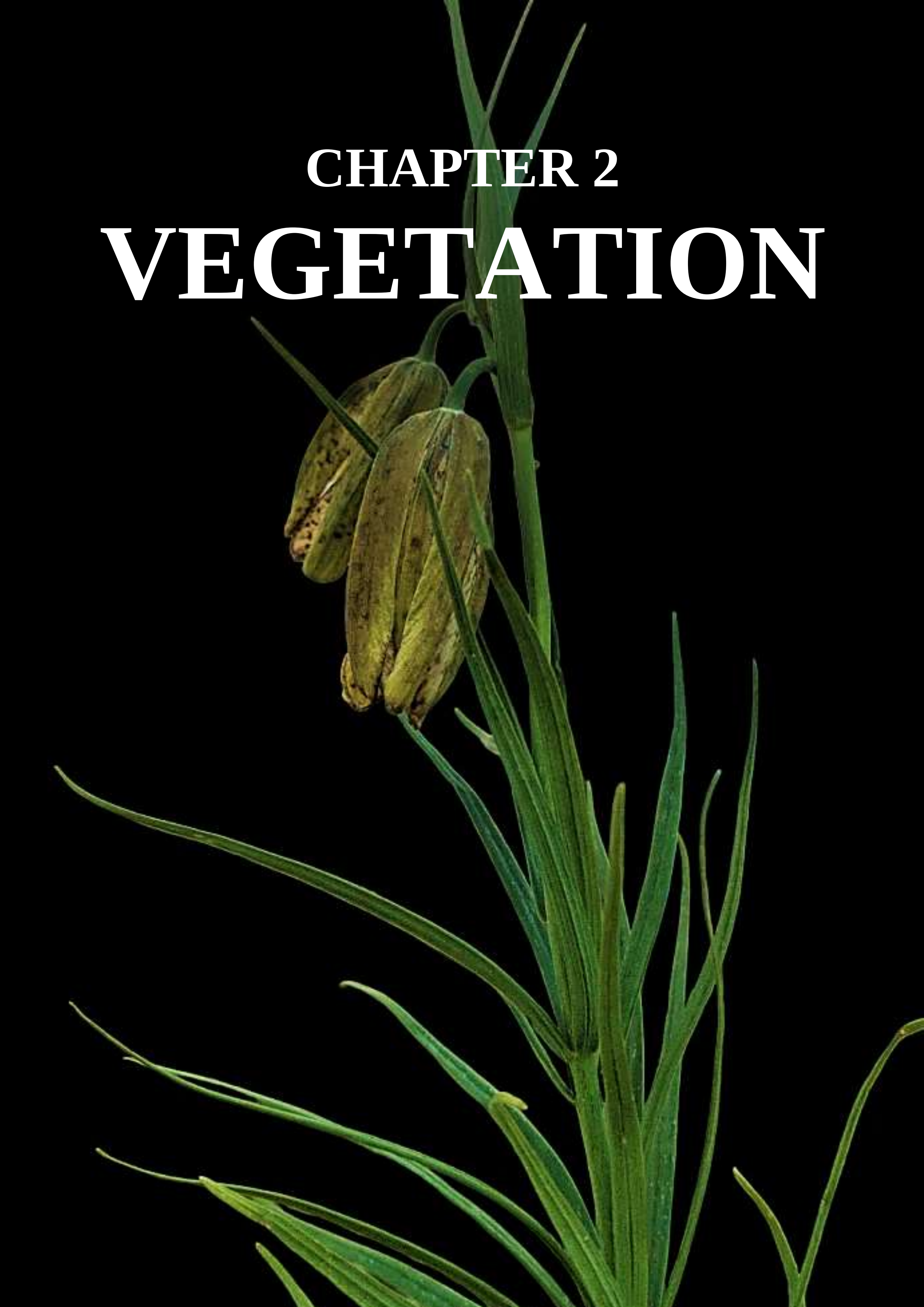
Among the mega-herbivores, presence of elephants (*Elephas maximus*) has been recorded, via direct sighting as well as indirect signs, in the landscape, which are known to occasionally cross over from the adjoining Kalesar National Park.

The informal discussion with the forest department officials also revealed that there has been no record of tiger in SNP since a long time. However, during the winters of 2019, few of the residents of the nearby village (Pilhori) reported sighting of a tiger in the landscape. Moreover, as the ungulate species along with primates are preferred prey species of large-sized carnivores such as the tiger (*Panthera tigris*) and common leopard (*Panthera pardus*) in the tropical forests of India (Ramesh et al. 2012; Majumder et al. 2013), the SNP landscape may have the potential to harbour these large carnivores. The sanctuary is the only conservation area in Himachal Pradesh where the occurrence of Tiger and Elephant has been reported (Sharma and Saikia 2009).

However, although camera traps were distributed throughout the forested regions of the National Park, none of the cameras recorded the presence of a tiger. Over the years even in adjoining Kalesar N.P. a high encounter rates have been recorded for leopard, but a no signs of tiger have been reported (Sarkar et al. 2013 & Sharma et al. 2013).

In our analysis, the SAC (species area curve) began to reach an asymptote by the end of the sampling, indicating that our sampling design was adequate for obtaining a robust inventory of the mammal community. The camera-trap survey effort was sufficient for capturing relatively common species (Tobler et al. 2008), and the plateau of the accumulation curve supported this notion. Although there is a stabilization of the species accumulation curve in our study, other species may also occur in the park. Previous study by Sharma & Saikia, 2009 reported species like Indian grey mongoose *Herpestes edwardsii*, Indian hare *Lepus nigricollius,* jungle cat *Felis chaus,* Indian gerbil *Tatera indica*, Indian pygmy pipistrelle *Pipistrellus tenuis* and Indian pangolin *Manis crassicllitiatu*. However, our intensive camera-trapping design could not photo-capture these species. This highlights the general challenges of assessing mammal species richness and suggests that even high sampling effort does not necessarily yield a complete mammal species list for a given area (Bowler et al. 2017). Hence, systematic, or randomized sampling protocols (such as our terrestrial camera-trapping monitoring scheme) are perhaps insufficient to obtain a complete mammal inventory.

CHAPTER 2
VEGETATION



2.1. INTRODUCTION

2.1. INTRODUCTION

The maintenance of biodiversity is essential to attain forest sustainability. It is undoubtedly justified that the long-term sustainability of the forest ecosystem is of great concern with plant diversity and their phytosociological attributes. Plant diversity is widely acknowledged to support many communities, including the human community. As the overall condition of a forest depends on its plant's composition, the information on the composition, diversity and ecological aspects of plant species is of primary importance in the planning and implementing forest biodiversity conservation efforts.

It is noted that findings from studies that address plant distribution patterns and dynamics of biological resources can provide a rational basis for planning and making decisions about the environment. Otherwise, restoring resources in their natural habitat would be very difficult. Vegetation is an essential part of the ecosystem that interprets the effects of the total environment (Billings, 1952). The vegetation complex cyclically fluctuates from one season over the years in a succession way. The fluctuations suggest a response of each species' population to prevailing heat, moisture and light as modified by the vegetation itself (Walt, 2015). Vegetation studies plant communities' composition, development, geography, distribution and environmental relationships (Legendere and Fortin, 1989). It deals with the importance of the environmental structures and strategies contributing to a healthy ecosystem.

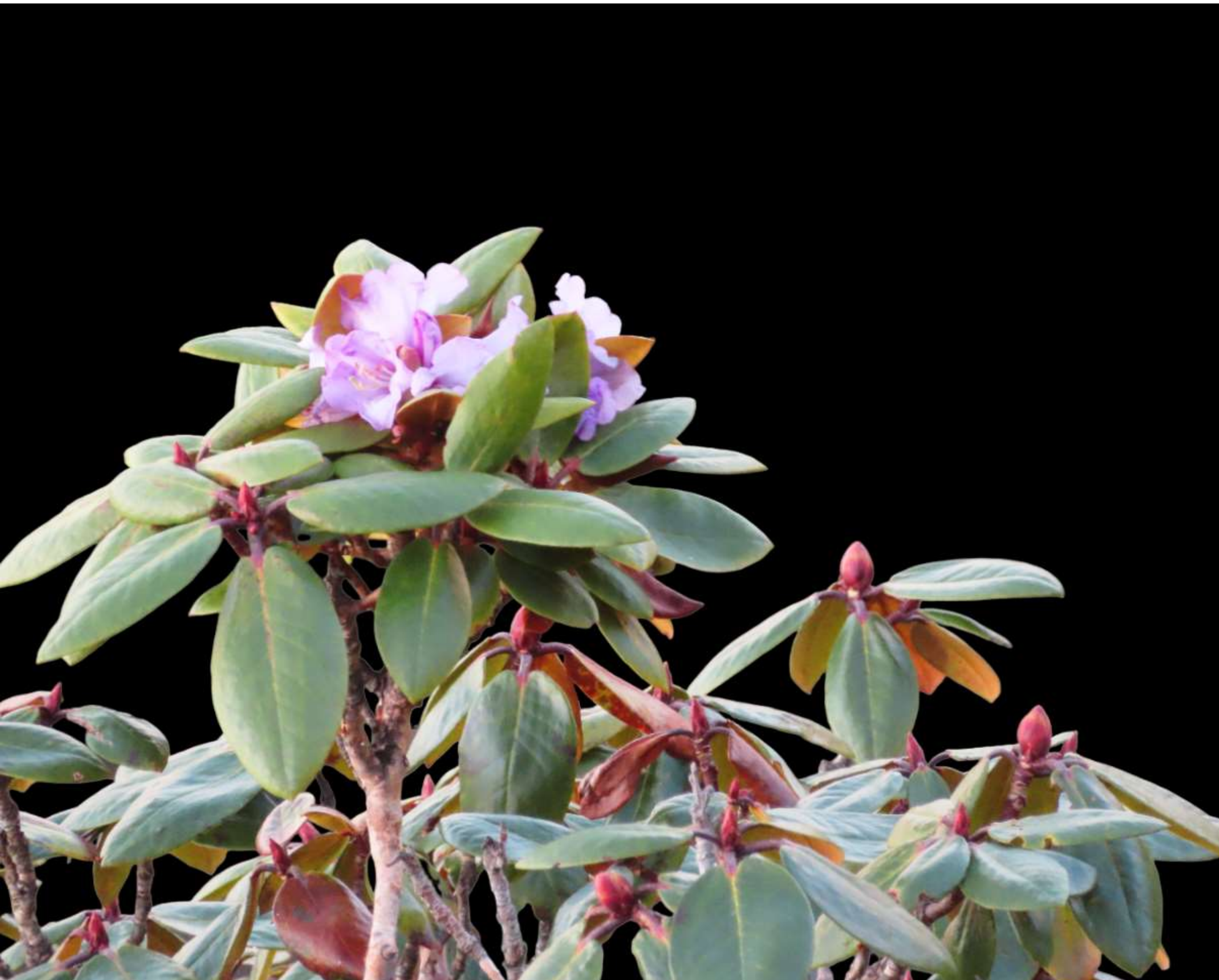
Phytosociological analysis of a plant community is the first and foremost basis of the ecological study of any piece of vegetation. It provides insights into the structure, dynamics and functioning of plant communities. It helps ecologists understand how different plant species interact with one another and their environment, including factors like soil type, climate, and topography. Furthermore, phytosociological studies aid in identifying native plant species that are integral to particular ecosystems. Oosting (1956) suggested the importance of phytosociological parameters for spatial problems in the sociological behavior of plants. Plants growing together have mutual relationships with the environment (Billings, 1952). Hence, studying interactions between plants and their environment is fundamental for biodiversity conservation, climate change mitigation and human well-being and underpins many aspects of environment management and sustainability.

The Himalayan Mountain Range forms a distinct biogeographic ecoregion with large topography and climate variation and harbors considerable plant diversity (Olson et al., 2000). The proportion of endemic taxa is substantial in the entire Himalayan Range. Thus, this ecoregion has been designated as a global biodiversity hotspot (Myers et al., 2000). Four thousand higher plant species and 29% of the endemic taxa of Indian dicotyledonous flora occur in the Himalayas (Singh & Singh, 1987). The prominent angiosperm families in the western Himalayan region are Asteraceae, Rosaceae, Poaceae, Ranunculaceae and Brassicaceae (Rau, 1975).

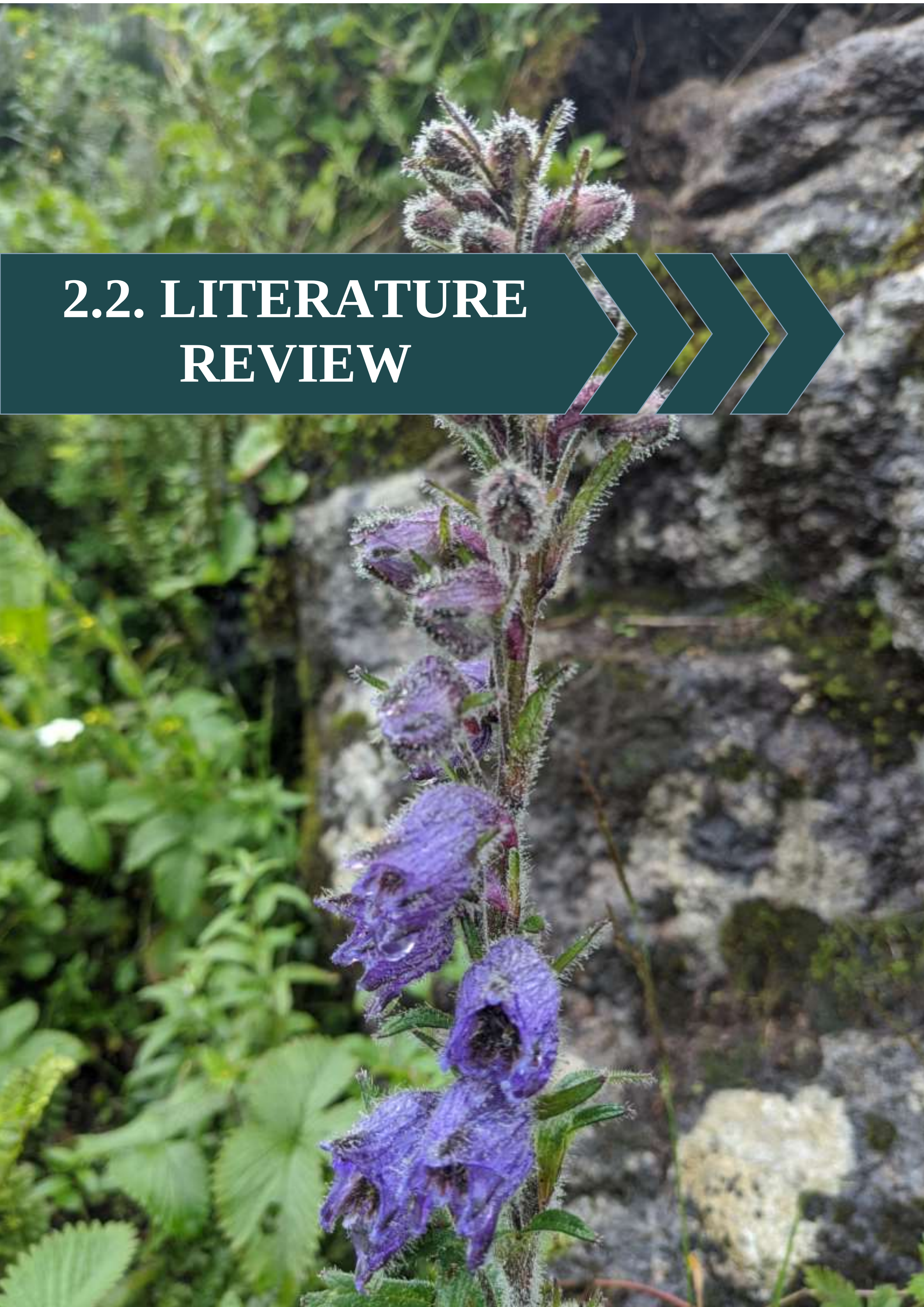
The Western Himalayan state of Himachal Pradesh covers a wide altitudinal range of about 240 m to almost 6900 meter above mean sea level. The mountainous state has eight forest types per Champion and Seth's classification, with climate varying from semi-tropical to semi-arctic. These general Climatic and physiographic conditions have influenced the rise of diverse natural ecosystems. Chowdhery & Wadhwa (1984) reported 3243 angiosperms from Himachal Pradesh, 26.8% of which are accounted for in Kinnaur's most dominant family Asteraceae (122 species; Chawla et al., 2012). The state has vegetation which is a mixture of Moist temperate deciduous forest, Coniferous Forest dominated in the middle and higher regions with oak (*Quercus* sp.), dry deciduous forest dominated with Sal (*Shorea robusta*), Himalayan alpine pastures, Rhododendron scrub forest, Ban oak forest, etc. (Chawla et al., 2012). The flora of cold desert Lahaul-Spiti comes under alpine and high alpine zone, which is situated between 2700m to 6000m. The alpine zone is mainly dominated by meadows, vast pasturelands, colorful moraines, marshes and screes (Singh et al., 2001).

Local communities and pastoral communities in the Trans-Himalayan region have a long history of dependence on wild plants for various aspects of their livelihoods and cultural practices (Mishra et al., 2003; Jackson, 2012). The unique ecological and climatic conditions of the Trans-Himalayan region have shaped the traditional knowledge and practices of these communities, leading to their reliance on wild plants for food, medicine, shelter, and other necessities. While traditional knowledge plays a crucial role in utilizing medicinal plants sustainably, certain practices can also contribute to threats. Such as over-extraction of valuable plants in trans-Himalaya may result in depletion of their natural populations (Kala, 2000).

Spiti Valley is a part of the Trans-Himalayan region and is known for its unique flora, including various medicinal plant species that have been traditionally used by local communities for centuries. The roughness and inaccessibility of the terrain, inhospitable climatic conditions, and the short growing season in Spiti are major constraints for ecological assessment of plants (Kala, 2004), these studies are imperative to understand species distribution patterns, which provide baseline information required to plan biodiversity conservation. These mountains are home to pastoralist and agro-pastoral communities, who depend substantially on these ecosystems for their sustenance (Mishra et al., 2003; Jackson, 2012). Due to their direct dependence on ecosystems to meet their basic needs, local communities are particularly reliant on provisioning services - the nutritional, material, and energetic outputs of ecosystems (McCartney & Van Koppen, 2004, Adekola et al., 2015). Singh (2012) conducted a study on the traditional plant use in the local healthcare system among the tribal communities of Lahaul-Spiti district that revealed the utilization of 86 plant species to treat around 70 diverse ailments. As not all the provisioning services have a market value, human dependence on these services is often undervalued (Peh et al., 2014). Studying the dependence of local people on wild flora and forests fosters a deeper understanding of the intricate relationships between humans and nature. This understanding is essential for promoting sustainable practices, conserving biodiversity, safeguarding cultural heritage, and achieving balanced and equitable development for present and future generations.



2.2. LITERATURE REVIEW



2.2. LITERATURE REVIEW

The significance of undertaking studies of floral wealth cannot be overstated. As Singh and Minoo (2003) emphasize, unknown plant species may vanish from existence without ever being known to science or humanity. This preservation of botanical knowledge traces back to the pioneering work of early explorers, exemplified by William Moorcroft (1765–1825), who embarked on one of the earliest plant collection expeditions in Himachal Pradesh. Moorcroft's efforts, documented in 1821 and spanning regions such as Kangra, Kullu, Lahaul, and Spiti, laid the foundation for subsequent botanical explorations in Himachal Pradesh (Chowdhery and Wadhwa, 1984). Through decades of research, a myriad of scholars has contributed to the knowledge base of Himachal Pradesh's floral composition and vegetation. Collett (1902), Champion and Seth (1968), Nair (1977), Chowdhery and Wadhwa (1984), Aswal and Mehrotra (1994), Dhaliwal and Sharma (1999), and Kaur and Sharma (2004) have collectively unraveled the complex mosaic of more than 3500 plant species that constitute the state's flora.

The West Himalaya region, characterized by its unique biogeographic zone, encompasses two prominent states, Uttarakhand and Himachal Pradesh. This region has received significant attention from researchers and scholars interested in studying its diverse flora and vegetation. Several workers (Adhikari et al. 1991, Adhikari et al. 1998, Adhikari et al. 2009, Mazumdar and Adhikari, 2012, Rai et al. 2012, Bhatt et al. 2020) have previously well-documented investigations on floristic diversity, vegetation community composition and structure of forests in Uttarakhand.

On a similar note, Himachal Pradesh, the other significant state within the West Himalaya region, has also been a focal point for vegetation studies. Workers such as Pant and Samant (2012), Thakur et al. (2012, 2021), Sharma and Samant (2013), Devi et al. (2019), Thakur et al. (2021), Bhardwaj et al. (2021), Rana et al. (2011), and Verma and Kapoor (2014) have diligently examined the community composition, structure, and ecological dynamics of Himachal Pradesh's vegetation.

A series of comprehensive studies has significantly expanded our understanding of the plant species richness within different regions of Himachal Pradesh. Subramani et al. (2007) conducted a meticulous floristic study within the Renuka Wildlife Sanctuary, unveiling a rich array of 395 plant species spanning 316 genera and 115 families. This collection featured 228 species with medicinal and aromatic properties, alongside 85 exotic species. These findings shed light on the sanctuary's ecological significance and potential contributions to traditional medicine and local livelihood.

In the Pooh Valley of Kinnaur, Verma and Kapoor (2010) delved into the intricacies of floristic diversity across altitudinal gradients. Their study identified 163 plant species, a noteworthy 10 of which were categorized as threatened. This exploration highlighted the vulnerability of certain species and emphasized the need for conservation efforts.

Thakur et al. (2012) explored Bandli Wildlife Sanctuary in Mandi district, revealing a diverse assemblage of 144 plant species spanning 52 families. Similarly, the Darlaghat Wildlife Sanctuary in Solan district was a subject of investigation, revealing a diverse array of 302 plant species across 99 families (Thakur, et al., 2012).

In the Theog Forest division of Shimla, Pal et al. (2014) conducted an extensive floristic inventory. Their efforts culminated in the identification of a remarkable 442 vascular plant species, illustrating the rich biodiversity concealed within these forested landscapes. In Bhabha Valley (Kinnaur), Negi and Thakur (2021) focused on woody species, recording a total of 73 species from 48 genera and 27 families.

Naik et al. (2021) conducted a study into Col. Sher Jung National Park, offering the first systematic and comprehensive account of its floral diversity. Their findings unveiled a total of 184 species, comprising 63 tree species, 42 shrub species, 42 herb species, 22 grass species, 5 sedge species, 3 fern species, 6 climber species, and 1 creeper species dwelling within the park's boundaries.

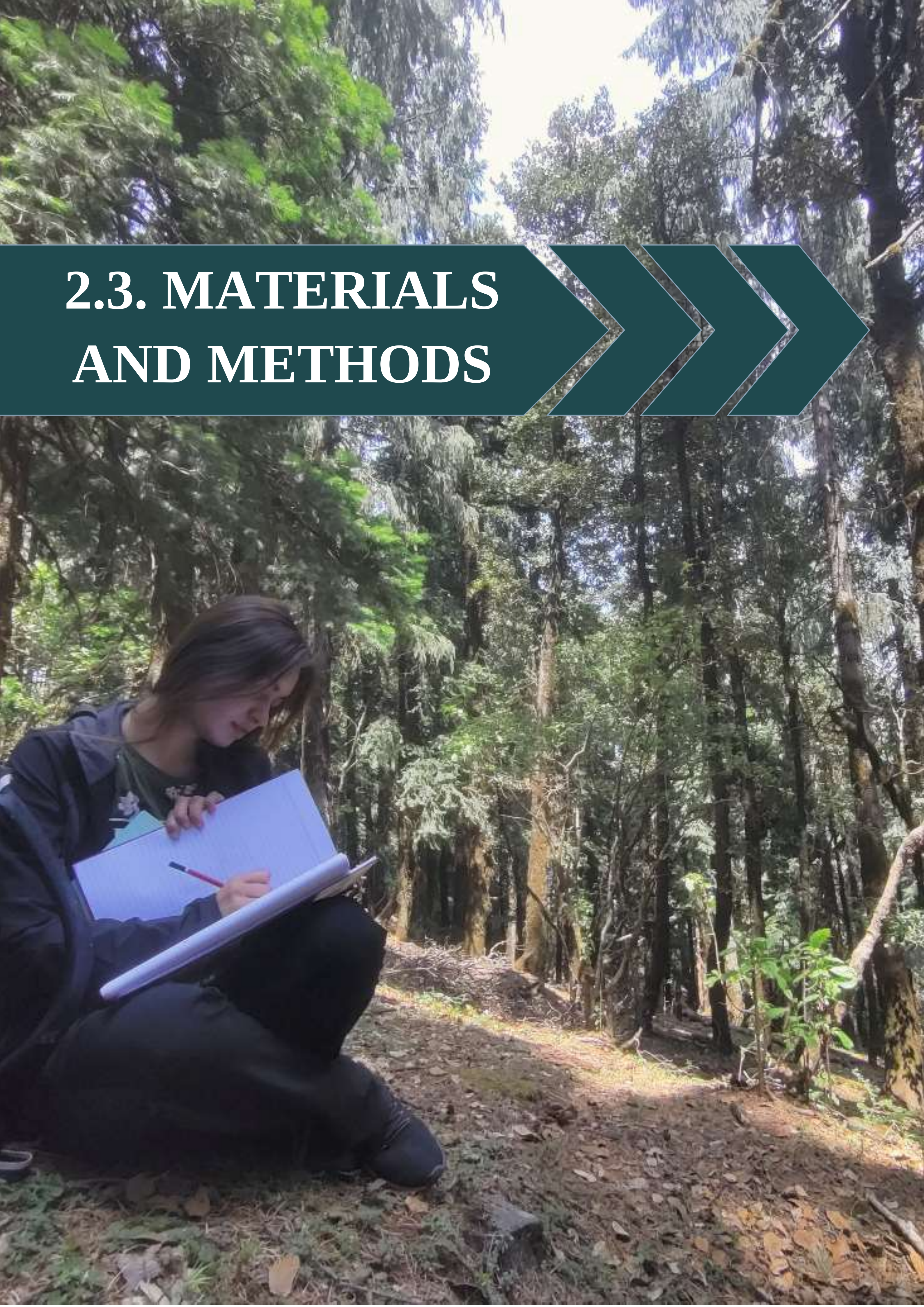
Chaudhary and Lee (2012) focused their study on Churdhar Wildlife Sanctuary, presenting detailed insights into its arboreal, shrub, and herb layers, in addition to highlighting medicinal and economically valuable plant species. Subramnai et al. (2014) advanced this knowledge further, identifying a total of 352 phanerogam species, which included 251 dicotyledons, 97 monocotyledons, and four gymnosperm species within the sanctuary. Puri et al. (2019) embarked on an ethno-medicinal investigation within the Churdhar Wildlife Sanctuary, revealing 41 medicinal plant species distributed across different families, including 24 herbs, 8 shrubs, 7 trees, and 2 climbers.

Dey et al. (2021) conducted an in-depth assessment of floral diversity in Chandratal Wildlife Sanctuary, documenting a list of 125 vascular plant species. Meanwhile, within Pin Valley

National Park, Targe et al. (2022) carried out an extensive study, revealing a notable usage of forty-seven endangered plant species in treating various ailments. A prominent condition treated was osteoarthritis (12%), accompanied by a significant decline in the Amchi population by 45% over recent decades.

These studies have undeniably enriched our understanding of the diverse plant species, their distributions, ecological interactions, and potential benefits in Himachal Pradesh. However, continued research in Himachal Pradesh remains vital to fill the existing knowledge gaps, track changing ecosystems, assess threats in changing environments and inform conservation strategies, building on the foundation laid by previous studies.

2.3. MATERIALS AND METHODS



2.3. MATERIALS AND METHODS

2.3.1 Study area

- **Col. Sher Jung National Park (CSJNP)**

Col. Sher Jung National Park (CSJNP) is situated in the Paonta valley of Sirmaur district within the lower hill region of the Shiwalik ranges in the Indian Himalayas (Figure 2.1). The park spans an area of 27.88 square kilometers and encompasses an elevation range of 350 meters to 700 meters above mean sea level (amsl).

The climate is influenced by its proximity to the Himalayas though it retains the typical continental monsoon climate characterized by three distinct seasons viz. monsoon (July-September), winter (November -February) and summer (April-June). October (autumn) and March (spring) are the transitional periods. The temperature ranges from 4ºC - 48ºC and receives a mean annual rainfall of about 1260 mm while the relative humidity varies from 100% during monsoon to 26% in summer.

The soil is generally sandy loam varying from light gray to brown. The soil is generally sandy loam varying from light gray to brown. The hills are composed of unconsolidated silt stone, sandstone and conglomerate that are more susceptible to erosion (Naik et al., 2020).

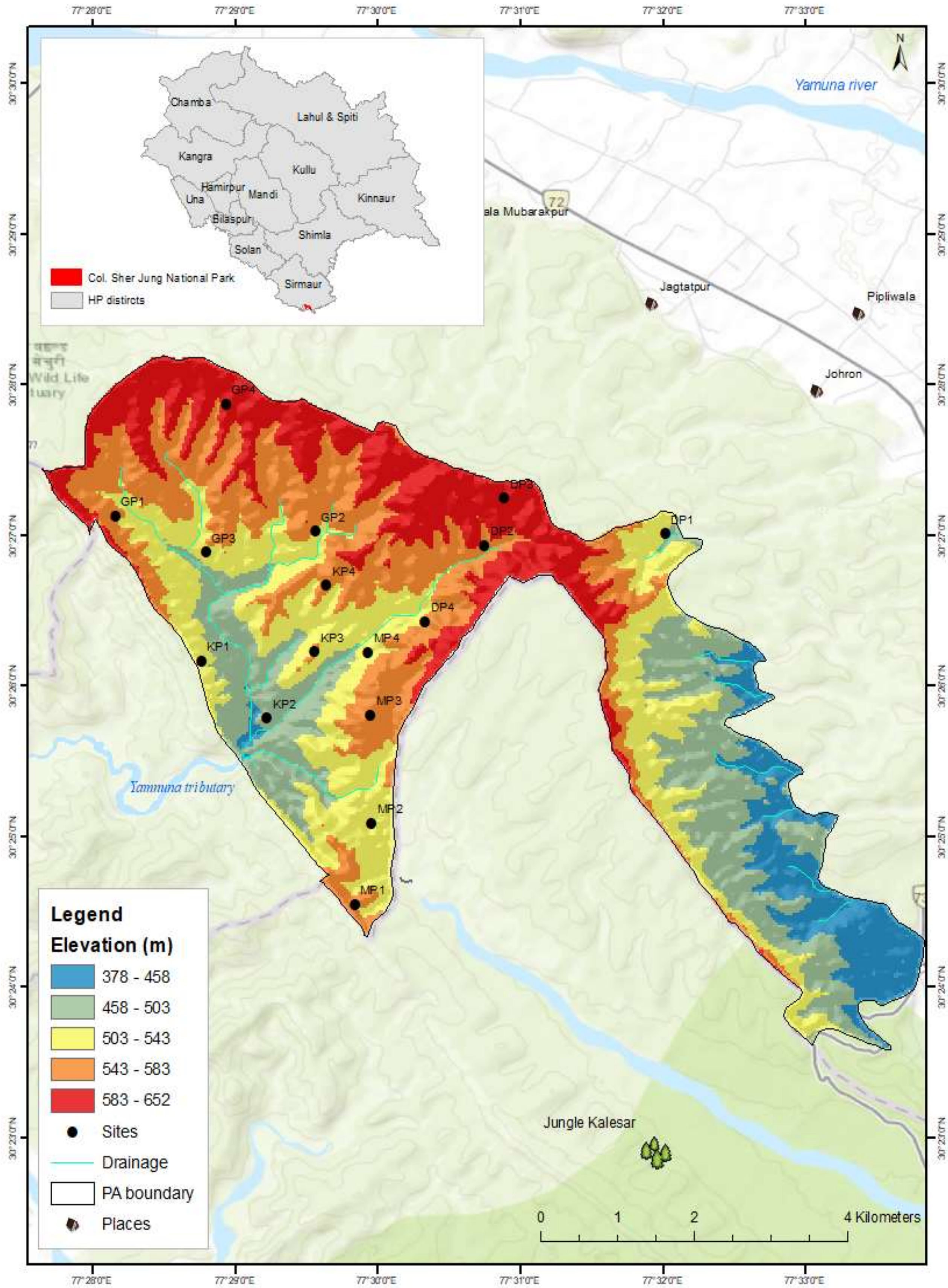


Figure 2.1: Map showing sampling locations along the elevation gradient in CSJNP, Himachal Pradesh.

- **Churdhar Wildlife Sanctuary (CWS)**

Churdhar Wildlife Sanctuary (CWS) is located in the state of Himachal Pradesh, Western Himalaya, between the geographical extremes of 77°23′32″-77°29′49″E Long and 30°48′37″-30º54′39″ N Lat, with elevation range from 1900 to 3600 masl (Figure 2). Administratively, the CWS falls under the Sirmaur (65%) and Shimla (35%) districts of Himachal Pradesh (Fig.1) with undulating and hilly terrain. According to Champion and Seth (1968), eight forest types have been identified in Himachal Pradesh (FSI 2021, HPFD 2023). Among these eight forest types, Himalayan moist temperate forest, Himalayan alpine temperate pasture, moist sub-alpine and dry alpine scrub have been found in the study area, of which Himalayan moist temperate forest largely predominates the CWS. IUCN Red listed threatened tree species of CWS in the study area includes *Taxus contorta* and *Abies spectabilis* that are categorized as Endangered and Near Threatened, respectively (Thomas 2011, Zhang et al. 2011).

Some of the faunal species viz. Goral Naemorhedus goral, Himalayan black bear *Ursus thibetanus*, barking deer *Muntiacus muntjak*, Red jungle fowl *Gallus gallus*, Rock partridge *Alectoris graeca*, Snow partridge *Lerwa lerwa*, Koklass pheasant *Pucrasia macrolopha* occurs in CWS (Eliza & Sarma 2016). Generally, the wet season approximately lasts from mid-June to mid-September, with a precipitation peak during July to September. The maximum rainfall occurs during the rainy season of which the main source is the southwest monsoon (Usha, et al. 2021). The winter season extends from mid-September to February, with the higher reaches (>3100 m) covered with snow. The maximum snowfall has been recorded during the months of December and January. The border of the CWS is surrounded by ca. 28 villages which are inhabited by natives with large cattle holdings. The CWS is very often visited by tourists and local people for religious purposes during the non-snowfall period (March – mid-November) due to the presence of a holy temple situated within the protected area. The common rock types found in the study area are sandstone, granite, limestone, gneiss and quartzite (Thakur & Bisht, 2020).

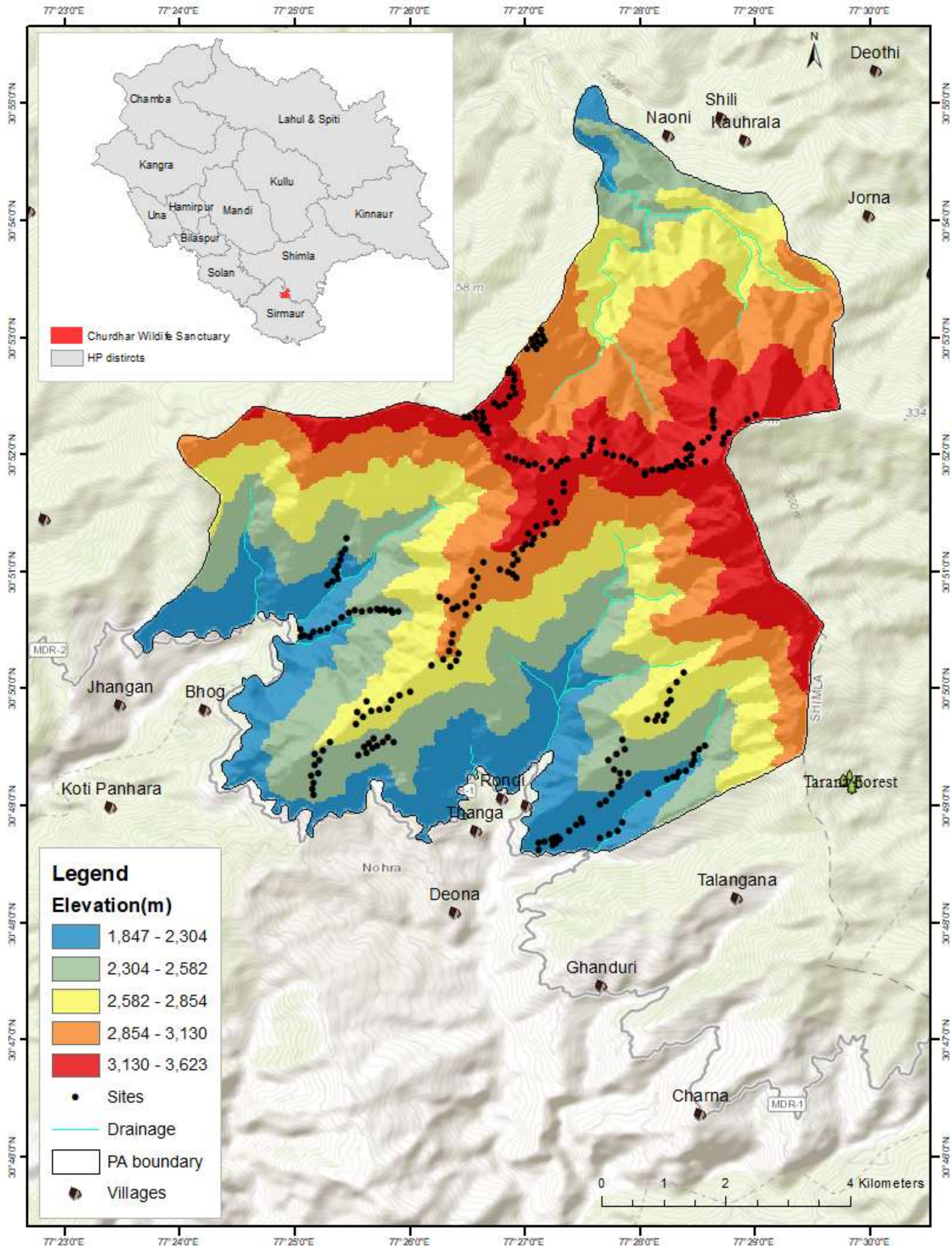


Figure 2.2: Map showing sampling sites along the elevation gradient in the CWS, Himachal Pradesh.

- **Chandratal Wildlife Sanctuary (CTWS)**

Chandratal Wildlife Sanctuary, situated in the Lahaul and Spiti district of Himachal Pradesh, India, covers an area of approximately 38.5 square kilometers and lies within the altitude range of 4,111 - 5, 601 meters above sea level. The region's isolation and extreme climatic conditions have contributed to the development of a unique ecosystem harboring an array of flora and fauna, making it a prime study area for biodiversity research. It is situated within the geo coordinates North (32°31′44″ N & 77°36′15″ E), East (32°27′42″ N & 77°38′39″ E), South (32°23′13″ N & 77°36′58″ E) and West (32°30′45″ N & 77°34′22″ E) (Figure 2.3). The Chandratal Wildlife Sanctuary falls under the Spiti Wildlife Division of Himachal Pradesh Forest Department. The sanctuary gets its name from the pristine lake, Chandratal (Moon Lake), which lies at an altitude of 4300 meters above sea level.

Chandratal region has emerged as an invaluable repository of geological knowledge, boasting an almost complete sequence of exposed sediments ranging from the Pre-Cambrian era to the Cretaceous period (Wadia, 1967). The area displays distinct shifts in rock compositions, featuring quartzite, shales, limestones, and conglomerates. The geomorphological landscape is notably intricate, characterized by an immature topography and crisscrossed by deep valleys and towering hill ranges.

The weather is arid and frigid, with intense winter snowfall and temperatures plunging as low as -45°C. Annual rainfall is scant (Singh et al., 2007). Frequent and strong winds contribute to the aridity and hinder tree growth, creating a desiccated atmosphere. Overall, the climate remains dry and cold, with a protracted winter period extending from mid-November to March.

The vegetation in CTWS is typically classified as 'alpine scrub' (Champion and Seth, 1968) or 'dry alpine steppe' vegetation (Puri et al., 1989). The open steppe is dominated by species like Stipa, Carex, Leymus, and Kobresia. However, due to the region's harsh climate, plants have a short growth season from May to August, with low temperatures prevailing during the rest of the year. Soil moisture availability becomes a crucial limiting factor for plant growth during this brief growing season (Mishra, 2001). Among the common plant species found in the Chandratal Wildlife Sanctuary, *Taraxacum* and *Bistorta* are particularly abundant.

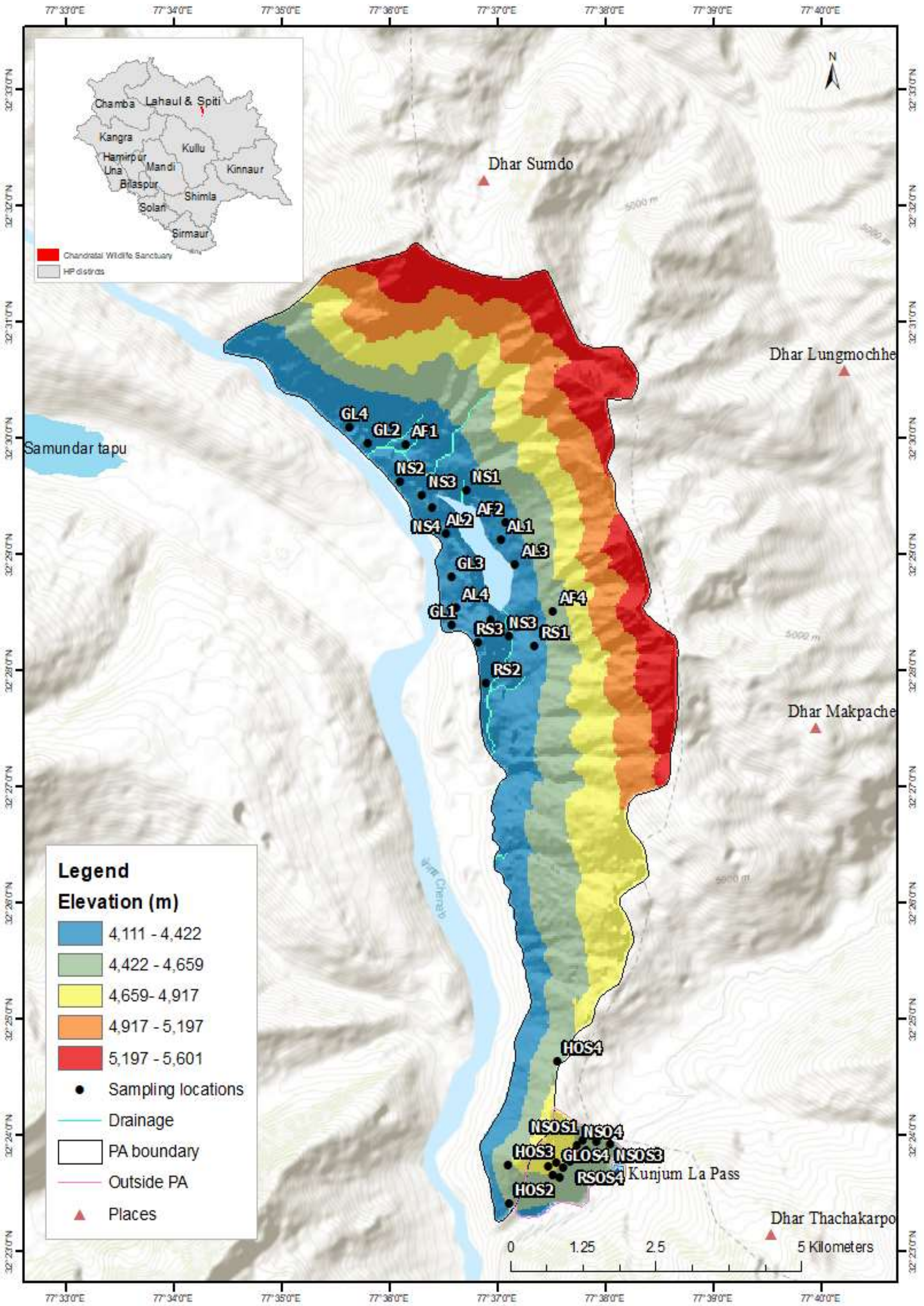


Figure 2.3: Map showing sampling sites in different landforms located inside and outside of CTWS, Himachal Pradesh.

- **Pin Valley National Park (PVNP)**

Located in the Lahaul and Spiti district of Himachal Pradesh, India, Pin Valley National Park (31°06'40" to 32°02'20" N and 77°04'21" to 7806'19" E) is a cold desert nestled in the North-West Himalayan region (Figure 2.4). The study area spans altitudes ranging from 3,341 m to 6,340 m above mean sea level, encompassing an area of approximately 1825 km2. Within this expanse, around 675 km² has been designated as the core zone (Pandey, 1991). Bounded on all sides by mountain ranges of the greater and middle Himalaya, the park shares borders with Tibet to the East, Kinnaur to the South, Kullu to the West, and Ladakh to the North.

The temperatures in this region fluctuate dramatically, ranging from -40ºC in peak winter to over 30ºC in peak summer (Murali et al., 2017). With an extreme cold, semi-arid to arid climate, the region experiences low plant productivity and a short growing season lasting about two and a half months from mid-June to August. Precipitation mainly occurs in the form of snow during winter, which begins to melt in late March.

The landscape is rocky, featuring steep slopes predominantly covered with grasses and shrubs. In this sparsely inhabited region, most villages are situated along the banks of rivers and streams (Figure 4). The region remains snowbound for over six months each year, with a brief summer lasting from mid-May to late August. Precipitation levels are low, resulting in a dry and dusty environment. The local economy thrives on agro-pastoral practices, tourism, and civil government activities, which provide employment opportunities and substantial subsidies to the population.

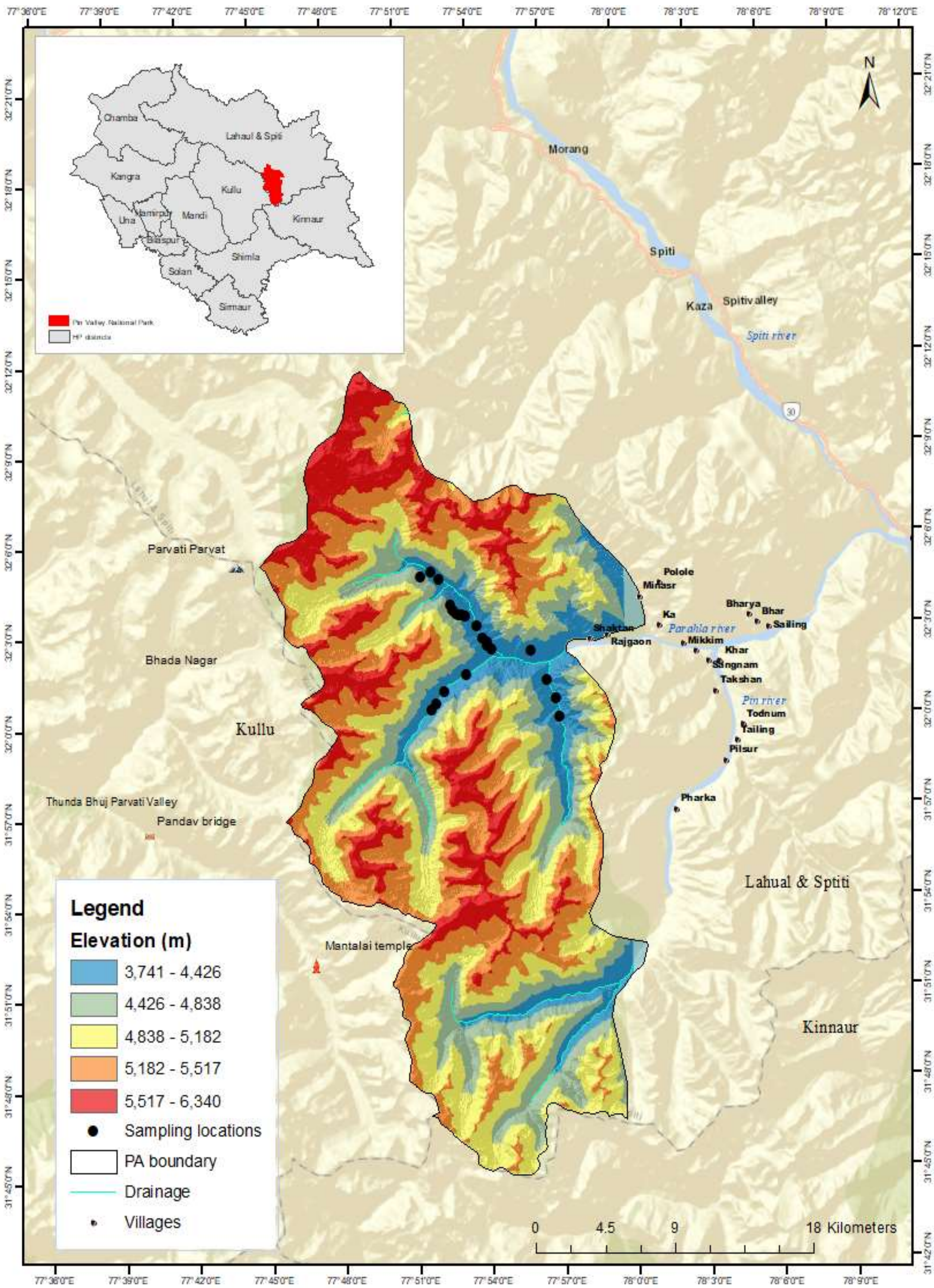


Figure 2.4: Map showing sampling locations along the elevation gradient in PVNP, Himachal Pradesh.

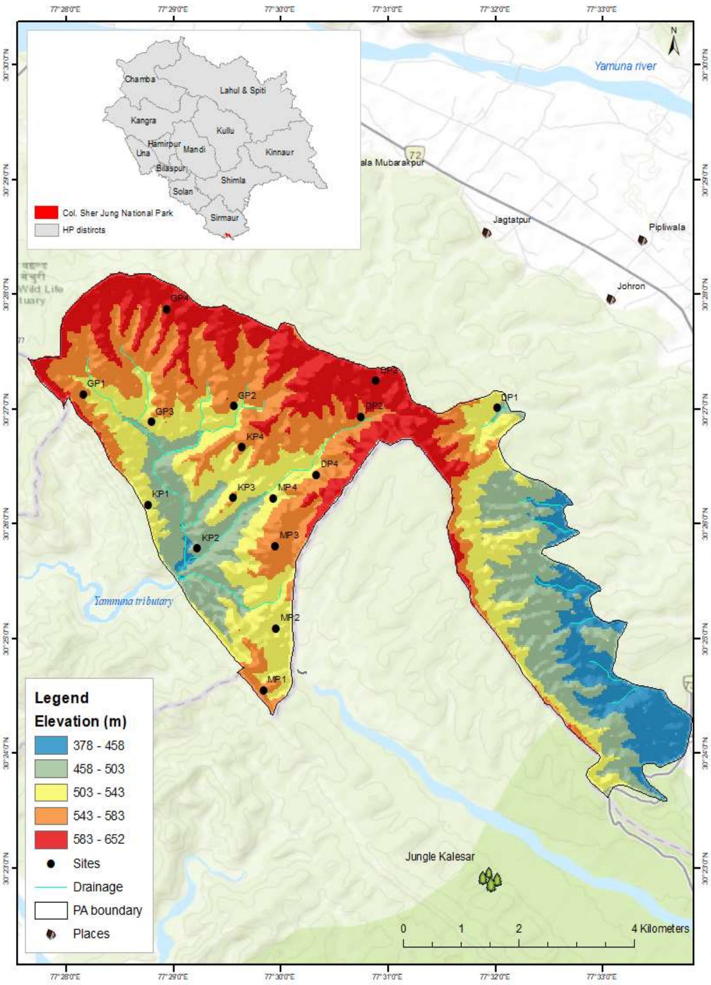
2.3.2. Vegetation sampling & data analysis

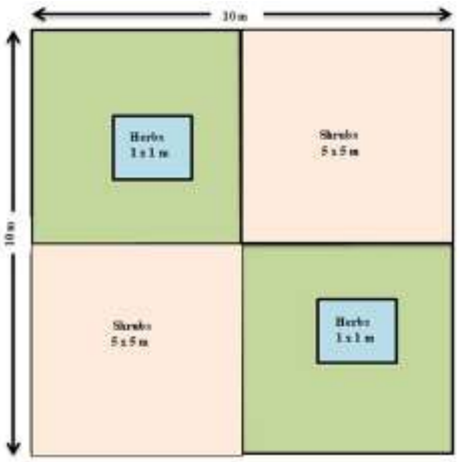
- **Col. Sher Jung National Park (CSJNP)**

The study was conducted between April-May, 2021. The sampling was done by two methods, (i) through random quadrat method and (ii) transect method. Random quadrats were carried out in the 4 forest beats (Garuk, Kaludev, Marusidh and Danda) of the national park and in each beat 4 sites having 1 ha area were selected. Within each beat 4 sites were identified for data collection. At each site, ten quadrats of 10 x 10m were randomly laid (Figure 2.5). Trees, saplings and seedlings were analyzed by using 10 x10 m size quadrat, shrubs by 5 x 5 m and herbs by 1x1m quadrats within each plot (Curtis and McIntosh 1950 and Phillips 1959). Circumference at breast height (cbh at 1.37m from the ground) of all the trees and saplings was measured in each quadrat.

In the transect method, 8 transects (namely T1, T2, T3, T4, T5, T6, T7 and T8) of 1 km were selected in the study area. For trees, saplings and seedlings, 6 circular plots of 15 m radius were laid in each transect at the distance of 200 m, within it, for shrubs two circular plots of 5 m radius was laid and for herbs two square quadrats of 1 X 1 m was laid (Figure 2.6)

The vegetation data were quantitatively analyzed for frequency, density, abundance (Curtis and McIntosh, 1950), relative frequency, relative density and relative basal area represented as Importance Value Index (IVI) for the various species and for the forest sites (Curtis, 1959) by using following expressions (Curtis and McIntosh, 1950).

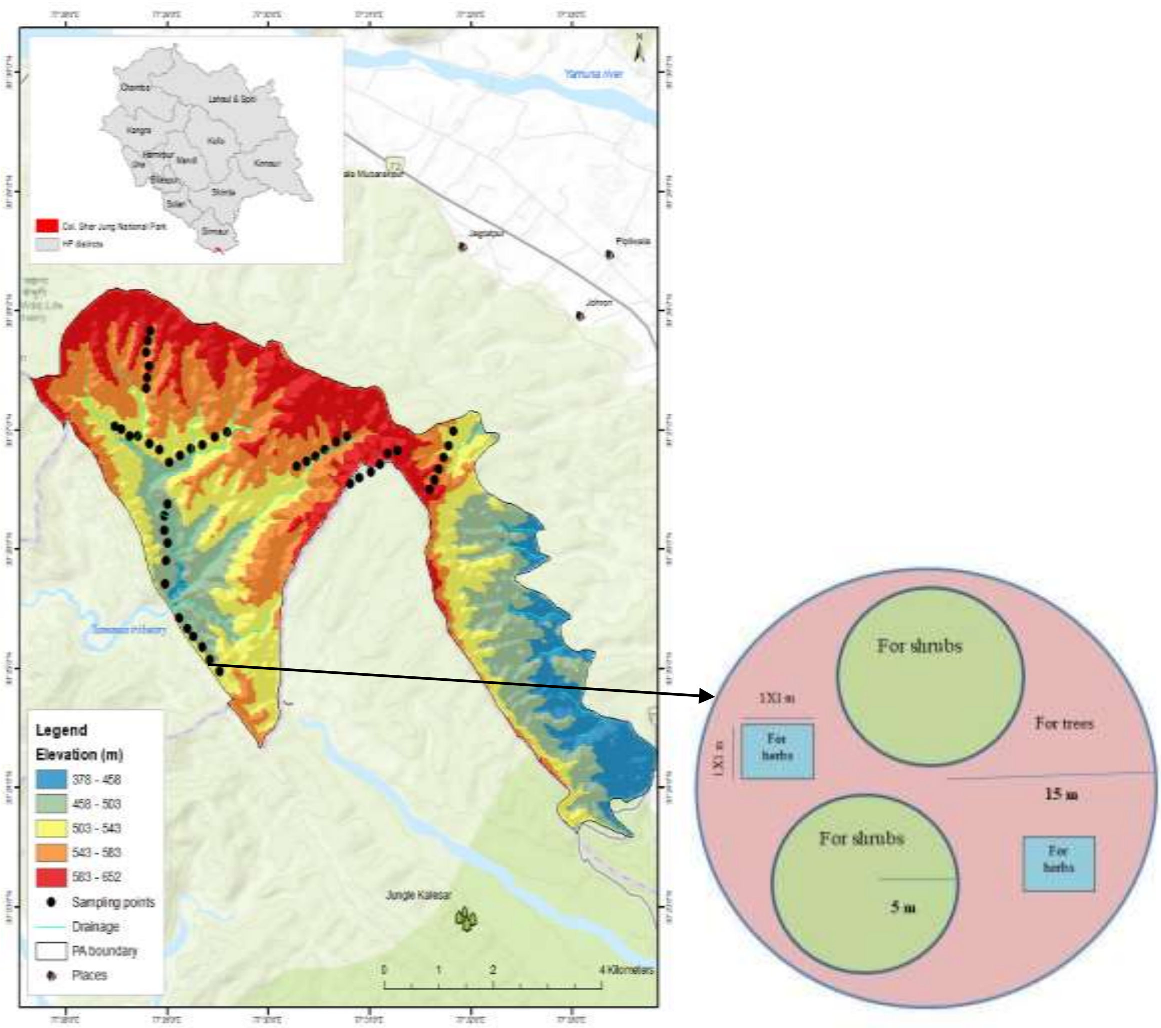




Col. Sher Jung National Park

Garuk Beat	Kaludev Beat	Marusidh Beat	Danda Beat
GP1, GP2, GP3, GP4	KP1, KP2, KP3, KP4	MP1, MP2, MP3, MP4	DP1, DP2, DP3, DP4

Figure 2.5: Schematic representation of quadrat method for different vegetation layer in CSJNP, Himachal Pradesh



Col. Sher Jung National Park

T1	T2	T3	T4	T5	T6	T7	T8

Within each transect, 6 circular plots of 15 m radius were laid

Figure 2.6: Schematic representation of transect method for different vegetation layer in CSJNP, Himachal Pradesh.

The vegetation data were quantitatively analyzed for frequency, density, abundance (Curtis and McIntosh, 1950), relative frequency, relative density and relative basal area represented as Importance Value Index (IVI) for the various species and for the forest sites (Curtis, 1959) by using following expressions (Curtis and McIntosh, 1950).

$$\text{Frequency (\%)} = \frac{\text{Number of quadrats in which species occurred}}{\text{Total number of quadrats studied}} \text{X } 100$$

$$\text{Density} = \frac{\text{Total number of individuals in all the quadrats}}{\text{Total number of quadrats studied}}$$

$$\text{Abundance} = \frac{\text{Total number of individuals in all the quadrats}}{\text{Total number of quadrats in which the species occurred}}$$

- **A/F Ratio**

The distribution pattern of different species was studied using the ratio of abundance to frequency (A/F) following (Cotton and Curtis, 1956). This ratio indicates regular (less than 0.025), random (0.025-0.050) and contagious (more than 0.050) distribution of species.

$$\text{A/F ratio} = \frac{Abundance}{Frequency}$$

- **Basal Area**

The basal area and total basal area of tree species were calculated by:

Mean Basal Area of woody species (Tree/sapling) = $\frac{cbh^2}{4\pi}$

Total basal area = Mean basal area of a species x density of that species

- **Important Value Index (IVI)**

The calculation of the Importance Value Index (IVI) of the vegetation was done by computing the relative frequency, relative density, relative domination, relative abundance, relative basal area following (Curtis, 1959).

$$\text{Relative Frequency (RF)} = \frac{Number\ of\ occurrence\ of\ the\ species}{Number\ of\ occurrence\ of\ all\ species} \text{ x } 100$$

$$\text{Relative Density (RD)} = \frac{Number\ of\ the\ individual\ species}{Total\ number\ of\ the\ individuals\ of\ all\ species} \text{ x } 100$$

$$\text{Relative dominance (RDm)} = \frac{TBA\ \ of\ the\ individual\ species}{Sum\ of\ TBA\ of\ all\ species}\ X\ 100$$

The Importance Value Index (IVI) of trees was calculated by using the value of the relative frequency (RF), relative density (RD) and relative basal area (MBA).

Importance Value Index (IVI) = RF + RD + RDm

For seedlings, the Provenance Value (PV) index was calculated by summing up the value of relative frequency and relative density.

Provenance value (PV) = RF + RD

Species (Shannon-Wiener Index)

Diversity is measured as the number of species occurring within an area of a given size (Huston, 1994). Species richness was taken as a count of a total number of species in a particular area. The index of diversity was calculated after Shannon & Wiener (1949). If pi is the proportion of individuals (from the sample total) of species i.e., then diversity (H') is,

$$H' = -\sum_{i=1}^{s} (Pi)(ln\ Pi)$$

Where, P is a proportion (n/N) of individual of one particular species found (n) to a total number of individuals found (N), ln is a natural log, ∑ is sum of the calculations, and s is a number of species.

- **Concentration of dominance (Cd)**

Simpson (1949) purposed for the first time a widely used index, which varies inversely with species heterogeneity, and in fact measures the concentration of dominance (Cd) and was calculated as:

Cd = (Ni/N)2

Where, Ni=total number of individuals of a species.

N = total number of individuals of all species.

- **Equitability or Evenness (e)**

It represents the distribution of individuals among the species and calculated by Pielou (1966).

e=H'/lnS

Where, H'=Shannon index and

S=number of species

- **TWINSPAN**

analysis was performed using the R package for Two-way indicator analysis (Hill 1979) which divides the vegetation into distinct communities. This R package utilizes the similar Fortran code, but allows using TWINSPAN from R together with other R functions for community ecology and statistics. A dendrogram was prepared using the ‘factoextra’ package in R studio. Then, species, richness, diversity and evenness for each community was calculated using paleontological Statistical Software (PAST) version 4.03.

- **Regeneration** status of individual tree species was determined on the basis of the following categories following Uma Shankar (2001):

a. Good regeneration, if seedlings>trees;

b. Fair regeneration, if seedling<trees;

c. Poor regeneration, if the species survives only at sapling stage, but not as seedling (though saplings may be less, more or equal to tree).

d. No regeneration, if a species is absent both in sapling and seedling stage, but present only as trees.

e. New, if the species has no trees but only seedling and /or saplings.
f. No regeneration, if a species is absent both in sapling and seedling stage, but present only as trees.

g. New, if the species has no trees but only seedling and /or saplings.

- **Churdhar Wildlife Sanctuary (CWS)**

A rapid reconnaissance survey of the study area was carried out during June to October in 2022. The data was collected using the random sampling quadrat method following Misra (1968). A total of 230 sites were selected and vegetation was sampled by laying 10 quadrats of 10 ×10m (100 m^2) size in each (hectare plot) site selected for the study. A sampling of shrub species was done by marking sub-quadrats of 5 × 5 m within 10 × 10 m quadrats. Circumference at breast height (cbh i.e. 1.37m above the ground) was measured for each individual tree. The density, frequency and total basal area was calculated following Mueller-Dombois and Ellenberg

(1974), while, Importance Value Index (IVI) was calculated by summing up the relative values of density, frequency and total basal area as per Curtis (1959).

TWINSPAN analysis was performed to divide the vegetation into distinct communities using the R package. Species, richness, diversity and evenness for each community was calculated using paleontological Statistical Software (PAST) version 4.03.

- **Chandratal Wildlife Sanctuary (CTWS)**

The study was conducted from mid-August to mid-October 2021, focusing on the collection and recording of plant species within and outside the protected area (PA). Plant species were systematically collected and documented for various landforms present both inside and outside the protected area (PA), as shown in Table 1. For the vegetative analysis, four replicates of each site were selected. A total 25 plots of 1 x 1 meter were randomly established for analyzing the herbaceous vegetation. Trees and shrubs were not present in the study area. The methods used for vegetation analysis followed standard techniques as described by Curtis and McIntosh (1950), Phillips (1959), Mueller-Dombois and Ellenberg (1974), Kent and Coker (1992).

- **Pin Valley National Park (PVNP)**

Within the protected area, 29 plots of 1 x 1 meter were randomly established for analyzing the herbaceous vegetation (Figure). Trees and shrubs were not present in the protected area. Furthermore, a survey was conducted to study resource utilization in the villages adjacent to Pin Valley National Park, involving the local residents of seven villages (Table 2.2). A semi-structured questionnaire survey was administered to 30% of the households in each village. The survey primarily focused on collecting information related to the available resources and their various uses within the community. The respondents were randomly selected and interviewed to ensure a representative sample for the study.

Table 2.1: Type of landforms along with their latitude in decimal degrees North, longitude in decimal degrees East, found within and outside of CTWS, Himachal Pradesh.

Land forms	**Abbreviation**	**Latitude (DD)**	**Longitude (DD)**
Within PA			
Alluvial fan	AF	32.46888 - 32.501674	77.60169 - 77.62060
Around lake	AL	32.47589 - 32.485418	77.61104 - 77.61740

Near stream	NS	32.47446 - 32.49865	77.60001 - 77.61734
Road side	RS	32.46091 - 32.47393	77.60932 - 77.61790
Grassland	GL	32.46864 - 32.50257	77.59273 - 77.61619
Outside PA			
Hill Outside	HOS	32.39386 - 32.40970	77.61844 - 77.63059
Near stream Outside	NSOS	32.39112 - 32.39685	77.63430 - 77.63714
Road side Outside	RSOS	32.39079 - 32.39521	77.63177 - 77.63526
Grassland Outside	GLOS	32.39365 - 32.39578	77.63263 - 77.63429

Table. 2.2: List of villages along with their latitude in decimal degrees North, longitude in decimal degrees East (DD) and altitude (m) in Spiti valley, Himachal Pradesh.

Village	**Latitude (DD)**	**Longitude (DD)**	**Altitude (m)**
Fukchung	32.038794	78.047313	3660
Gechang	32.044598	77.994885	3780
Ka	32.046585	78.023400	3774
Khar	32.029551	78.064225	3643
Mikkim	32.037757	78.060180	3632
Mud	31.959369	78.032152	3821
Sagnam	32.029530	78.056870	3653

2.4. RESULTS

2.4. RESULTS

2.4.1 Floristic composition

- **Col. Sher Jung National Park (CSJNP)**

A comprehensive survey conducted at CSJNP reported a total of 168 plant species. Among these, 35.12% were categorized as trees, 19.64% as shrubs, 38.69% as herbs, 4.17% as climbers, and 2.38% as ferns (Figure 2.7). The analysis of the overall vegetation indicated that the highest number of species belonged to the herb growth form, followed by trees, shrubs, climbers, and ferns. In terms of plant families, Poaceae emerged as the richest family, with the highest number of individuals recorded, followed by Fabaceae and Asteraceae (Figure 2.8). Among the recorded tree species, *Tectona grandis* has been classified as endangered as per the International Union for Conservation of Nature (IUCN).

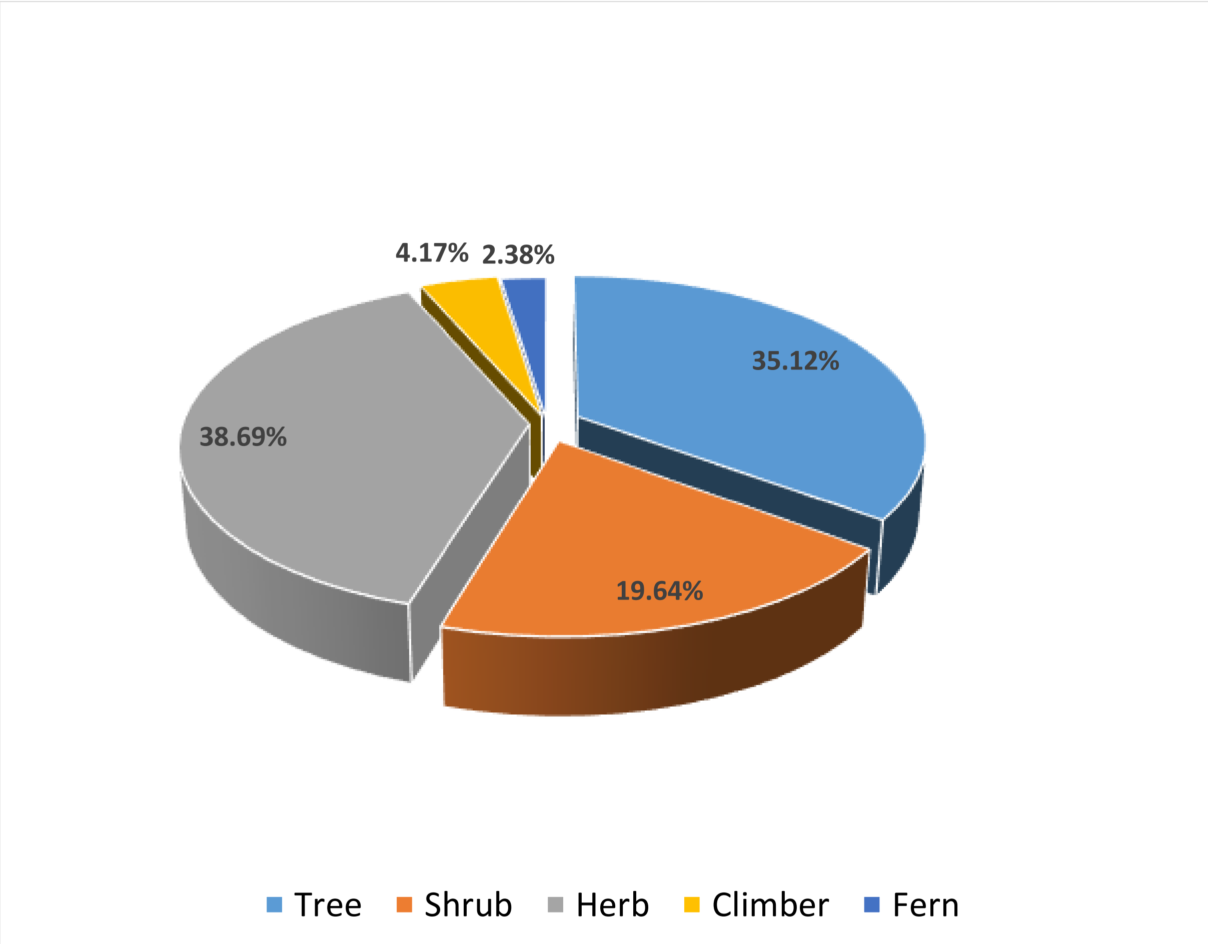


Figure 2.7: Pie chart indicating vegetation proportion of different growth forms in CSJNP, Himachal Pradesh.

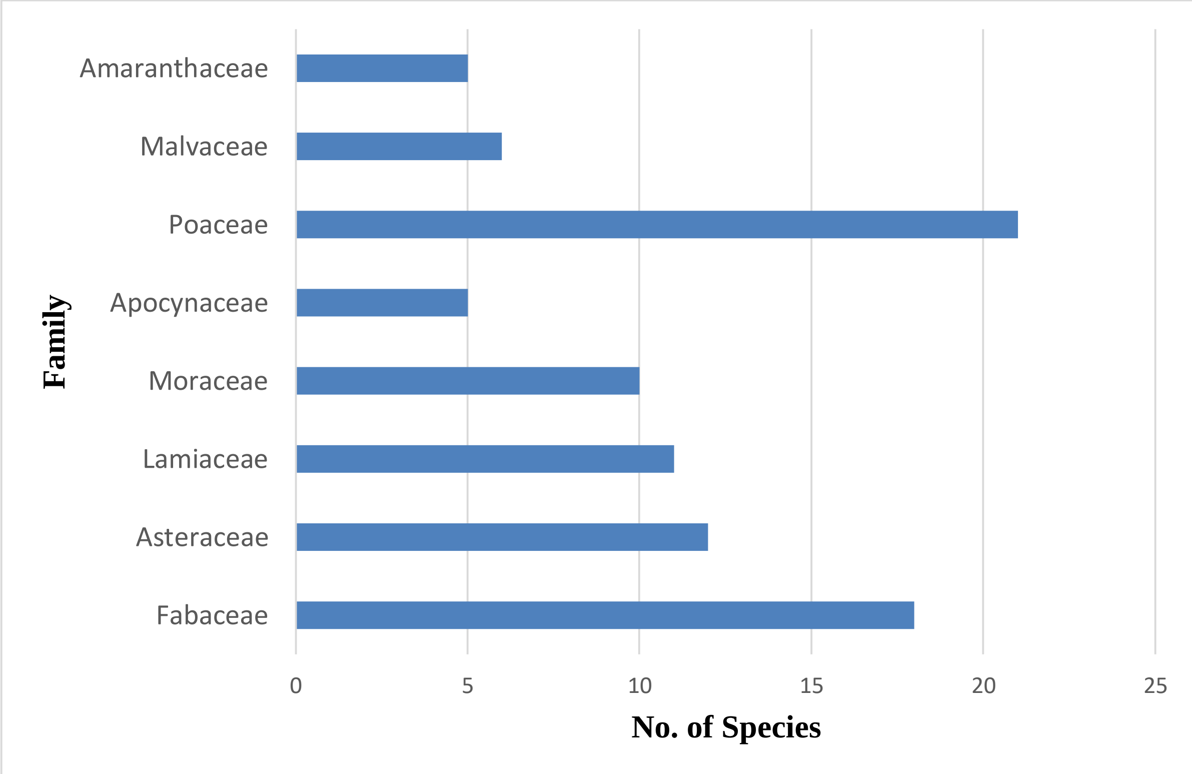


Figure 2.8: Bar graph showing number of species under dominant plant families of CSJNP, Himachal Pradesh.

- **Churdhar Wildlife Sanctuary (CWS)**

A total of 387 species were recorded from Churdhar WLS, of which 69% were herbs, 14% were shrubs, 10% were trees, 4% were climbers, and 3% were ferns. The results indicated that the maximum herb species were present in the study area, followed by shrubs, trees, climbers, and ferns (Figure 2.9). Asteraceae was the richest family having the highest (21 individuals) number of individuals followed by Rosaceae (16 individuals) and Poaceae (15 individuals) (Figure 2.10). During the field survey, we encountered threatened species such as *Taxus contorta* that has been classified as an endangered species as per IUCN. Among herbs, threatened species include *Fritillaria cirrhosa* (Vulnerable), *Trillium govanianum* (Endangered), and *Dactylorhiza hatagirea* (Endangered).

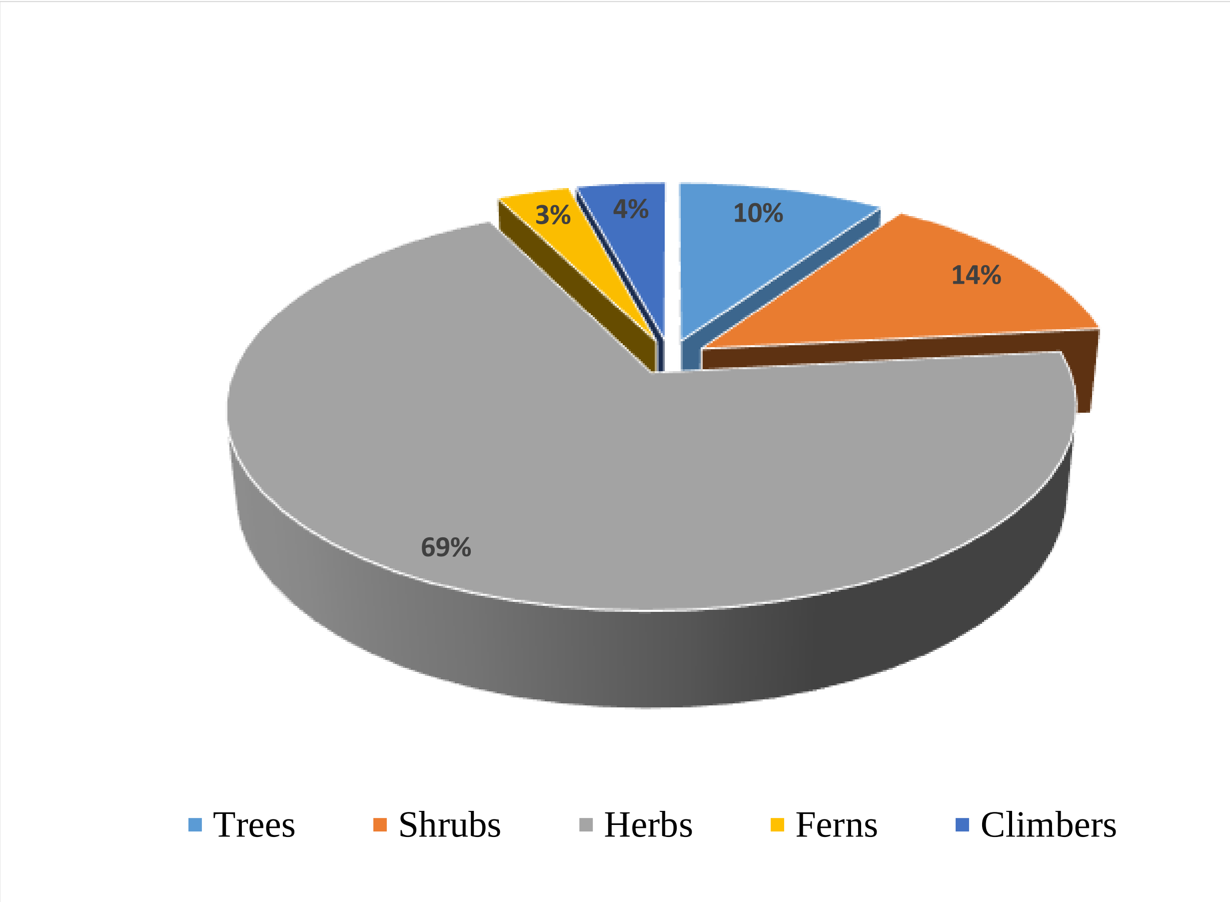


Figure 2.9: Pie chart indicating proportion of different vegetation growth forms for CWS, Himachal Pradesh.

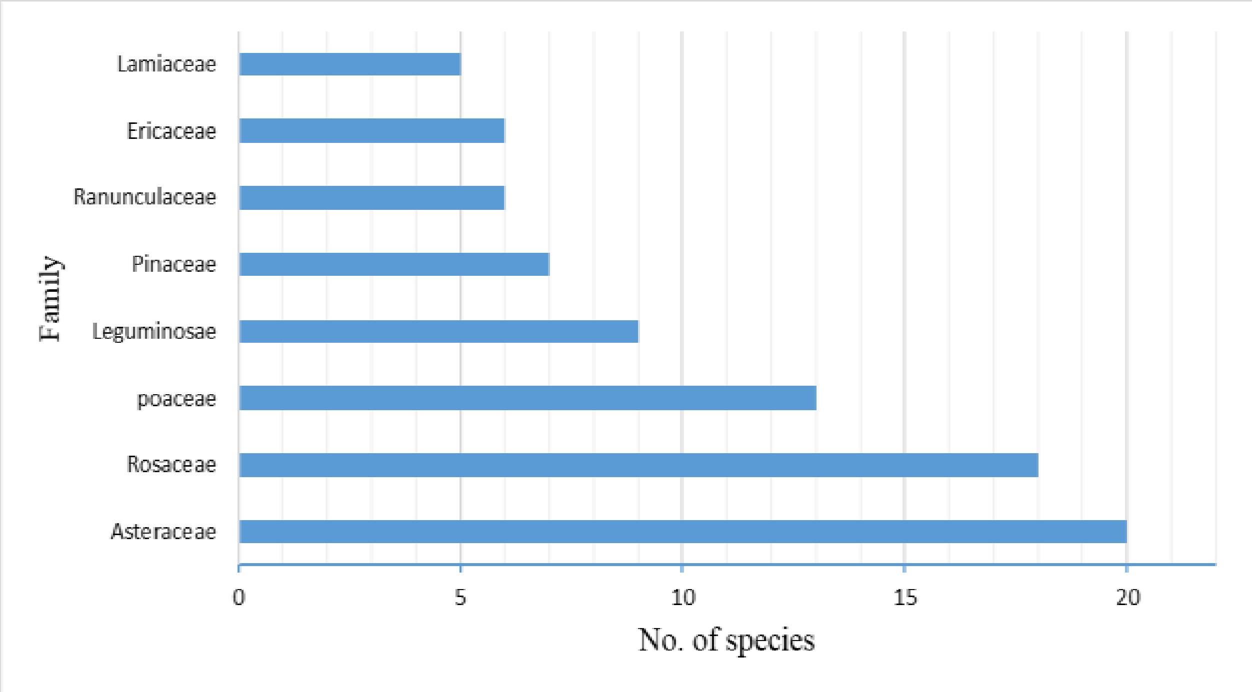


Figure 2.10: Bar graph showing number of species under dominant plant families in CWS, Himachal Pradesh.

- **Chandratal Wildlife Sanctuary (CTWS)**

A total of 62 herb species were recorded from CTWS belonging to 58 genera and 28 families. Asteraceae was the richest family with the highest (11 species) number of individuals followed by Fabaceae (6 species), Poaceae (4) and Polygonaceae (4) (Figure 2.11). Out of 62 species, 52 were reported within the protected area while 34 species were reported from outside the protected area. Inside the protected area, maximum species (23 species) were recorded in alluvial fan followed by around lake as well as near stream (20 species) and then roadside (14 species), minimum species (10 species) were recorded in grassland. On the other hand, outside the protected area, maximum species were recorded in hill outside (19 species), followed by near stream outside (15 species) and then roadside outside (13 species), minimum species (10 species) were found in grassland outside (Figure 2.12).

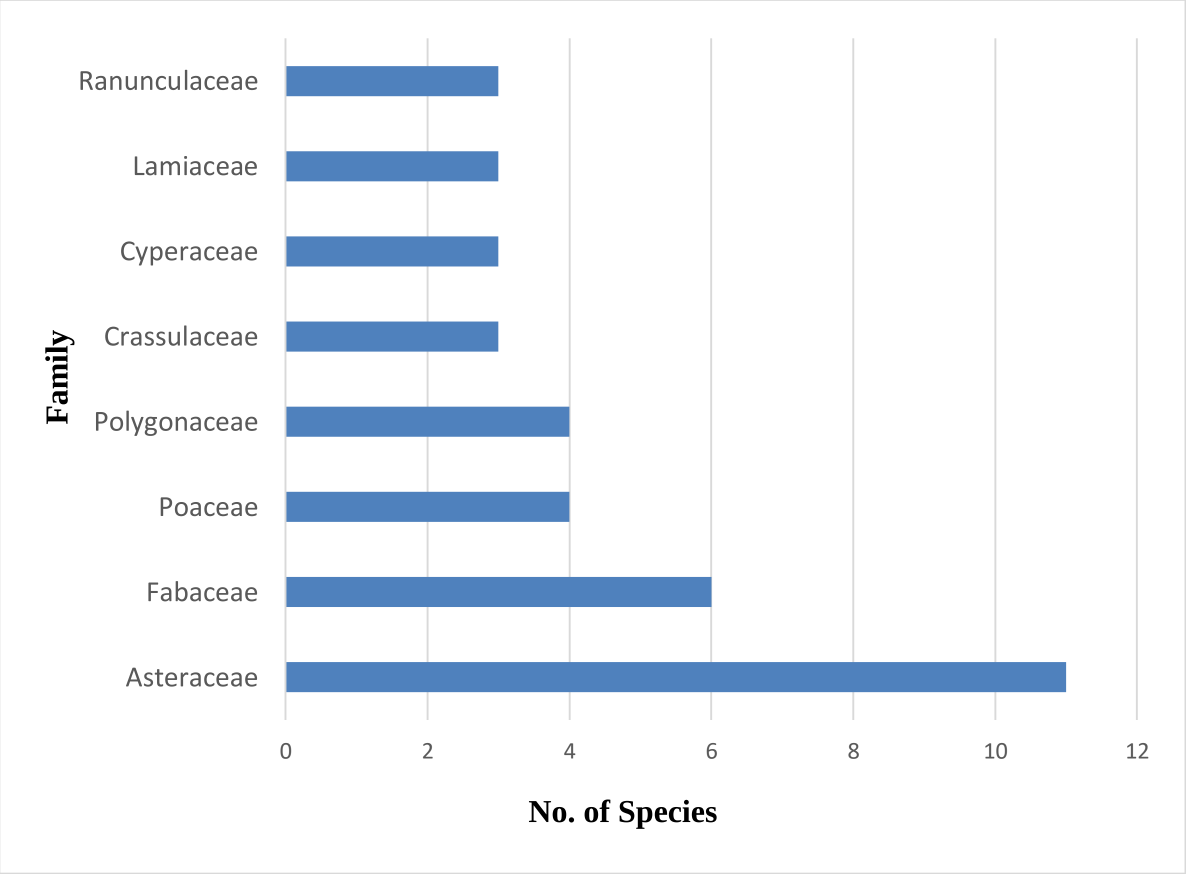
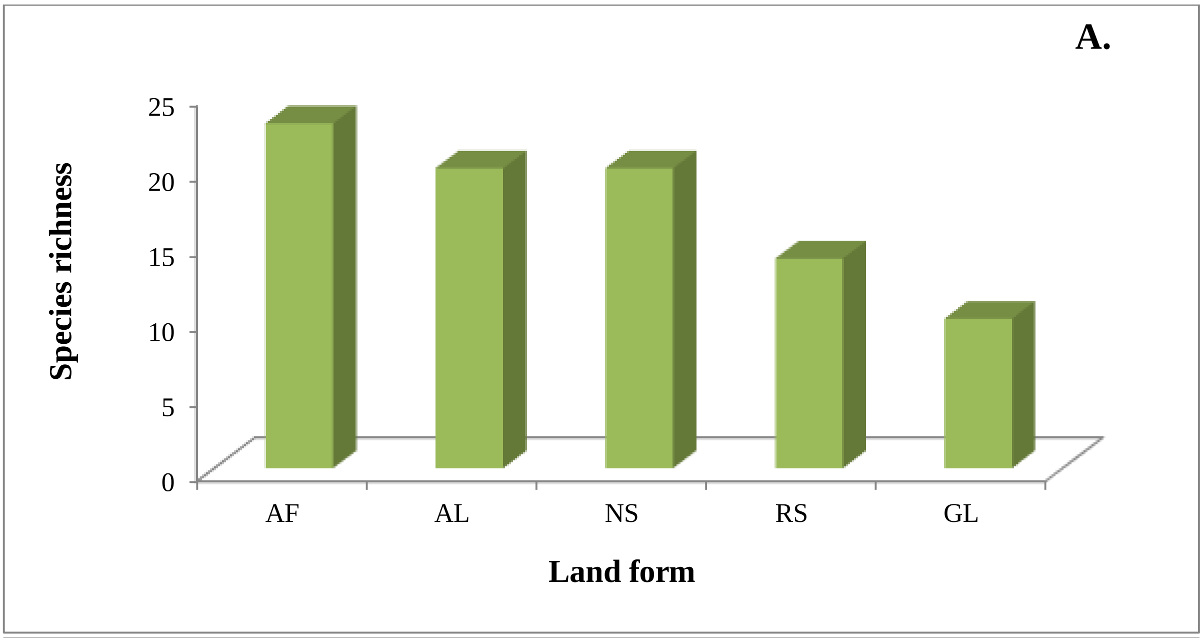


Figure 2.11: Bar graph showing number of species under dominant plant families of CTWS, Himachal Pradesh.



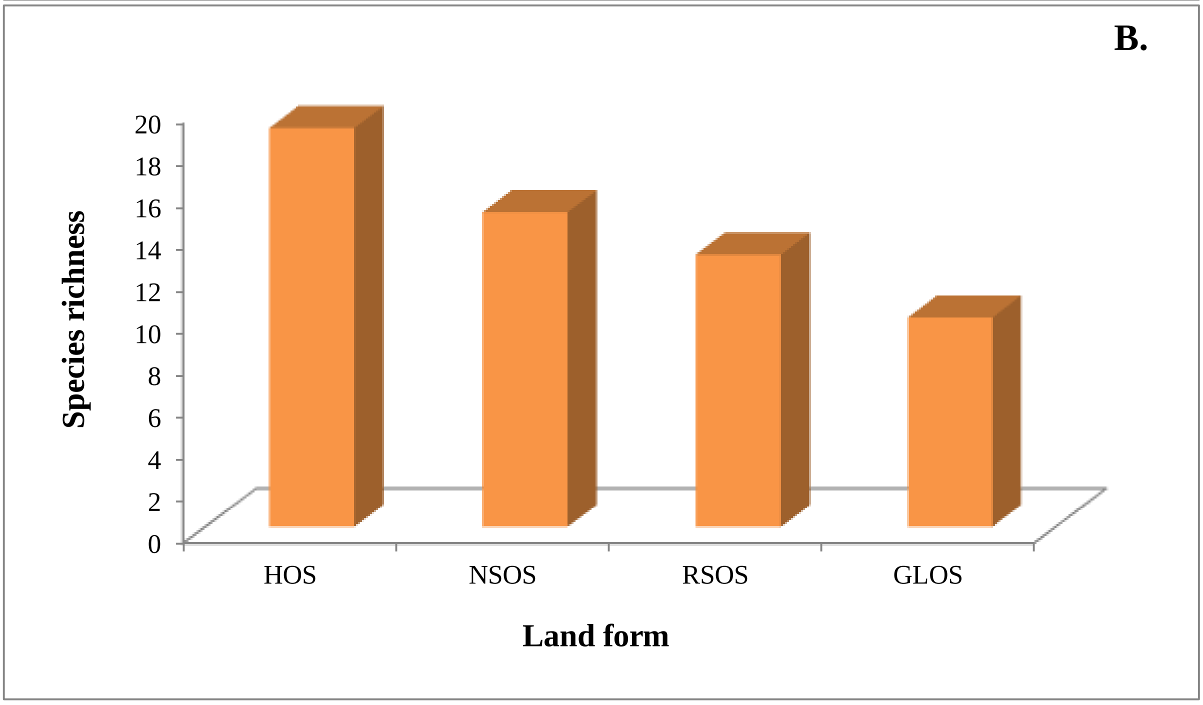


Figure 2.12: Species richness among studied landforms of a) Protected and b) Non-protected area in CTWS, Himachal Pradesh.

- **Pin Valley National Park (PVNP)**

A total of 41 herb species were recorded in the study area belonging to 33 genera and 16 families. Polygonaceae was the richest family with the highest (6 species) number of individuals followed by Poaceae (5 species), Rosaceae (4 species) and Lamiaceae (4 species) as shown in Figure 2.13.

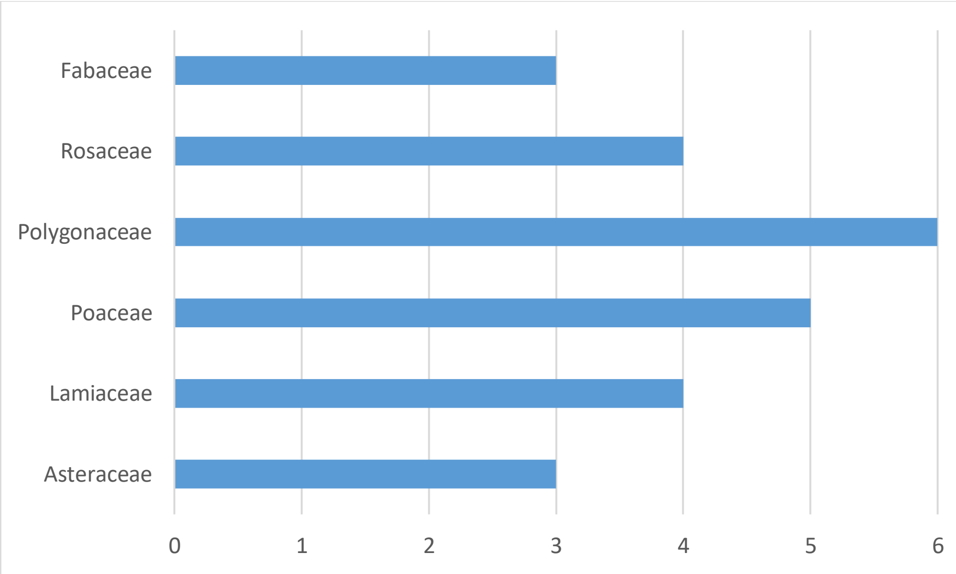


Figure 2.13: Bar graph showing number of species under dominant plant families of PVNP, Himachal Pradesh.

2.4.2. Phytosociology

- **Col. Sher Jung National Park (CSJNP)**

Community composition:

Four distinct vegetation communities were recognized based on TWINSPAN analysis as shown in Figure 2.14., where the height along the vertical axis represents the total Chi-squares of divisions. TWINSPAN is a divisive clustering based on splitting first correspondence analysis axis and then, recursively working with each split subset. The stopping point of the group formation was set at height 5, which resulted in the formation of four vegetation communities.

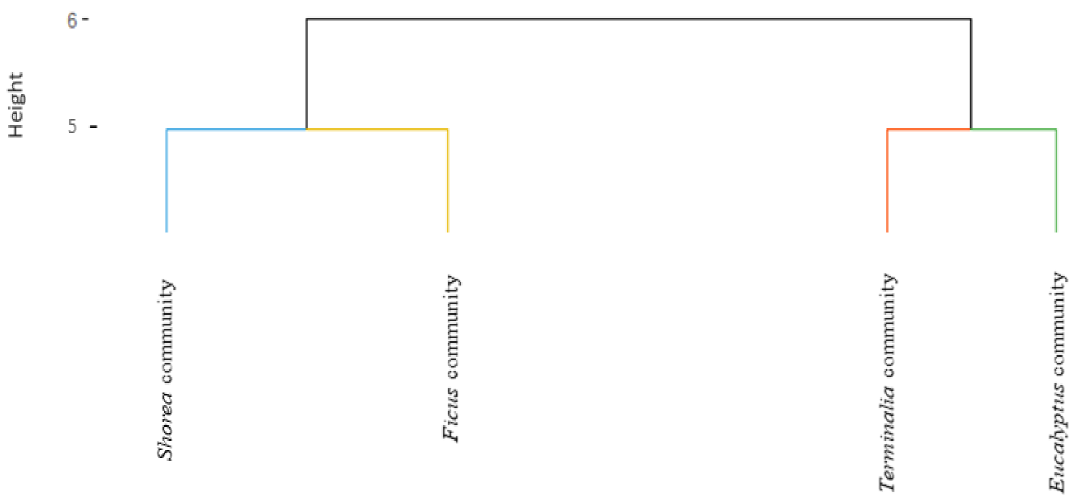


Figure 2.14: Twinspan dendrogram showing four distinct communities in CSJNP, Himachal Pradesh.

Quadrat method

Data of Species dominancy for tree, sapling and seedling layer of each beat is given in (Supplementary Table 4.)

❖ TREE LAYER

Among 43 tree species, maximum species were observed in Garuk beat, followed by Kaludev beat, Danda beat and Marusidh beat. The distribution of dominant species of the study area is given in Figure 5.

Garuk Beat:

The total tree density varied from 950 ind ha^{-1} to1090 ind ha^{-1} in GP1 and GP2 sites. The highest basal area 50.29 m^{-2} ha^{-1} was recorded for *F. racemosa* in GP3 site whereas, *Z. jujuba* showed the least basal area 0.15 m^2 ha^{-1} in GP2 site. *S. robusta* was the dominating tree species in GP1 and GP4 sites whreas, *F. racemosa* was dominant in GP2 and GP3 sites.

Kaludev Beat:

Total 26 tree species were recorded in Kaludev beat, out of which, 17 species were recorded at site KP1 site, 11 species were observed at KP2 site, 14 species at KP3 site and 17 species at KP4 site. The total tree density varied from 1010 ind ha^{-1} (KP2 site) to 1150 ind ha^{-1} (KP4 site). Total basal area varied from 0.09 m^2 ha^{-1} (*D. sisso*) to 17.09 m^2 ha^{-1} (*S. robusta*) at KP1 site, 0.17 m^2 ha^{-1} (*C. tomentosa*) to 37.00 m^2 ha^{-1} (*S. robusta*) at KP2 site, 0.83 (*C. tomentosa*) to 46.77 (*S. robusta*) at KP3 site and 0.76 (*P. humilis*) to 43.57 (*S. robusta*) at KP4 site. *S. robusta* was the dominant species at all the sites.

Marusidh Beat:

Total 21 tree species were observed in this beat, out of which 10 species were recorded at MP1 site, 15 species were observed at site MP2 site and 14 species at MP3 as well as MP4 sites. Maximum tree density was shown by *S. robusta* in all the sites. The total tree density varied from 970 ind ha^{-1} (MP1 site) to 1160 ind ha^{-1} (MP4 site). Total basal area varied from 0.16 m^2 ha^{-1} (*G. oppositifolia*) to 58.76 m^2 ha^{-1} (*T. alata*) at MP1 site, 0.24 m^2 ha^{-1} (*Z. jujuba*) to 33.17 m^2 ha^{-1} (*S. robusta*) at MP2 site, 0.63 (*P. humilis*) to 35.46 (*S. robusta*) at MP3 site and 0.58 (*P. humilis*) to 27.69 (*S. robusta*) at MP4 site. *T. alata* was dominated at MP1 site while, *S. robusta* was the dominated species at rest all the sites.

Danda Beat:

Out of the total 25 tree species, 17 species were recorded at DP1 and DP2 site, 13 species at DP3 site and 11 species at DP4 site. The total tree density varied from 930 ind ha^{-1} (DP3 site) to 1110 ind ha^{-1} (DP2 site). The values of total basal area observed between 0.62 m^2 ha^{-1} (*P.*

humilis) 4 and 5.04 m^2 ha^{-1} (*E. citriodora*) at DP1 site, 0.27 m^2 ha^{-1} (*C. fistula*) and 17.06 m^2 ha^{-1} (*S. robusta*) at DP2 site, 0.15 (*T. alata*) and 33.44 (*S. robusta*) at DP3 site and 3.12 (*M. paniculata*) and 23.66 (*S. robusta*) at DP4 site. *E. citriodora* (51.38) was the dominated at DP1, *F. racemosa* (47.76) was the dominated at DP2, *F. benghalensis* (66.70) was the dominated at DP3 and *S. robusta* (45.05) was the dominated at DP4 site.

❖ SAPLING LAYER

Garuk beat:

Out of total 07 species, maximum (05) species were recorded at GP1 and GP2 sites while, minimum species (03) at GP3 site. The total sapling density varied from 240 ind ha^{-1} (GP4 site) to 400 ind ha^{-1} (GP1 site). Total basal area varied from 0.038 m^2 ha^{-1} (*C. dichotoma*) to 0.507 (*S. robusta*) at GP1 site, 0.067 (*O. oogeinensis*) to 0.313 (*M. philippinensis*) at GP2 site, 0.141 (*S. cumini*) to 0.256 (*M. philippinensis*) at GP3 site and 0.094 (*S. cumini*) to 0.188 (*S. robusta*) at GP4 site. *S. robusta* was dominant species at GP1 and GP4 sites with the IVI values 103.33 and 85.53, respectively whereas, at site GP2 and GP3, *M. philippinensis* was the dominated species having the IVI values 83.16 and 129.67, respectively.

Kaludev beat:

At KP1 site 03 species, at KP2 site 04 species, at KP3 and KP4 sites 05 species were observed out of the total 09 species. The total sapling density varied from 240 ind ha^{-1} (KP3 site) to 390 ind ha^{-1} (KP2 site). Total basal area varied from 0.025 m^2 ha^{-1} (*D. melanoxylon*) to 0.506 m^2 ha^{-1} (*S. robusta*) at KP1 site, 0.118 m^2 ha^{-1} (*E. laevis*) to 0.582 m^2 ha^{-1} (*S. robusta*) at KP2 site, 0.041 (*E. citriodora*) to 0.291 (*S. robusta*) at KP3 site and 0.036 (*M. indica*) to 0.449 (*S. robusta*) at KP4 site. *S. robusta* was the dominant species at all the sites.

Marusidh beat:

Total 10 sapling species were observed in this beat. At MP1 site 04 species, at site MP2 site 07 species, at MP3 and MP4 sites 06 species were observed under sapling layer. The total sapling density varied from 360 ind ha^{-1} (MP2 site) to 480 ind ha^{-1} (MP3 site). Total basal area varied from 0.02 m^2 ha^{-1} (*D. melanoxylon*) to 0.55 m^2 ha^{-1} (*S. robusta*) at MP1 site, 0.06 m^2 ha^{-1} (*A. catechu*) to 0.55 m^2 ha^{-1} (*S. robusta*) at MP2 site, 0.03 (*Z. jujuba*) to 0.53 (*S. robusta*) at MP3 site and 0.05 (*C. dichotoma*) to 0.45 (*S. robusta*) at MP4 site. *S. robusta* was the dominant species at all the sites except the site MP4, which was dominated by *M. philippennsis*.

Danda beat:

Out of total 10 species, 05 species at DP1 site, 06 species at DP2 site and 04 species at DP3 as well as DP4 sites were observed. The total sapling density varied from 320 ind ha^{-1} (DP4 site) to 640 ind ha^{-1} (DP2 site). Total basal area varied from 0.10 m^2 ha^{-1} (*D. melanoxylon*) to 0.65 m^2 ha^{-1} (*M. philippensis*) at DP1 site, 0.06 m^2 ha^{-1} (*B. retusa*) to 0.78 m^2 ha^{-1} (*M. philippensis*) at DP2 site, 0.11 (*O. oojeinensis*) to 0.74 (*S. robusta*) at DP3 site and 0.14 (*M. paniculata*) to 0.46 (*S. robusta*) at DP4 site. *M. philippensis* was the dominant species at DP1 (106.52) and at DP2 (92.77) sites while S. *robusta* at DP3 (105.16) and DP4 (105.99) sites.

❖ SEEDLING LAYER

Garuk beat:

Total 13 species were recorded in this beat, from which maximum were observed in the GP3 site followed by GP1 as well as the GP4 site and GP2 site. Highest seedling density (240 ind ha^{-1}) was observed for *M. philippinensis* at GP1 site, for *S. cumini* (110 ind ha^{-1}), at GP2 site, for *M. philippinensis* and *S. cumini* (230 ind ha^{-1}) at GP3 site, and for *D. melanoxylon* and for *M. philippinensis* (170 ind ha^{-1}) at GP4 site. PV values revealed the dominance of *S. robusta* (75.64) at GP1, *S. cumini* (74.29) at GP2, *M. philippensis* at site GP3 (71.69) and GP4 (62.64).

Kaludev beat:

12 species were recorded in this beat, out of which 07 species were observed in KP1 and KP2 sites whereas, 06 species were found in KP3 and KP4 sites. The total seedling density varied from 460 ind ha^{-1} (KP3 site) to 840 ind ha^{-1} (KP1 site). *M. philippensis* was dominated at all the sites except KP4, where the dominance was shown by *S. robusta*.

Marusidh beat:

10 species were observed at site MP1 while 06 species were recorded at the rest of the sites under the seedling layer. The total seedling density varied from 640 ind ha^{-1} (MP1 site) to 760 ind ha^{-1} (MP2 site). *M. philippensis* was dominated at MP1 sites, whereas *S. robusta* was the dominated species at MP2 and MP3 sites and MP4 sites.

Danda beat:

Out of 15 species, 10 species were observed at DP1 site, 05 species at KP2 site while 06 species were recorded at DP3 and 07 species were KP4 sites under the seedling layer. The total seedling density varied from 530 ind ha^{-1} (DP4 site) to 860 ind ha^{-1} (DP3 site). *M. philippensis* was dominated at DP1, DP2 and DP4 sites whereas, *S. robusta* was the dominated species at DP3 sites.

- **SHRUB LAYER**

Garuk beat:

Total 09 shrub species were observed under this layer, out of which 04 species were present in GP1 as well as GP4 sites, 05 species were present in GP2 site and 03 species were present in GP3 site. Highest value of density was observed for *C. infortunatum* at GP1 (780 ind ha^{-1}) and GP3 (640 ind ha^{-1}) sites, for *C. oppositifolia* (900 ind ha^{-1}) at GP2 site and for *P. benghalensis* (800 ind ha^{-1}) at GP4 site.

PV values showed the dominance of *C. opaca* (57.81) at GP1 site, *C. oppositifolia* at GP2 (57.21) and GP4 (65.31) sites while, *C. infortunatum* (41.16) at GP4 site.

Kaludev beat:

Total 09 species were observed in this beat and in each site 06 shrub species were present. The total shrub density varied from 3160 ind ha^{-1} (KP4 site) to 4480 ind ha^{-1} (KP2 site). *C. infortunatum* was dominated at KP1 and KP2 sites, *C. opaca* at KP3 site whereas, *L. camara* was dominated at KP4 sites.

Marusidh beat:

Out of 10 species, 05 shrub species were observed at MP1 and MP3 sites while 06 shrub species were recorded in MP2 and MP4 sites. The total shrub density varied from 2460 ind ha^{-1} (MP1 site) to 3080 ind ha^{-1} (MP4 site). PV values revealed that *C. oppositifolia* was dominated at MP1 and MP4 sites, wehereas *C. opaca* was dominated at MP2 and MP3 sites.

Danda beat:

Total 09 shrub species were recorded in this beat, out of which 07 shrub species were observed at DP1 site, 04 species at DP2, 06 species DP3 site and 05 shrub species were recorded at DP4 site. The total shrub density varied from 2900 ind ha^{-1} (DP2 site) to 5160 ind ha^{-1} (DP1 site). *C. opaca* was dominated at DP1site, *C. oppositifolia* at DP2 and DP3 sites and *C. infortunatum* at site DP4.

Table 2.3: Shrub density (Ind ha^{-1}) recorded for different forest beats in the CSJNP, Himachal Pradesh.

Species	**Garuk**	**Kaludev**	**Marusidh**	**Danda**
A. solanacea	45	-	270	100
C. procera	105	-	50	-
C. opaca	440	770	860	860
C. infortunatum	450.0	1010.0	200.0	770.0
C. oppositifolia	645.0	630.0	880.0	1060.0
H. antidysenterica	305.0	40.0	90.0	280.0
I. heterantha	25.0	70.0	20.0	-
J. adhatoda	-	-	-	110.0
L. camara	200.0	635.0	260.0	280.0
P. benghalensis	200.0	-	-	-
R. occidentalis	-	225.0	-	200.0
V. negundo	-	70.0	135.0	-
W. fruticosa	-	50.0	50.0	30.0

- **HERB LAYER**

Dominance diversity of the herb layer is given in Figure 2.15.

Garuk Beat:

Total 18 species of herbs were recorded in this beat, out of which, 09 herb species were present in GP1 and GP4 sites while, 08 herb species were present in GP2 and GP3 sites. Maximum density (16.80 ind m^{-2}) was recorded for *A. adenophora* in MP3 site, while minimum density (0.40 ind m^{-2}) was observed for *M. extensa* in MP3 site. PV value showed the dominance of *C. dactylon* (49.13) in MP1 site, dominance of *A. adenophora* in MP2 (54.42) as well as MP3 (64.50) sites and the dominance of *D. bupleuriodes* (43.19) in MP4 site.

Kaludev beat:

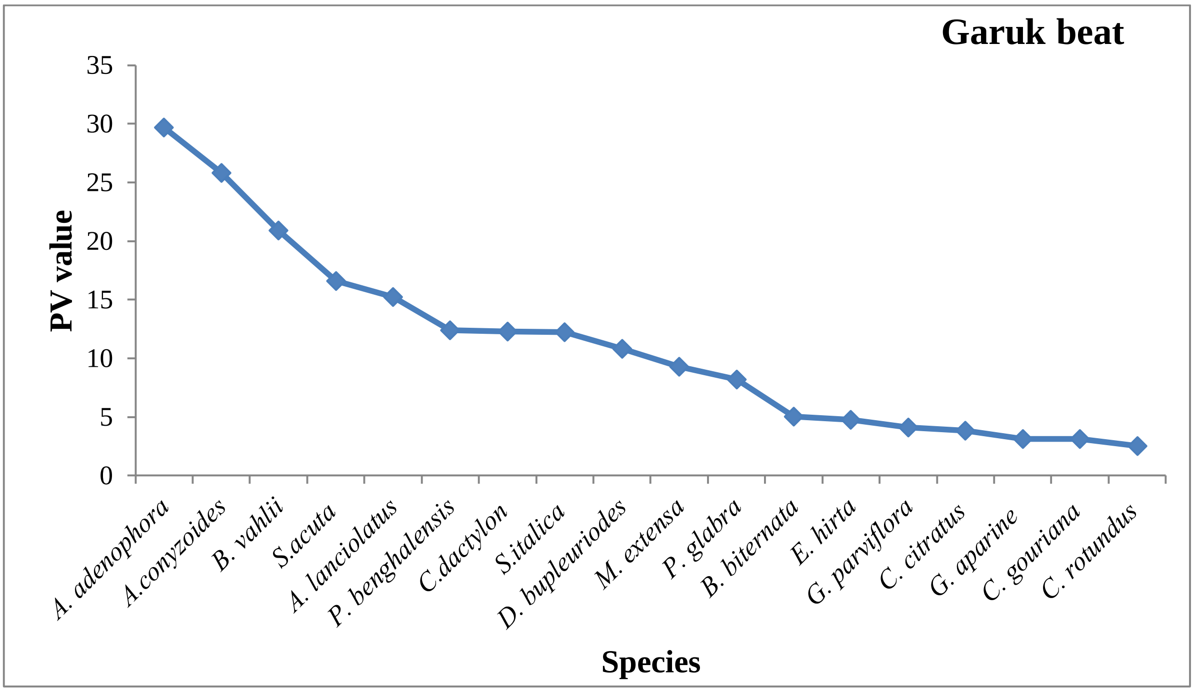
Out of 16 species, 08 herb species were observed at KP1 and KP3 sites, 07 species were recorded at KP2 and 09 species were observed at KP4 site. The total shrub density varied from 33.40 ind m^{-2} (KP2 site) to 38.80 ind m^{-2} (KP3 site). *A. lanciolatus* was dominated at KP1 and KP3 sites while, *A. adenophora* at KP2 and KP4 sites.

Marusidh beat:

Total 17 shrub species were recorded in this beat, out of which 09 species were present at MP1 and MP4 sites while, 07 species were present at MP2 and 08 species were present at MP3 site. The total herb density varied from 24.00 ind ha^{-1} ind m^{-2} (MP2 site) to 44.40 ind m^{-2} (MP3 site). *A. adenophora* was dominated at MP1 site, *B. vahlli* at MP2, *A. conyzoides* at MP3 site, and *C. zizanioides* at MP4 site.

Danda beat:

Out of total 15species, 07 herb species were observed at DP1, DP3 and DP4 sites while, 08 species at DP2 site. The total herb density varied from 25.60 ind m^{-2} (DP3 site) to 36.80 ind m^{-2} (DP2 site). PV values revealed the dominance *G. aparine* at DP1 site, *S. italica* at site DP2, *C. dactylon* at DP3 and DP4 sites.



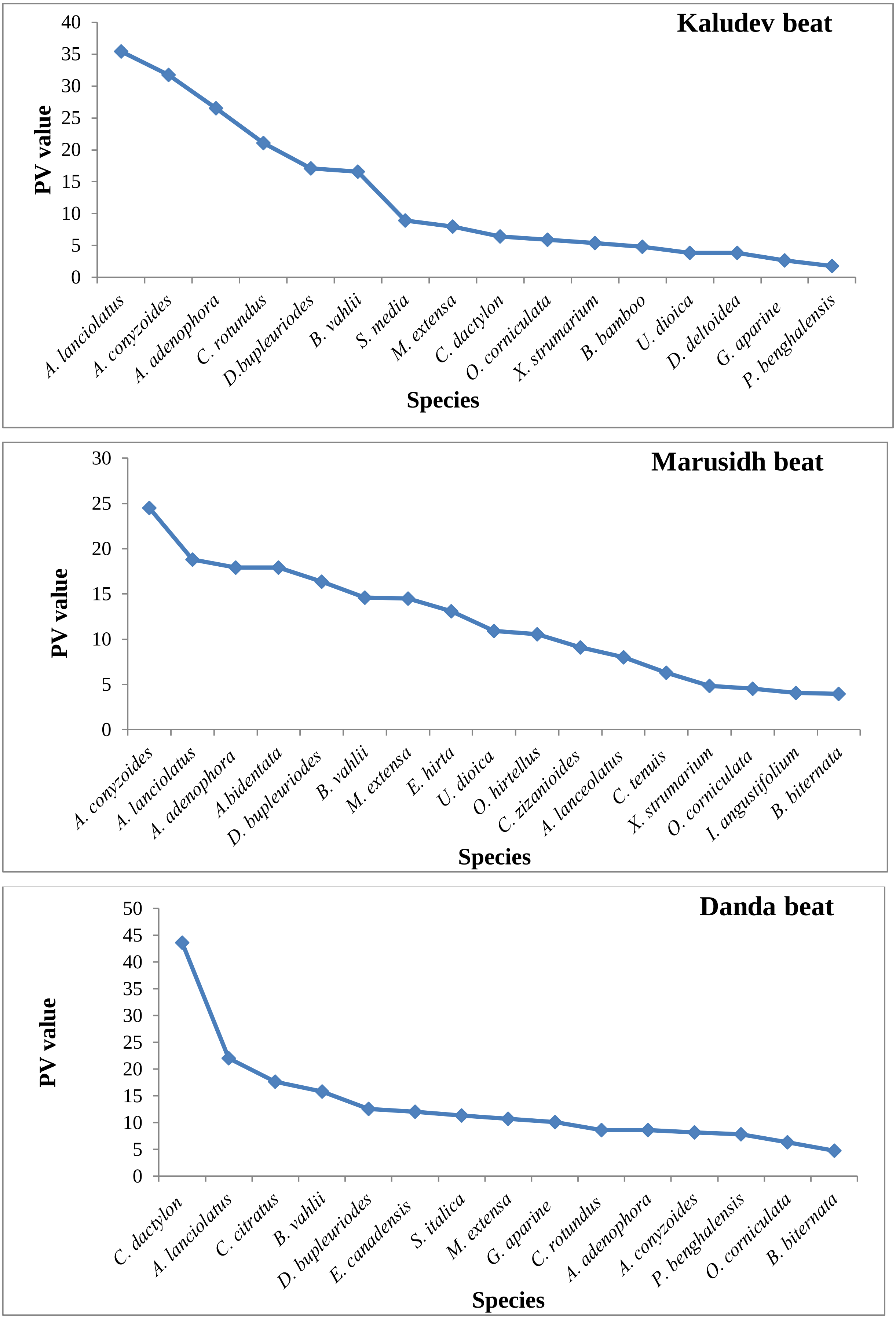


Figure 2.15: Dominance diversity curve for herb layer in CSJNP, Himachal Pradesh.

- **Transect Method**

❖ **TREE LAYER**

In all the transect sites, the total tree density varied from 650 ind ha^{-1} to1235 ind ha^{-1} in T1 and T2 sites respectively (Figure 2.16). The highest basal area 44.31 m^{-2} ha^{-1} was recorded for *S. robusta* in T4 site whereas, *D. sissoo* showed the least basal area 0.18 m^{2} ha^{-1} in T6 site. *S. robusta* was the dominating tree species in all the sites except T2 and T5 sites where M. *philippensis* was dominant tree species.

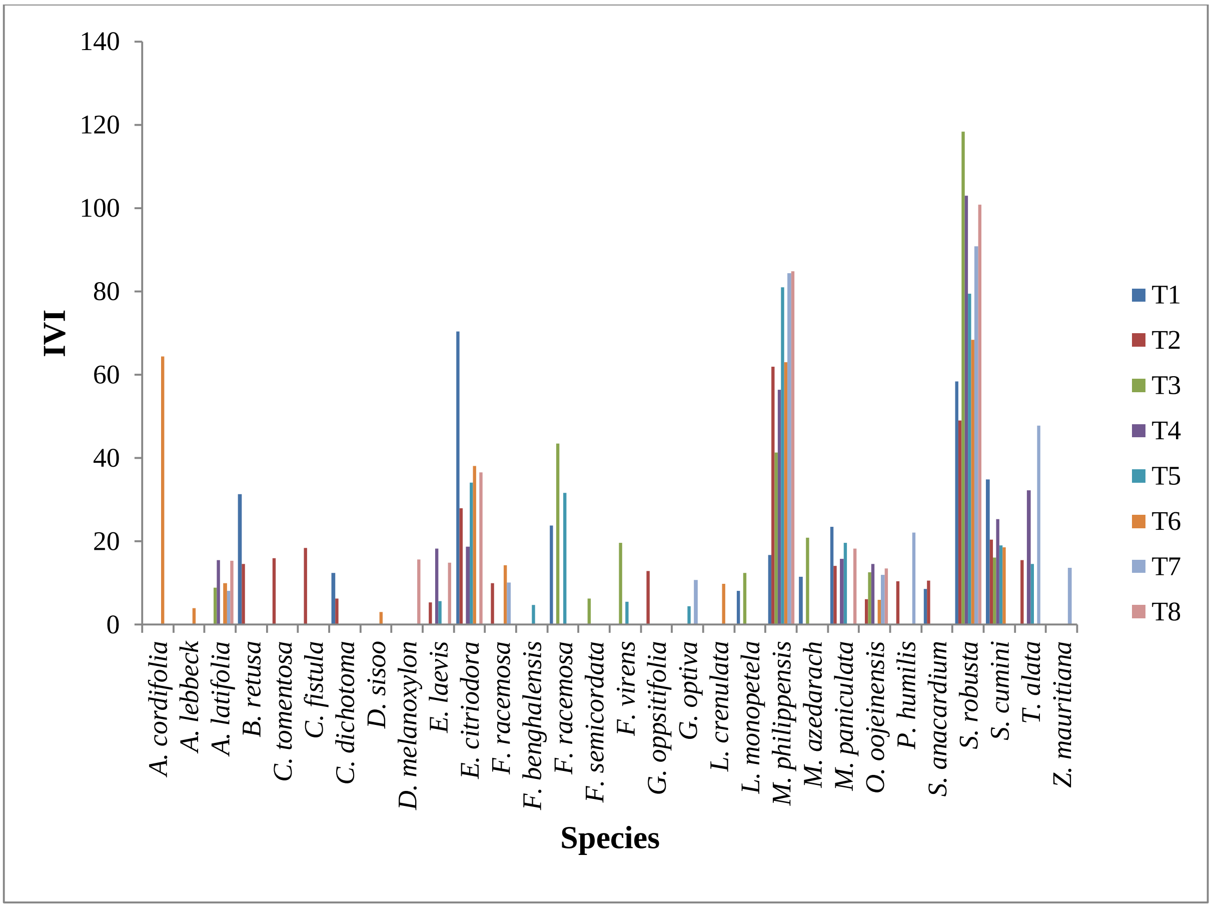


Figure 2.16: Ecological attributes of tree layer in transects in CSJNP, Himachal Pradesh.

❖ **SAPLING LAYER**

Among all the transect sites, the total sapling density varied from 613 ind ha^{-1} to 990 ind ha^{-1} in T1 and T2 sites respectively. The highest basal area 1.20 m^{-2} ha^{-1} was recorded for *S. robusta* in T7 site whereas, minimum for *C. equisetifolia* 0.02 m^{2} ha^{-1} in T1 site. *S. robusta* was the dominant species in all the sites except T1 and T3 sites where, *S. cumini* and *M. philippensis* were dominant tree species respectively (Table 2.4).

Table. 2.4: Dominancy attributes of sapling and seedling layer in CSJNP, Himachal Pradesh.

❖ SEEDLING LAYER

The values of total seedling density are observed between 532.98 ind ha^{-1} (T7) to 1094.27 (T4) ind ha^{-1}. Maximum seedling density was observed for *S. robusta* in T4 site, whereas minimum for *M. azedarach* in T1 site. *M. philippensis* was dominant species in all the sites except T1 and T8 sites where *E. citriodora* and *S. robusta* were dominant species (Table 2.4).

❖ SHRUB LAYER

Total shrub density varied from 2611 ind ha^{-1} (T4) to 3524 (T8) ind ha^{-1}. *P. benghalensis* was dominant shrub in T1, T2, T4 and T8 sites were dominated by *C. infortunatum*, T3 and T7 sites were dominated by *C. oppaca* whereas, T5 and T6 sites were dominated by *C. oppositifolia* (Figure 2.17).

❖ HERB LAYER

Total herb density varied from 21 ind m-2 to 27 ind m-2 in T4 and T1 sites. *A. adenophora* was the dominant herb in T1, T2, T5 and T7 sites, T3 site was dominated by *C. rotundus*, T4 site was dominated by *C. dactylon* whereas, T8 site was dominated by E. hirta (Figure 2.18).

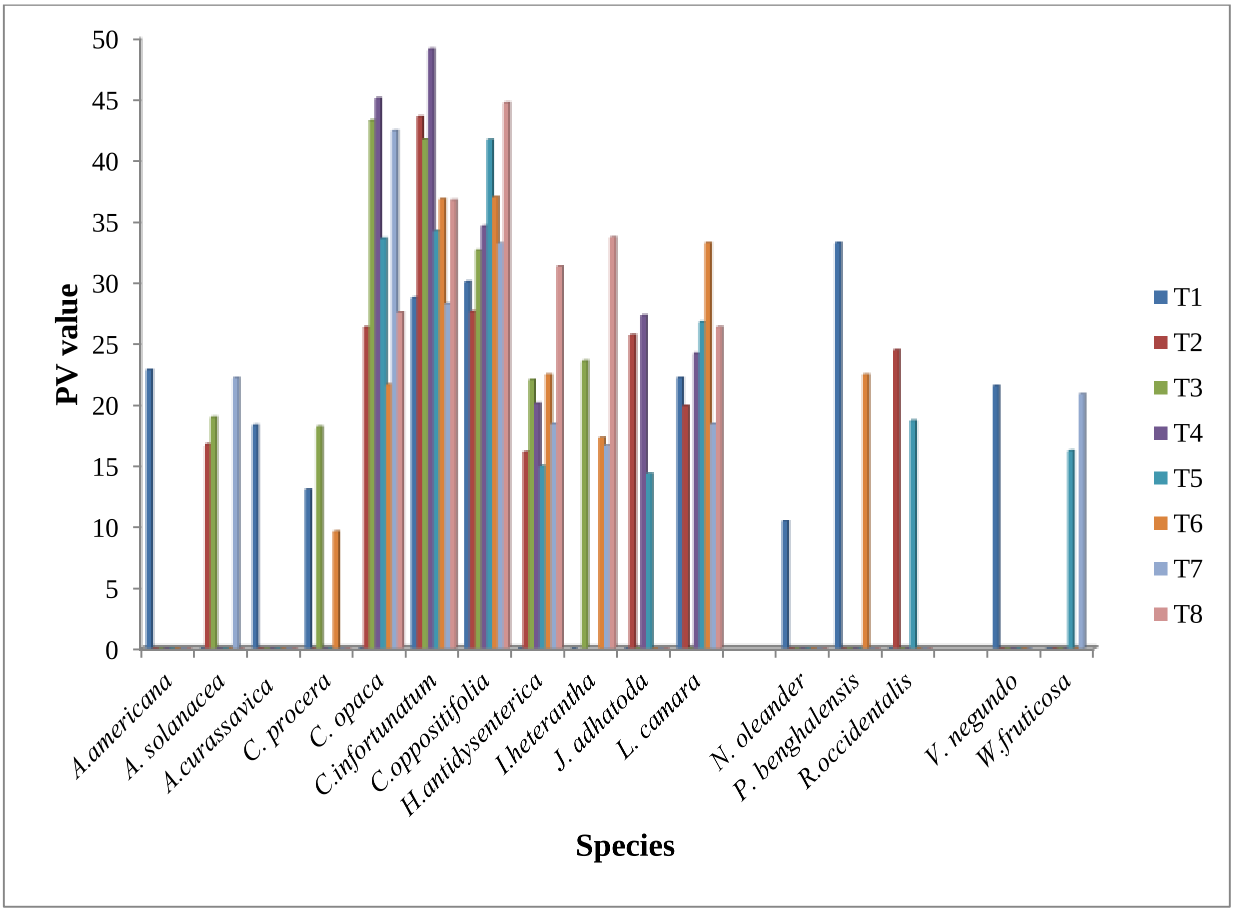
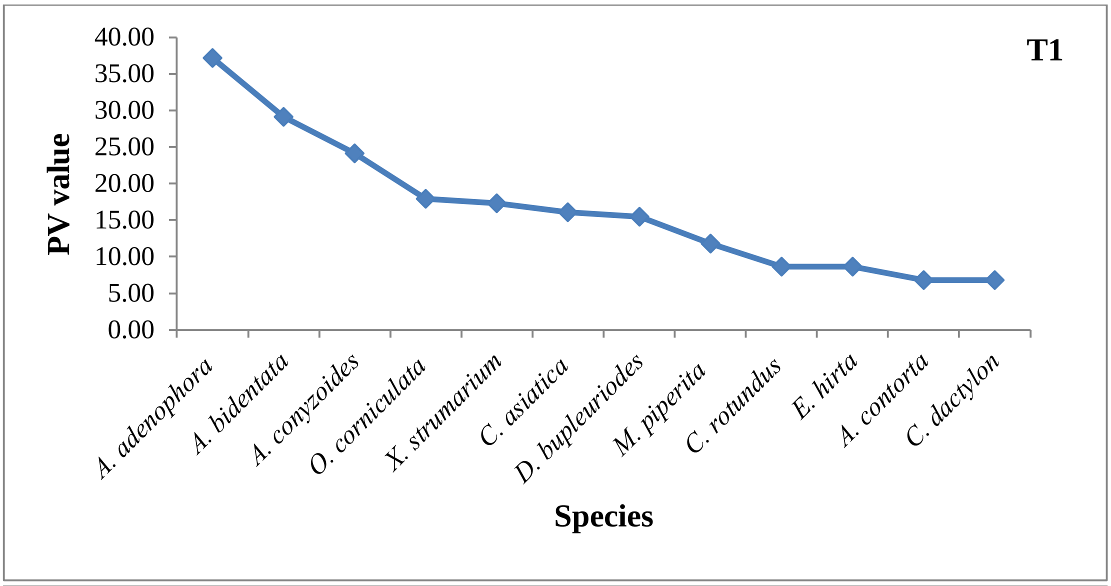
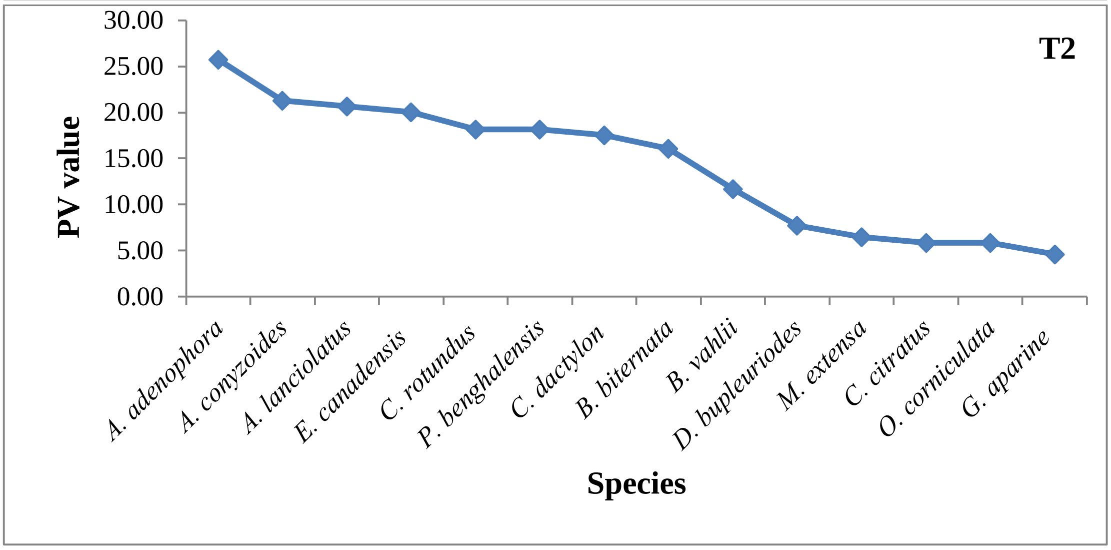


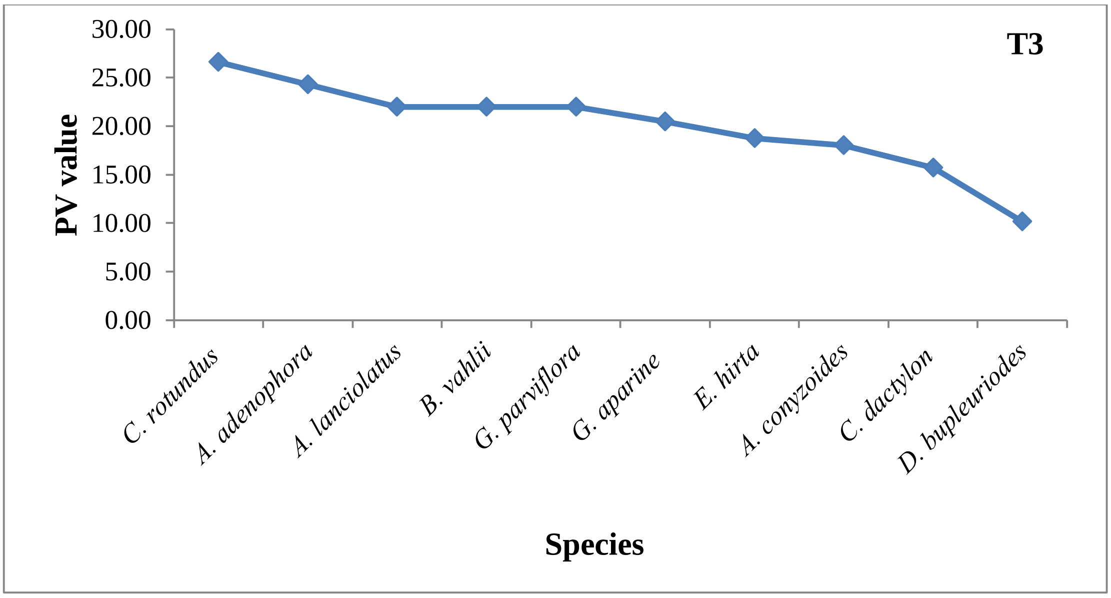
Figure 2.17: Dominancy attributes of the shrub layer in transects in CSJNP, Himachal Pradesh.

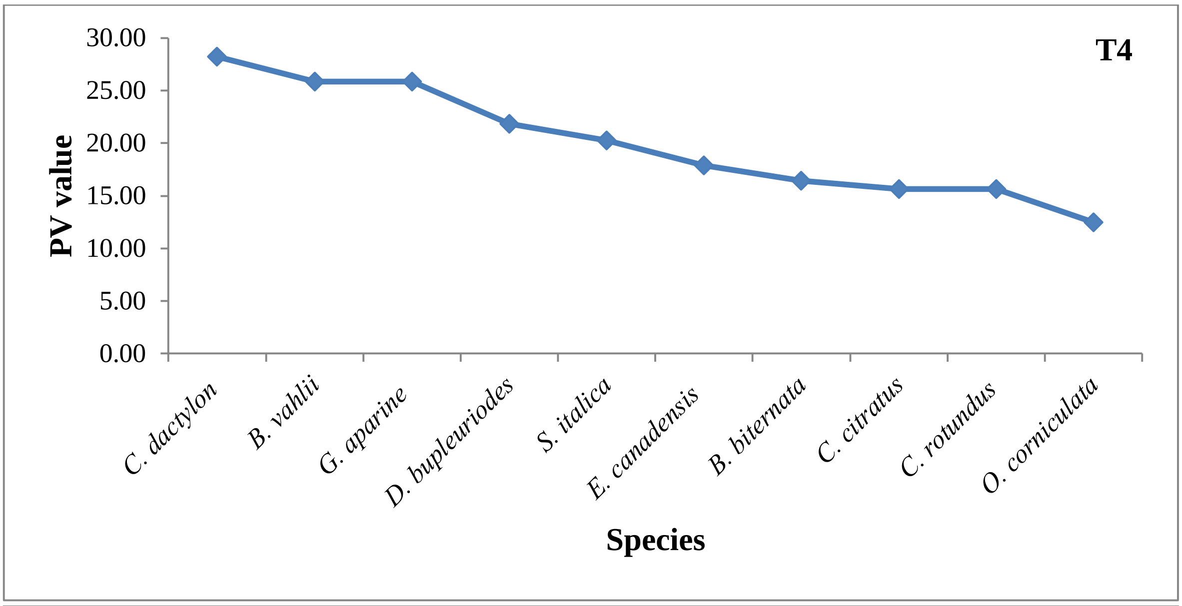
Table. 2.4: Dominancy attributes of sapling and seedling layer in CSJNP, Himachal Pradesh.

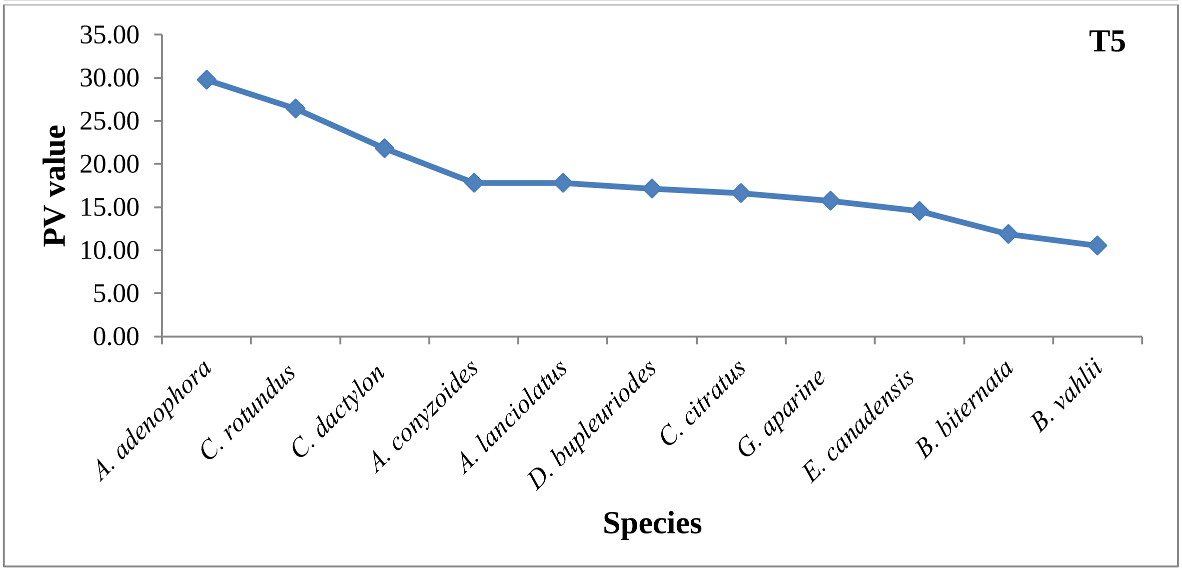
	Sapling								Seedling							
Species	T1	T2	T3	T4	T5	T6	T7	T8	T1	T2	T3	T4	T5	T6	T7	T8
B. retusa	-	17.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C. tomentosa	-	23.7	-	-	-	-	-	-	8.82	15.9	-	-	-	-	-	-
C. fistula	-	15.7	-	-	-	-	-	-	-	21.1	-	-	-	-	-	-
C. equisetifolia	9.73		-	-	-	-	-	-	-	-	-	-	-	-	-	-
C. dicotoma	-	7.85	-	-	-	-	-	-	-	16.9	-	-	-	-	-	-
E. laevis	20.3	15.1	-	-	44.4	-	-	14.4	-	15.3	-	-	33.5	-	-	-
E. citriodora	67.4	23.8	-	14	31	72.5	-	55.8	50.3	13.2	-	45.5	31.1	40	-	40.4
G. optiva	-	-	-	-	9.05	-	-	-	-	-	-	-	-	-	-	-
H. integrifolia	16.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M. philippensis	18.1	49	105.3	69.4	63.5	67.5	90.9	77	25.9	36	61.6	57	42.6	54.2	81.8	51.3
M. azedarach	-	21.7	33.53	24	22.8	-	-	45.4	9.39	-	-	-	-	-	-	-
M.paniculata	-	27.6	39.89	23.2	-	28.5	19.04	24.1	-	-	25.6	-	22.5	-	-	26
O.oojeinensis	70.2	64.3	99.09	95.8	87	90.8	108.6	83.3	-	-	41.3	-	-	19.6	33.8	12.9
S. robusta	98	16.9	22.18	42.3	24.2	40.7	-	-	47.2	29	35.4	53.7	35.5	36.9	52.4	69.4
S. cumini	-	16.9	-	31.3	18.1	-	62.18	-	58.4	19.6	36.1	43.8	17.1	49.2	-	-
T. alata	-	-	-	-	-	-	19.3	-	-	32.9	-	-	17.7	-	32	-
Z. mauritiana	-	21.7	33.53	24	22.8	-	-	45.4	-	-	-	-	-	-	-	-

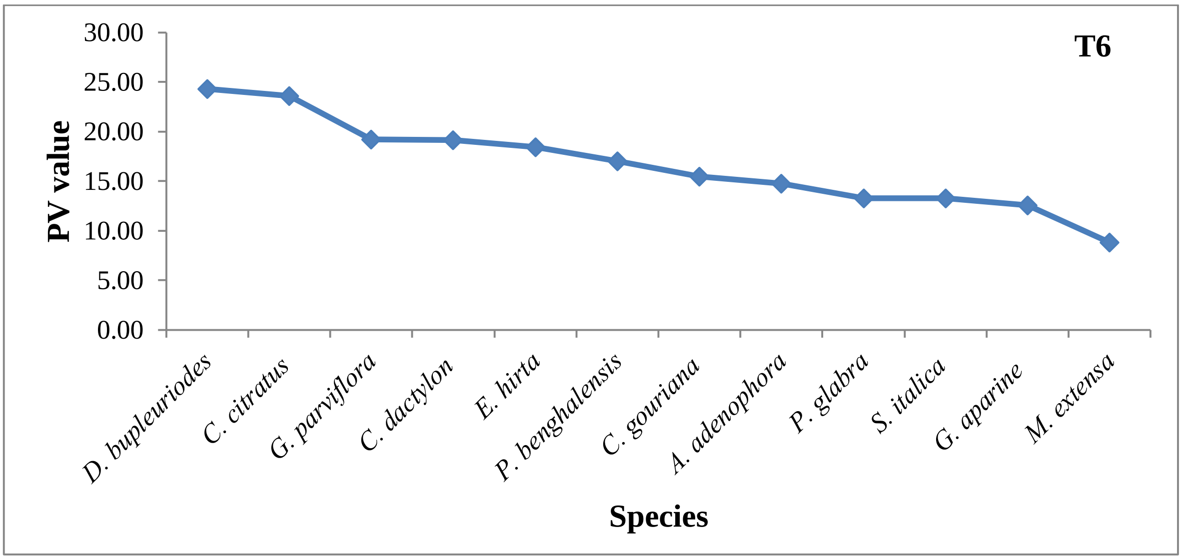

T1
PV value
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
A. adenophora
A. bidentata
A. conyzoides
O. corniculata
X. strumarium
C. asiatica
D. bupleuriodes
M. piperita
C. rotundus
E. hirta
A. contorta
C. dactylon
Species

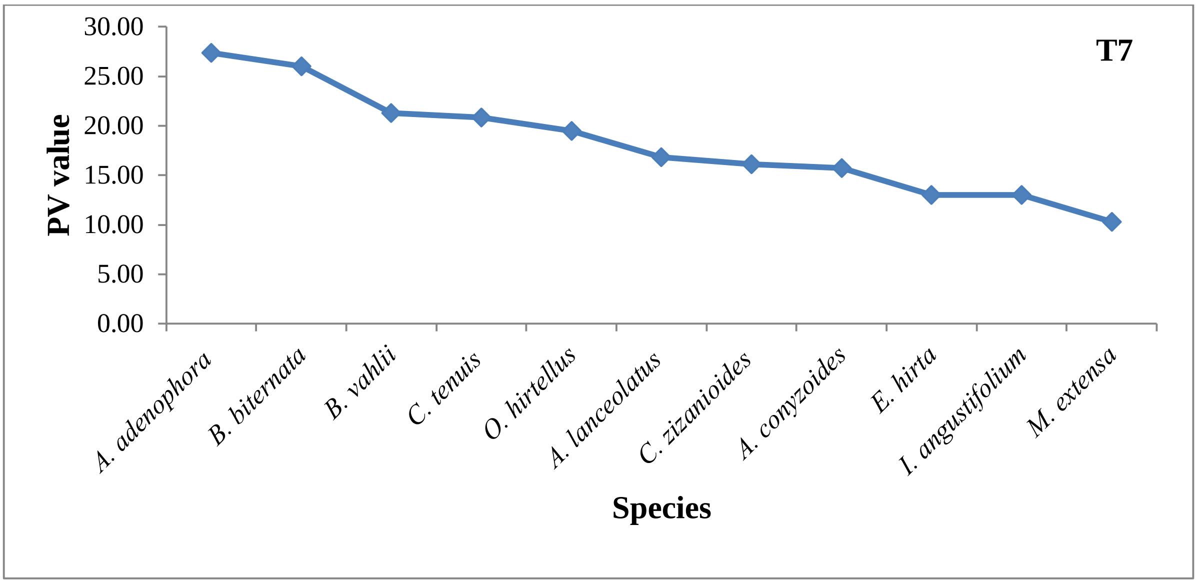

T2
PV value
30.00
25.00
20.00
15.00
10.00
5.00
0.00
A. adenophora
A. conyzoides
A. lanciolatus
E. canadensis
C. rotundus
P. benghalensis
C. dactylon
B. biternata
B. vahlii
D. bupleuriodes
M. extensa
C. citratus
O. corniculata
G. aparine
Species


T3
PV value
30.00
25.00
20.00
15.00
10.00
5.00
0.00
C. rotundus
A. adenophora
A. lanciolatus
B. vahlii
G. parviflora
G. aparine
E. hirta
A. conyzoides
C. dactylon
D. bupleuriodes
Species


T4
PV value
30.00
25.00
20.00
15.00
10.00
5.00
0.00
C. dactylon
B. vahlii
G. aparine
D. bupleuriodes
S. italica
E. canadensis
B. biternata
C. citratus
C. rotundus
O. corniculata
Species


T5
PV value
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
A. adenophora
C. rotundus
C. dactylon
A. conyzoides
A. lanciolatus
D. bupleuriodes
C. citratus
G. aparine
E. canadensis
B. biternata
B. vahlii
Species


T6
PV value
30.00
25.00
20.00
15.00
10.00
5.00
0.00
D. bupleuriodes
C. citratus
G. parviflora
C. dactylon
E. hirta
P. benghalensis
C. gouriana
A. adenophora
P. glabra
S. italica
G. aparine
M. extensa
Species



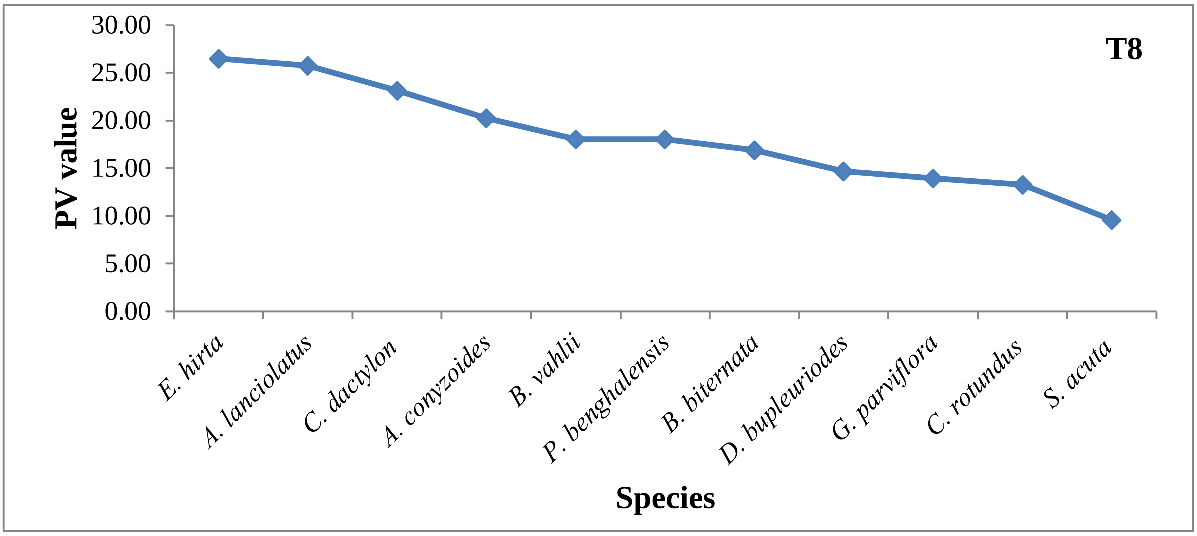


Figure 2.18: Dominance diversity curve for herbs in transects in CSJNP, Himachal Pradesh.

- **REGENERATION STATUS:**

All the studied sites of National Park showed the Fair regeneration having the highest individuals of trees followed by seedlings and then saplings (Figure 2.19). Maximum individuals of trees were observed at GP2 site (62.50%), saplings were recorded at DP2 site (25.91%) and seedlings were observed at KP1 site (37.33%) (Figure 2.20). Tree individuals were highest in Garuk beat, saplings were maximum in Danda beat and seedlings were in greater number in Kaludev beat.

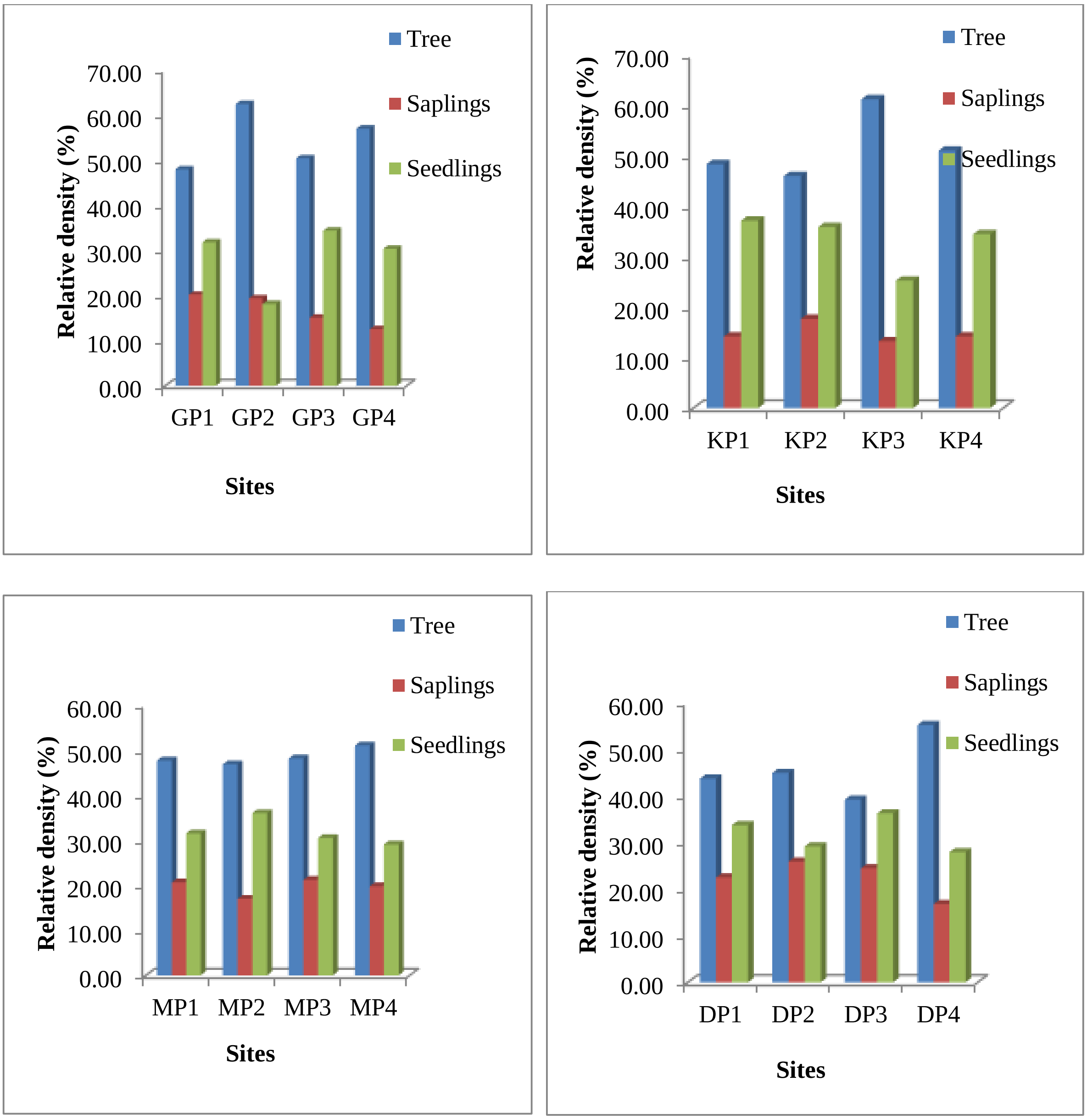


Figure 2.19: Regeneration pattern of selected sites in CSJNP, Himachal Pradesh.

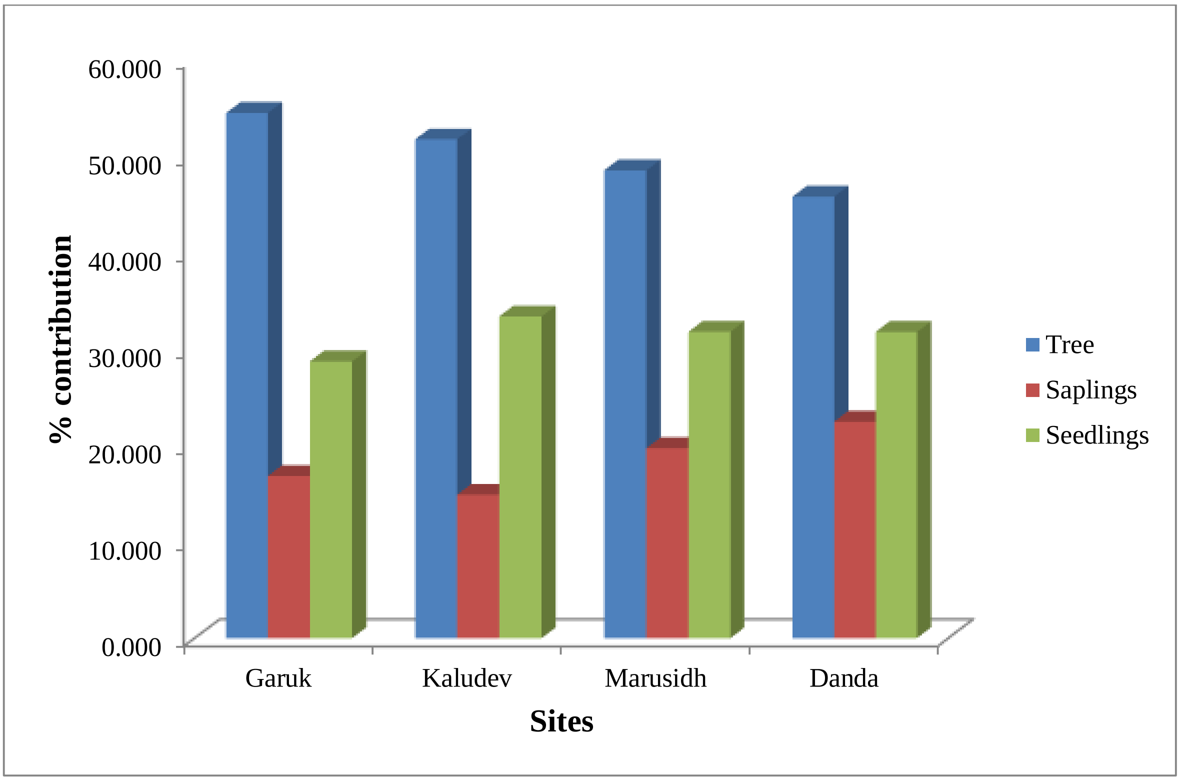


Figure 2.20: Percent contribution of trees, sapling, and seedlings in selected sites of CSJNP, Himachal Pradesh.

❖ Species richness and diversity

The species richness was observed highest in Garuk beat followed by kaludev, Danda and Marusidh beats for tree and seedling layers. In shrub layer, the species richness was recorded high in Marusidh beat than the other beats. The herb species richness was high in Garuk beat and low in Danda beat (Table 2.5). The diversity varied from 2.8 to 3.1 for tree layer, 1.7 to 2.0 for sapling layer, 2.0 to 2.3 for seedling layer, 1.6 to 2.3 for shrub layer and 2.7 to 2.9 for herb layer.

Table. 2.5: Species richness and diversity in forest beats of CSNJP, Himachal Pradesh.

	Species richness				**Diversity (H')**			
	Garuk	**Kaludev**	**Marusidh**	**Danda**	**Garuk**	**Kaludev**	**Marusidh**	**Danda**
Tree	28	26	21	25	2.8	3.0	2.8	3.1
Sapling	7	9	10	10	1.8	1.7	2.0	1.9

Seedling	13	12	10	15	2.2	2.2	2.0	2.3
Shrub	9	9	10	9	1.6	2.3	1.7	2.1
Herb	18	16	17	15	2.7	2.8	2.9	2.8

- **Churdhar Wildlife Sanctuary (CWS)**

The stopping point of the group formation was set at height 4, which resulted in the formation of seven vegetation communities. Seven distinct vegetation communities were recognized based on TWINSPAN analysis as shown in Figure. 2.21, where the height along the vertical axis represents the total Chi-squares of divisions. Further description of communities has been given below.

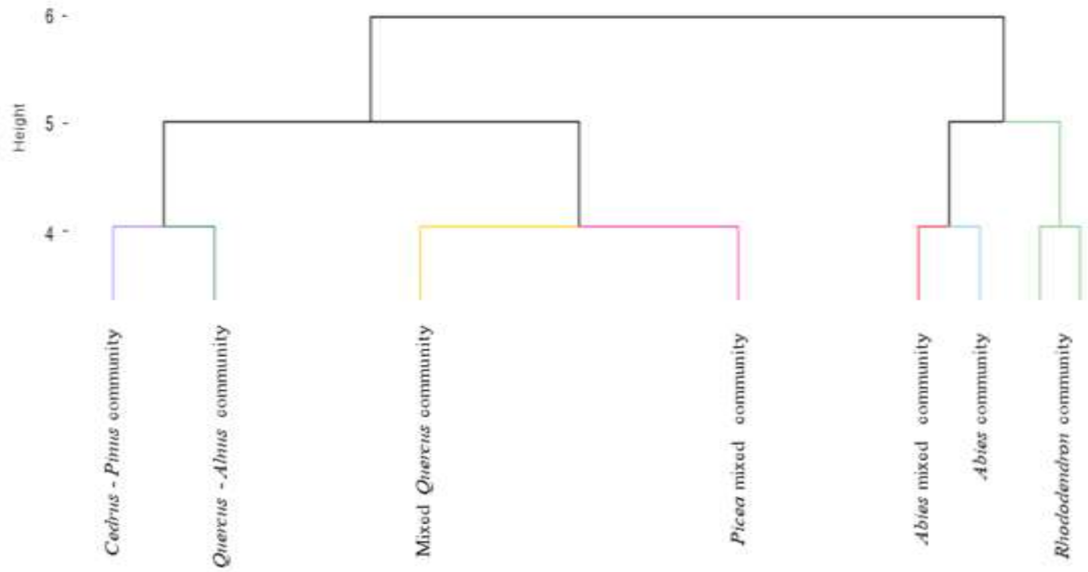


Figure 2.21: Twinspan dendrogram showing seven distinct plant communities in CWS, Himachal Pradesh.

***Rhododendron* community:** In this community, the tree density ranged from 30 to 250 trees ha-1 and total basal area from 0.14 to 3.15 m2 ha^{-1}. *Rhododendron campanulatum* was the most dominant species in the community with highest average IVI (217.76). The average total tree density in the community was 215.52 trees ha^{-1}, of which 77% and 23 % contributed by *Rhododendron campanulatum* and *Sorbus microphylla*, respectively (Table 2.6). The average total basal area of the community was 1.46 m2 ha^{-1}, of which the maximum exhibited by *Rhododendron campanulatum* (79%). The average total shrub density was 1117.42 individual's ha-^{1}, of which 50% contributed by *Juniperus squamata*, followed by *Lonicera obovata* (12%) and *Lonicera angustifolia* (11%).

***Abies* community:** In this community, the tree density ranged from 100 to 330 trees ha^{-1} and total basal area from 0.15 to 13.43 m2 ha^{-1}. *Abies spectabilis* was the most dominant species in the community with highest average IVI (240.89). The average total tree density was 270.0 trees ha^{-1}, of which 76% contributed by Abies spectabilis and 20% by *Rhododendron campanulatum*. The average total basal area of the community was 7.7 m2 ha-^{1}, of which 94% contributed by *Abies spectabilis*, while 5% contributed by *Rhododendron campanulatum*. The average total shrub density was 1343.33 individuals ha^{-1}, of which Juniperus squamata contributed the maximum (24%), followed by *Lonicera obovata* (16%) and *Rhododendron lepidotum* (14%).

***Abies* mixed community:** In this community, the tree density ranged from 30 to 170 trees ha-1 and total basal area from 0.16 to 6.19 m2 ha-1. *Abies spectabilis* was the most dominant species in the community with average maximum IVI (109.40). The average total tree density was 227.50 trees ha^{-1}, of which *Abies spectabilis* contributed the maximum (36%), followed by *Rhododendron campanulatum* (22%). The average total basal area was 4.7 m2 ha^{-1}, of which *Abies spectabilis* exhibited the maximum (64%), followed by *Betula utilis* (21%). The average total shrub density was 1170.0 individuals ha^{-1}, of which *Lonicera obovata* contributed the maximum (26%), followed by *Rhododendron anthopogon* (21%) and *Rosa sericea* (13%).

***Picea* mixed community:** Across the sites, the tree density ranged from 20 to 690 trees ha^{-1} and total basal area from 0.47 to 58. 45 m2 ha^{-1}. *Picea smithiana* was the most dominant species in the community with average highest IVI (123.04). The average total tree density was 578.57 trees ha^{-1}, of which 38% and 36% contributed by *Picea smithian*a and *Quercus semecarpifolia*, respectively. The average total basal area was 33.5 m2 ha^{-1}, of which Picea smithiana contributed the maximum (40%), followed by *Quercus semecarpifolia* (38%). The average total shrub density was 1298.10 individuals ha^{-1}, of which *Viburnum grandiflorum* contributed the maximum (49%), followed by *Berberis aristata* (7%) and *Wickstroemia canescens* (6%).

Mixed *Quercus* community: In this community, the tree density ranged from 10 to 730 trees ha-1 and total basal area from 0.14 to 20.80 m2 ha^{-1}. *Quercus leucotrichophora* was the most dominant species in the community with average highest IVI (135.66). The average total tree density was 563.78 trees ha^{-1}, of which *Quercus floribunda* exhibited the maximum (44%), followed by *Quercus leucotrichophora* (34%) and *Litsea consimilis* (7%). The average total basal area was 15.9 m2 ha^{-1}, of which *Quercus floribunda* contributed the maximum (47%), followed by *Quercus leucotrichophora* (34%). The average total shrub density was 1130.0 individuals ha^{-1}, of which *Berberis aristata* contributed the maximum (20%), followed by *Sarcococca saligna* (16%) and *Berberis coriaria* (10%).

Table 2.6: Average values of density (trees ha^{-1}), TBA (m^{2} ha^{-1}) and IVI of tree species in identified communities in CWS, Himachal Pradesh.

Species	**Density (Trees ha^{-1})**	**TBA (m^{2} ha^{-1})**	**IVI**
	***Rhododendron* community**		
Rhododendron companulatum	165.51±9.25	1.16±0.11	217.76±3.73
Sorbus microphylla	50.0±2.93	0.31±0.03	82.24±3.72
	***Abies* community**		
Rhododendron companulatum	53.33±22.28	0.37±0.21	45.29±14.47
Abies spectabilis	205.00±21.79	7.33±2.03	240.89±18.46
Sorbus microphylla	11.66±07.99	0.06±0.04	13.81±9.26
	***Abies* mixed community**		
Rhododendron companulatum	42.5±0	0.14±0	35.45±35.45
Abies spectabilis	82.5±27.83	3.01±27.83	109.40±43.05
Betula utilis	52.5±11.54	0.98±11.54	78.31±11.31
Sorbus microphylla	50.0±17.55	0.58±17.55	76.83±12.31
	***Picea* mixed community**		
Picea smithiana	221.43±16.78	13.37±1.21	123.04±9.51
Quercus floribunda	37.65±11.27	1.36±0.39	16.64±4.65
Quercus semicarpifolia	205.98±20.31	12.67±1.36	108.20±9.06
Abies pindrow	42.51±11.65	1.91±0.65	15.99±4.34
Abies spectabilis	33.76±9.11	2.48±0.67	22.72±5.86

Rhododendron arboreum	23.25±6.51	1.64±0.49	11.86±3.32
Lyonia ovalifolia	0.37±0.37	0.01±0.01	0.34±0.34
Litsea consimilis	1.43±0.714	0.02±0.01	0.92±0.41
Aesculus indica	0.16±0.16	0.01±0.01	0.18±0.18
Taxus contorta	0.30±0.30	0.01±0.01	0.20±0.20
Acer caesium	11.69±3.35	0.02±0.02	0.52±0.37
Mixed *Quercus* community			
Quercus leucotrichophora	189.77±36.0	5.46±1.05	82.19±14.61
Quercus floribunda	247.34±22.54	7.39±0.75	135.66±13.03
Picea smithiana	9.78±7.53	0.36±0.27	4.21±2.99
Alnus nitida	0.45±0.31	0.02±0.01	1.23±0.96
Ficus neriifolia	0.45±0.45	0.01±0.01	0.45±0.45
Jugland regia	0.67±0.49	0.01±0.01	0.28±0.28
Pyrus pashia	2.0±1.25	0.03±0.02	1.67±1.05
Rhus punjabensis	0.45±0.45	0.01±0.01	0.69±0.69
Lisea consimilis	42.22±7.86	0.59±0.11	22.53±4.62
Ilex dipyrena	7.33±2.74	0.15±0.06	5.40±2.21
Machilus odoratissima	16.45±5.93	0.45±0.17	10.22±4.46
Rhododendron arboreum	38.45±12.05	1.15±0.37	28.95±6.89
Eunonymus lucidus	5.78±3.56	0.11±0.05	4.80±2.59
Acer caesium	0.45±0.45	0.02±0.01	0.89±0.6

Lyonia ovalifolia	0.88±0.69	0.04±0.02	0.15±0.15
Toona serrata	1.33±1.33	0.02±0.02	1.21±0.84
***Quercus - Alnus* community**			
Quercus leucotrichophora	70.0±42.11	3.00±1.52	113.19±38.69
Cedrus deodara	6.0±4.26	0.18±0.12	30.96±20.67
Alnus nitida	17.0±3.0	0.39±0.07	110.65±27.33
Ficus palmata	1.0±1.0	0.02±0.02	3.62±3.62
Morus serrata	1.0±1.0	0.08±0.08	3.79±3.79
Ficus neriifolia	6.0±3.05	0.08±0.04	22.69±12.53
Jugland regia	1.0±1.0	0.05±0.03	7.90±6.71
Salix alba	3.0±3.0	0.03±0.03	2.60±2.60
Prunus cornuta	1.0±1.0	0.03±0.03	1.26±1.26
Toona serrata	2.0±2.0	0.05±0.05	3.34±3.34
***Cedrus - Pinus* Community**			
Cedrus deodara	310.00±97.03	8.05±3.38	181.94±45.7
Pinus wallichiana	122.50±42.80	2.78±1.0	96.62±34.4
Ficus neriifolia	12.50±12.50	0.45±0.33	17.74±14.6
Robinia-pseudoacacia	2.50±2.50	0.06±0.06	3.70±3.70

***Quercus - Alnus* community:** As per the TWINSPAN analysis, 10 sites are under this community. Across the sites, the tree density ranged from 10 to 350 trees ha^{-1} and total basal area from 0.19 to 13.34 m2 ha^{-1}. *Quercus leucotrichophora* was the most dominant species in the community with average highest IVI (113.19). The average total tree density was 108.0 trees ha^{-1}, of which *Quercus leucotrichphora* exhibited the maximum (65%), followed by *Alnus nepalensis* (16%) and Ficus neriifolia (5%). The average total basal area was 3.9 m2 ha-1, of which *Quercus leucotrichophora* contributed the maximum (76%), followed by *Alnus* *nepalensis* (10%). The average total shrub density was 1586.0 individuals ha^{-1}, of which *Berberis aristata* contributed the maximum (33%), followed by *Prinsepia utilis* (17%) and *Rubus niveus* (13%).

***Cedrus - Pinus* community:** As per the TWINSPAN analysis, 4 sites are under this community. Across the sites, the tree density ranged from 10 to 490 trees ha^{-1} and total basal area from 0.44 to 14.47 m2 ha^{-1}. *Cedrus deodara* was the most dominant species with average maximum IVI (181.94). The average total tree density was 448.50 trees ha^{-1}, of *which Cedrus deodara* exhibited the maximum density (69%), followed by *Pinus wallichiana* (27%). The average total basal area was 11.4 m2 ha^{-1}, of which *Cedrus deodara* contributed the maximum (71%), followed by *Pinus wallichiana* (25%). The average total shrub density was 2570.0 individuals ha^{-1}, of which 26%, 19% and 18% contributed by *Cotoneaster microphyllous* and *Cotoneaster integrifolius* respectively.

❖ Sapling, seedling and herb layer

Rhododendron community: The total sapling density was 120 individuals ha^{-1}, of which 75% and 25 % contributed by *Rhododendron companulatum* and *Sorbus microphylla,* respectively (Table 2.7). The total herb density was 99 individuals m^{-2} of which 13%, 9% and 6% contributed by *Faragria vesca*, *Sibbaldia cuneata* and *Achillea millefolium* respectively. The total seedling density was 3914 individuals ha^{-1}, of which 85% and 15 % contributed by *Rhododendron companulatum* and *Sorbus microphylla,* respectively.

***Abies* community:** The total sapling density was 515.5 individuals ha^{-1}, of which maximum contributed by *Abies spectabilis* (83%), followed by *Rhododendron companulatum* (10%) and *Sorbus microphylla* (7%), respectively. The total herb density was 95 individuals m^{-2} of which 18%, 6% and 5% contributed by *Faragria vesca*, *Bistorta affinis* and *Tanacetum longifolium* respectively. The total seedling density was 7666.6 individuals ha^{-1}, of which maximum contributed by *Abies spectabilis* (54%), followed by *Rhododendron companulatum* (39%) and *Sorbus microphylla* (7%), respectively.

***Abies mixed* community:** The total sapling density was 290 individuals ha^{-1}, of which *Ab Sorbus microphylla* contributed the maximum (45%), followed by *Rhododendron companulatum* (38%) and *Abies spectabilis* (10%). The total herb density was 83 individuals m^{-2} of which 21%, 9% and 7% contributed by *Faragria vesca*, *Bistorta affinis* and *Ligularia amplexicaulis* respectively. The total seedling density was 5500 individuals ha^{-1}, of which *Ab*

Rhododendron companulatum contributed the maximum (43%), followed by *Sorbus microphylla* (39%) and *Abies spectabilis* (17%).

***Picea* mixed community**: The total sapling density was 1153.8 individuals ha^{-1}, of which maximum contributed by *Picea smithiana* (46%) and followed by *Quercus semecarpifolia* (35%) and *Rhododendron arboreum* (6%). The total herb density was 339 individuals m^{-2}, of which *fragaria vesca* contributed the maximum (13%), followed by *Geranium wallichianum* (5%) and *Prunella vulgaris* (5%). The total seedling density was 11939.4 individuals ha^{-1}, of which maximum contributed by *Picea smithiana* (41%) and followed by *Quercus semecarpifolia* (37%) and *Abies spectabilis* (7%).

Table. 2.7: Average total values of density for trees ((ind ha^{-1}), saplings (ind ha^{-1}), seedlings (ind m^2), shrubs (ind ha$^-$1) and herbs ((ind m^2) in different communities in CWS, Himachal Pradesh.

S.No.	Community	Tree density (ind ha^{-1})	Saplings (ind ha-1)	Seedlings (ind m^2)	Shrub density (ind ha^{-1})	Herbs (ind m^2)
1.	*Rhododendron* community	215.52	120	3913.7	1117.24	99.1
2.	*Abies* community	270.0	515.6	7666.7	1343.33	95.8
3.	*Abies* mixed community	227.50	290	5500	1170.0	83.5
4.	*Picea* mixed community	578.57	1153.8	11939.4	1298.10	339
5.	Mixed *Quercus* community	563.78	959.7	11244.4	1130.0	59.1
6.	*Quercus* - *Alnus* community	108.0	434.7	7000	1586.0	92.02

7.	*Cedrus - Pinus* community	448.50	490	9500	2570.0	81.2

Mixed *Quercus community:* The total sapling density was 959.7 individuals ha^{-1}, of which *Quercus floribunda* exhibited the maximum (50%), followed by *Quercus leucotrichophora* (34%) and *Rhododendron arboreum* (10%). The total herb density was 59 individuals m^{-2} of which 7%, 6% and 5% contributed by *Bistorta affinis, Bistorta amplexicaulis* and *Trifolium repens* respectively. The total seedling density was 11244 individuals ha^{-1}, of which *Quercus floribunda* exhibited the maximum (50%), followed by *Quercus leucotrichophora* (32%) and *Rhododendron arboreum* (11%).

***Quercus - Alnus community*:** The total sapling density was 434.7 individuals ha^{-1}, of which *Quercus leucotrichphora* exhibited the maximum (60%), followed by *Cedrus deodara* (34%) and *Alnus nitida* (6%). The total herb density was 92 individuals m^{-2} of which 9%, 7% and 6% contributed by *Thymus serphyllum, Erigeron annus* and *Cyanotis axillaris* respectively. The total seedling density was 7000 inidviduals ha^{-1}, of which *Cedrus deodara* exhibited the maximum (56%), followed by *Quercus leucotrichphora* (36%) and *Alnus nitida* (11%).

***Cedrus - Pinus community*:** The total sapling density was 490 inidviduals ha^{-1}, of which *Cedrus deodara* exhibited the maximum (86%), followed by *Pinus wallichiana* (7%) and *Picea smithiana* (7%). The total herb density was 81 individuals m^{-2} of which 13%, 10% and 10% contributed by *Trifolium repens, Prunella vulgaris* and *Rosocoea purpurea* respectively. The total seedling density was 9500 inidviduals ha^{-1}, of which *Cedrus deodara* exhibited the maximum (50%), followed by *Pinus wallichiana* (42%) and *Ficus neriifolia* (8%).

- **Species richness and diversity**

***Rhododendron* community:**

Within this community, the tree species richness was 2 across all the sites while the diversity ranged from 0.39 to 0.68 with an average value of 0.545 ± 0.02. The shrub species richness ranged from 1 to 4 with an average value of 2.0 and shrub species diversity ranged from 0.63 to 1.35 with an average value of 0.549 ± 0.08.

***Abies c*ommunity:**

Within this community, the tree species richness ranged from 1-3 with an average of 2.3 and the tree species diversity ranged from 0 to 0.87 with an average value of 0.476 ± 0.05. The shrub species richness ranged from 2 to 4 with an average value of 3.0 ± 0.31 and shrub species diversity ranged from 0.63 to 1.09 with an average value of 0.98 ± 0.12.

***Abies* mixed community:**

Within this community, the tree species richness was 3 with an average of 3.0 ±0.08 and the tree species diversity ranged from 0.93 to 1.84 with an average value of 0.962 ± 0.06. The shrub species richness ranged from 1 to 4 with an average value of 2.7 and shrub species diversity ranged from 0.69 to 1.06 with an average value of 0.917 ± 0.08.

***Picea* mixed community:**

Within this community, the tree species richness ranged from 1 to 3 with an average value of 1.90 ± 0.03 and tree diversity ranged from 0 to 1.08 with an average value of 0.471 ± 0.01. The shrub species richness ranged from 1 to 4 with an average value of 2.08 and shrub species diversity ranged from 0 to 1.34 with an average value of 0.57± 0.03.

Mixed *Quercus* community:

Within this community, the tree species richness ranged from 1 to 4 with an average value of 2.82 ± 0.04 and tree species diversity ranged from 0 to 1.34 with an average value of 0.74 ± 0.04. The shrub species richness ranged from 1 to 6 with an average value of 3.0 ± 0.21 and shrub species diversity ranged from 0 to 1.73 with an average value of 0.905 ± 0.06.

***Quercus - Alnus* community:**

Within this community, the tree species richness ranged from 1 to 4 with an average value of 2.40 ± 0.11 and the tree species diversity ranged from 0 to 1.21 with an average value of 0.56 ± 0.11. The shrub species richness ranged from 1 to 4 with an average value of 3.70 and shrub species diversity ranged from 0 to 1.65 with an average value of 1.067 ± 0.19.

***Cedrus - Pinus* community:**

Within this community, the tree species richness ranged from 1 to 3 with an average value of 2.25 ± 0.48 and the tree species diversity ranged from 0.39 to 0.68 with an average value of 0.60 ± 0.22. The shrub species richness ranged from 3 to 5 with an average value of 4.25 ± 0.47 and shrub species diversity ranged from 1.05 to 1.59 with an average value of 1.364 ± 0.11. The average values of Species Richness (SR), Diversity (H') and Evenness (E) for trees and shrubs are given in Table 2.8.

Table 2.8: Average values of species richness (SR), Diversity (H`) and evenness (E) for trees and shrubs in identified communities of CWS, Himachal Pradesh.

Community	**Trees**			**Shrubs**		
	SR	**H'**	**E**	**SR**	**H'**	**E**
Rhododendron community	2.0 ± 0.02	0.545 ± 0.02	0.866 ± 0.02	2.0 ± 0.16	0.549 ± 0.08	0.962 ± 0.01
Abies community	2.30 ± 0.05	0.476 ± 0.05	0.892 ± 0.05	3.0 ± 0.31	0.984 ± 0.12	0.937 ± 0.01
Abies mixed community	3.0 ± 0.08	0.962 ± 0.06	0.880 ± 0.06	2.70 ± 0.25	0.917 ± 0.08	0.926 ± 0.03
Picea mixed community	1.90 ± 0.03	0.471 ± 0.01	0.894 ± 0.01	2.0 ± 0.07	0.573 ± 0.03	0.924 ± 0.01
Mixed *Quercus* community	2.82 ± 0.04	0.742 ± 0.02	0.794 ± 0.02	3.0 ± 0.21	0.905 ± 0.10	0.914 ± 0.01
Quercus - *Alnus* community	2.40 ± 0.11	0.563 ± 0.07	0.855 ± 0.07	3.70 ± 0.50	1.067 ± 0.10	0.910 ± 0.03
Cedrus - *Pinus* Community	2.25 ± 0.48	0.602 ± 0.06	0.892 ± 0.06	4.25 ± 0.47	1.364 ± 0.11	0.941 ± 0.01

- **Chandratal Wildlife Sanctuary (CTWS)**

Eight distinct vegetation communities were recognized based on TWINSPAN analysis as shown in figure. 2.22., where the height along the vertical axis represents the total Chi-squares of divisions. TWINSPAN is a divisive clustering based on splitting first correspondence analysis axis and then, recursively working with each split subset. The stopping point of the group formation was set at height 3, which resulted in the formation of eight vegetation communities.

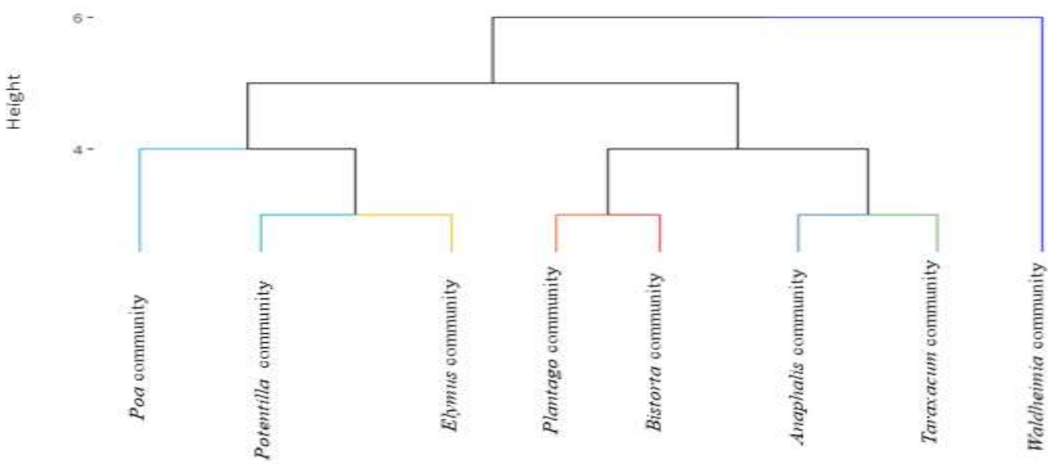


Figure. 2.22: Twinspan dendrogram showing eight distinct vegetation communities in CTWS, Himachal Pradesh.

Within the Protected Area, the maximum value of relative density (9.30%) was observed for *Kobresia royleana* while minimum (1.75%) was observed for *Silene himalayensis*, AF land-form. For AL landform, these values varied from 0.81% (for *Crementhodium decaisnei*) to 16.61% (for *Plantago depressa*). For NS land-form, the maximum value of relative density was 14.03% (for *Hygrophila lancea*) while, minimum relative densitywas 1.36% (for *Delphinium casherianum*). *Bistorta affinis* revealed the highest relative density while *Convolvulus arvensis* showed lowest value of relative density under the roadside land-form. For grassland land-form, the values of relative density are observed between 6.03% (*Leymus secalinus*) and 15.10% (*Poa alpigena*) (Table 2.9).

The maximum value of relative frequency was recorded for *Kobresia royleana* in AF land-form, for *Plantago depressa* in AL land-form, for *Thymus serphyllum* in NS land-form, for *Bistorta affinis* in RS land-form and *Elymus nutans* for GL land-form (Table 2.10).

Outside the Protected Area, four land-forms namely; HOS, NSOS, RSOS and GLOS were sampled during the study period. Among all the land-forms, the maximum relative density 16.47% was recorded for *Poa alpigena*, in GLOS land-form while, minimum relative density 1.46% was recorded for *Waldheimia glabra* in HOS land-form (Table 2.11).

The values of relative frequency for each species encountered in outside the Protected Area are given in Table 2.12. The value of relative frequency observed between 2.17% for *Saxifraga flagellaris* in HOS lanf-form and 15.40% for *Poa alpigena* in GLOS land-form.

Table 2.9: Relative density (%) of plant species occurred in several landforms of CTWS, Himachal Pradesh.

Species	AF	AL	NS	RS	GL
Adiantum venustum	-	-	3.17±3.2	-	-
Anaphalis nepalensis	2.57±2.6	9.10±3.2	5.94±3.5	7.30±5.2	-
Arabis collina	2.29±2.3	-	-	-	-
Arnebia euchroma	2.57±2.6	-	-	-	-
Aster flaccidus	-	-	-	-	-
Astragalus munroi	2.51±2.5	-	-	9.63±2.6	-
Bistorta affinis	-	-	8.02±4.8	26.40±9.3	-
Carex nivalis	7.57±4.5	4.99±2.9	-	2.51±2.5	-
Carex stricta	-	10.56±3.7	-		-
Chenopodium foliosum	-	-	-	2.34±1.5	-
Convolvulus arvensis	-	-	-	2.01±2.0	-
Crementhodium decaisnei	-	0.81±0.8	-	-	-
Delphinium casherianum	-	-	1.36±1.4	-	-
Eleocharis obusta	-	-	2.63±2.6	-	-
Elymus nutans	5.14±5.1	-	-	2.47±2.5	13.77±4.9
Glaux maritima	-	-	4.38±2.7	-	-
Hippuris vulgaris	-	4.28±2.5	6.06±3.6	-	-
Hygrophila lancea	-	-	14.03±1.5	-	-
Jurinea ceratocarpa	-	-	1.82±1.8	-	-
Kobresia royleana	9.30±3.6	-	5.84±3.4	-	-

launaea asplenifolia	-	2.58±2.6	-	-	-
Leontopodium ochroleucum	-	5.53±3.3	-	-	-
Leymus secalinus	3.46±3.5	-	-	-	6.03±3.5
Lomatogonium carinthiacum	-	4.76±2.8	-	-	-
Mentha longifolia	2.15±2.1	-	-	-	-
Myriophyllum verticillatum	-	3.24±3.2	-	-	-
Nepeta longibracteata	8.23±4.8	-	-	3.24±3.2	-
Oxyria digyna	5.47±3.4	-	4.75±4.8	-	-
Oxytropis microphylla	4.01±2.4	-	5.26±5.3	-	-
Plantago depressa	-	16.61±5.9	-	-	-
Poa alpigena	5.48±5.5	3.45±3.5	5.55±5.5	-	15.10±5.4
Polygonum plebeium	-	-	-	-	10.07±5.8
Potentilla argyrophlla	-	-	6.48±3.7	-	-
Potentilla venusta	3.36±3.4	-	-	7.82±4.6	12.71±7.4
Potentilla venusta /anseria	-	3.29±3.3	-	-	-
Pucinellia himalaica	-	-	-	-	8.71±8.7
Ranunculus hyperboreus	-	3.04±3.0	-	-	-
Rhodiola imbricata	4.17±4.2	-	-	-	-
Rotala rotundifolia	-	-	2.26±2.3	-	-
Rumex nepalensis	-	5.10±2.2	2.82±2.8	3.82±2.6	8.01±4.7
Saussurea jacea	4.52±4.5	-	-	8.79±5.9	-
Saxifraga flagellaris	2.38±2.4	-	-	6.65±2.9	-

Scirpus cunneata	-	2.08±2.1	-	-	-
Sedum ewersii	-		3.62±3.6	-	-
Sibbaldia cunneata	-	4.88±2.8	3.28±3.3	6.53±4.1	8.38±3.6
Silene himalayensis	1.75±1.7	-	-	-	-
Taraxacum officinale	2.27±2.3	2.57±2.6	6.06±3.0	10.48±3.7	10.35±3.8
Thymus serphyllum	5.63±5.6	-	8.20±4.7	-	6.88±4.6
Trifolium repens	-	1.07±1.1	-	-	-
Verbascum thapsus	5.01±2.9	-	-	-	-
Waldheimia glabra	6.34±3.7	-	-	-	-
Waldheimia tomentosa	3.82±2.4	-	-	-	-

Table. 2.10: Relative frequency (%) of plant species occurred in several landforms of CTWL sanctuary, Himachal Pradesh.

Species	AF	AL	NS	RS	GL
Adiantum venustum	-	-	3.31±3.3	-	-
Anaphalis nepalensis	2.42±1.2	7.81±2.8	5.88±3.4	6.41±4.0	
Arabis collina	3.13±1.6	-	-	-	-
Arnebia euchroma	3.63±1.8	-	-	-	-
Aster flaccidus	-	2.53±2.5	-	-	-
Astragalus munroi	3.13±1.6	-	-	9.54±1.7	-
Bistorta affinis	-	9.18±3.7	7.48±4.4	18.48±6.2	-
Carex nivalis	6.31±3.2	4.94±2.9	-	3.03±3.0	-
Carex stricta	-	10.51±3.7	-		-
Chenopodium foliosum	-	-	-	2.49±1.5	-
Convolvulus arvensis	-	-	-	2.74±2.7	-

Crementhodium decaisnei	-	1.01±1.0	-	-	-
Delphinium casherianum	-	-	1.84±1.8	-	-
Eleocharis obusta	-	-	3.26±3.3	-	-
Elymus nutans	4.03±2.0	-		3.05±3.0	13.72±5.0
Glaux maritima	-	-	4.58±2.9	-	-
Hippuris vulgaris	-	4.01±2.4	4.90±2.8	-	-
Hygrophila lancea	-	-	13.84±1.7	-	-
Jurinea ceratocarpa	-	-	2.96±3.0	-	-
Kobresia royleana	11.30±5.6	-	5.22±3.1	-	-
launaea asplenifolia	-	2.57±2.6	-	-	-
Leontopodium ochroleucum	-	5.83±3.4	-	-	-
Leymus secalinus	3.23±1.6	-	-	-	5.48±3.2
Lomatogonium carinthiacum	-	4.98±2.9	-	-	-
Mentha longifolia	2.04±1.0	-	-	-	-
Myriophyllum verticillatum	-	4.04±4.0	-	-	-
Nepeta longibracteata	6.63±3.3	-	-	2.88±2.9	-
Oxyria digyna	6.31±3.2	-	4.78±4.8	-	-
Oxytropis microphylla	4.34±2.2	-	4.71±4.7	-	-
Plantago depressa	-	14.67±5.0	-	-	-
Poa alpigena	4.55±2.3	3.67±3.7	4.71±4.7	-	13.64±4.8
Polygonum plebeium	-	-	-	-	8.18±4.7
Potentilla argyrophlla	-	-	6.53±3.8	-	-

Potentilla venusta	3.23±1.6	-	-	8.33±4.8	10.54±6.1
Potentilla venusta /anseria	-	2.33±2.3	-	-	-
Pucinellia himalaica	-	-	-	-	6.45±6.5
Ranunculus hyperboreus	-	2.78±2.8	-	-	-
Rhodiola imbricata	2.84±1.4	-	-	-	-
Rotala rotundifolia	-	-	2.90±2.9	-	-
Rumex nepalensis	-	6.76±3.1	3.26±3.3	4.59±2.9	10.87±6.4
Saussurea jacea	3.41±1.7	-	-	8.02±4.6	-
Saxifraga flagellaris	3.98±2.0	-	-	9.55±3.5	-
Scirpus cunneata	-	2.08±2.1	-	-	-
Sedum ewersii	-	-	3.31±3.3	-	-
Sibbaldia cunneata	-	6.25±3.7	3.68±3.7	8.05±4.9	8.97±3.7
Silene himalayensis	1.79±0.9	-	-	-	-
Taraxacum officinale	3.23±1.6	2.53±2.5	6.96±3.3	12.83±4.4	13.66±4.7
Thymus serphyllum	5.24±2.6	-	7.62±4.4	-	8.47±5.2
Trifolium repens	-	1.52±1.5	-	-	-
Verbascum thapsus	5.96±3.0	-	-	-	-
Waldheimia glabra	5.80±2.9	-	-	-	-
Waldheimia tomentosa	3.49±1.7	-	-	-	-

Table 2.11: Relative density (%) of plant species occurred in several landforms of outside the CTWS, Himachal Pradesh.

Species	**HOS**	**NSOS**	**RSOS**	**GLOS**
Anaphalis nepalensis	2.70±2.7	10.28±2.9	8.31±3.1	7.01±4.5
Aster flaccidus	9.16±5.3	-	-	-

Berginea stracheyi	3.22±3.2	-	7.65±4.4	-
Bistorta affinis	21.44±7.4	9.73±3.3	8.66±5.3	12.16±4.7
Bromus	-	-	3.24±3.2	-
Carex nivalis	-	7.17±2.9	-	-
Chesneya cuneata	-	-	8.28±2.8	-
Circium arvense	-	-	13.41±1.2	-
Epilobium angustifolium	4.65±4.6	-	5.47±3.2	-
Geranium pratense	6.97±4.1	-	-	-
Hygrophila lancea	-	10.05±3.5	-	-
Leontopodium ochroleucum	6.43±3.9	4.18±4.2	-	-
Lindelofia stylosa	-	-	9.06±3.6	-
Lomatogonium carinthiacum	3.31±3.3	1.51±1.5		-
Medicago falcata	-	-	5.13±3.0	-
Minuartia kashmirica	-	3.89±2.3	-	-
Nepeta longibracteata	4.10±4.1	-	-	-
Oxyria digyna	1.94±1.9	6.35±3.9	10.22±2.0	-
Oxytropis microphylla	2.67±2.7		-	-
Plantago depressa	-	6.29±3.7	-	10.62±3.7
Poa alpigena	-	-	-	16.47±6.3
Polygonum plebeium	2.97±2.9	-	-	-
Potentilla venusta	8.53±3.3	-	5.78±3.6	16.23±5.7
Rannunculus repens	2.76±2.8	-	-	-
Rhodiola imbricata	7.20±2.5	-	-	-

Rhodiola tibetica	-	8.70±5.2	-	-
Rumex nepalensis	-	-	-	8.69±3.1
Saxifraga flagellaris	1.89±1.8	7.85±0.8	-	-
Sibbaldia cunneata	-	2.96±2.9	-	9.19±6.0
Taraxacum officinale	-	5.86±3.4	7.93±2.8	8.06±5.4
Thymus serphyllum	3.83±2.2	9.23±4.0	6.86±2.9	8.07±2.8
Trigonell emodii	-	-	-	3.50±3.5
Waldheimia glabra	1.46±1.4	5.97±3.5	-	-
Waldheimia tomentosa	4.76±2.8	-	-	-

Table 2.12: Relative frequency (%) of plant species occurred in several landforms of outside the CTWS, Himachal Pradesh.

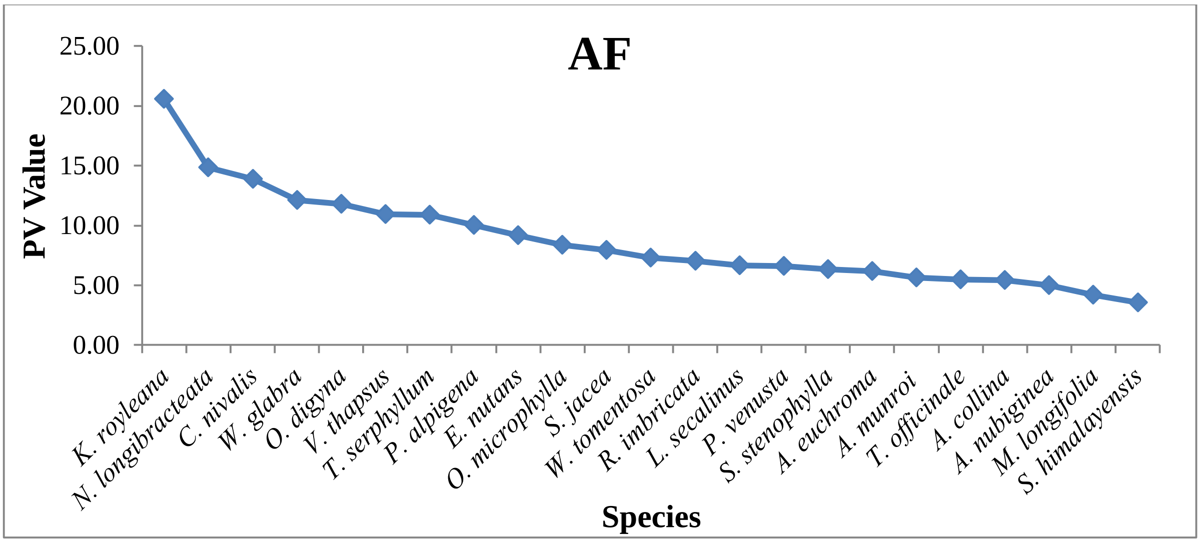
Species	**HOS**	**NSOS**	**RSOS**	**GLOS**
Anaphalis nepalensis	2.72 ± 2.7	9.74 ± 1.8	8.17 ± 2.9	6.97 ± 4.2
Aster flaccidus	7.29 ± 4.2	-	-	-
Berginea stracheyi	3.09 ± 3.1	-	6.57 ± 3.9	-
Bistorta affinis	15.16 ± 5.3	7.62 ± 2.6	7.84 ± 4.6	10.92 ± 3.7
Bromus sp.	-	-	3.09 ± 3.1	-
Carex nivalis	-	6.30 ± 3.0	-	-
Chesneya cuneata	-	-	9.03 ± 3.1	-
Circium arvense	-	-	11.93 ± 1.3	-
Epilobium angustifolium	3.96 ± 4.0	-	4.31 ± 2.5	-
Geranium pratense	7.62 ± 4.5	-	-	-
Hygrophila lancea	-	8.83 ± 3.0	-	-
Leontopodium ochroleucum	7.00 ± 4.3	4.33 ± 4.3	-	-
Lindelofia stylosa			9.73 ± 3.9	-
Lomatogonium carinthiacum	3.70 ± 3.7	2.33 ± 2.3	-	-

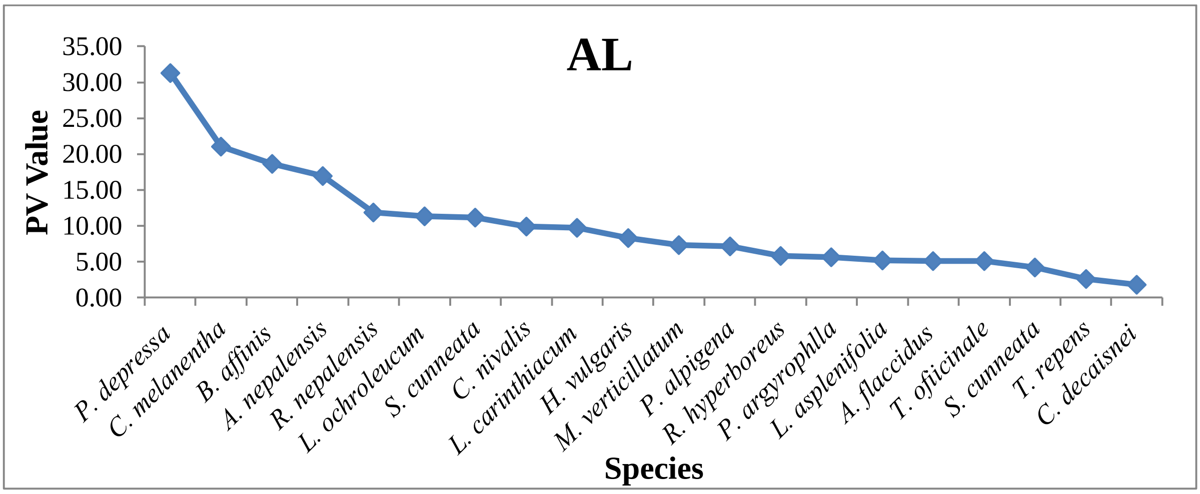
Medicago falcata	-	-	6.49 ± 3.8	-
Minuartia kashmirica	-	4.86 ± 2.9	-	-
Nepeta longibracteata	3.96 ± 4.0	-	-	-
Oxyria digyna	2.44 ± 2.4	6.87 ± 4.0	10.93 ± 2.2	-
Oxytropis microphylla	2.78 ± 2.8	-	-	-
Plantago depressa	-	5.82 ± 3.4	-	11.73 ± 4.6
Poa alpigena	-	-	-	15.40 ± 5.4
Polygonum plebeium	3.27 ± 3.3	-	-	-
Potentilla venusta	9.71 ± 3.4	-	5.91 ± 3.6	15.26 ± 5.5
Rannunculus repens	3.09 ± 3.1	-	-	-
Rhodiola imbricata	8.50 ± 3.0	-	-	-
Rhodiola tibetica	-	7.83 ± 4.5	-	-
Rumex nepalensis	-	-	-	9.60 ± 3.5
Saxifraga flagellaris	2.17 ± 2.1	9.16 ± 0.5	-	-
Sibbaldia cunneata	-	3.77 ± 3.8	-	9.66 ± 6.6
Taraxacum officinale	-	6.33 ± 3.7	9.76 ± 3.7	6.98 ± 4.7
Thymus serphyllum	5.46 ± 3.2	8.91 ± 3.3	6.25 ± 2.5	9.85 ± 3.5
Trigonell emodii	-	-	-	3.62 ± 3.6
Waldheimia glabra	2.44 ± 2.4	7.31 ± 4.3	-	-
Waldheimia tomentosa	5.64 ± 3.3	-	-	-

❖ Dominance diversity curve

Dominance diversity curve of recorded species of Protected Area is given in Figure 2.22. In AF land-form, *K. royleana* showed dominance with maximum (20.60) PV value. In AL land-form, *P. depressa* showed dominance with maximum (31.27) PV value. In NS land-form, *H. lancea* showed dominance with maximum (27.87) PV value. In RS land-form, *B. affinis* showed dominance with maximum (44.88) PV value. In GL land-form, *P. alpigena* showed dominance with maximum (28.74) PV value.

Dominance diversity curve of observed species outside the Protected Area is given in Figure 2.23. In HOS land-form, *B. affinis* showed dominance with maximum (36.59) PV value. In NSOS land-form, *A. nepalensis* showed dominance with maximum (20.03) PV value. In RSOS land-form, *C. arvense* showed dominance with maximum (25.34) PV value. In GLOS land-form, *P. alpigena* showed dominance with maximum (31.86) PV value. land-form, *P. alpigena* showed dominance with maximum (31.86) PV value.





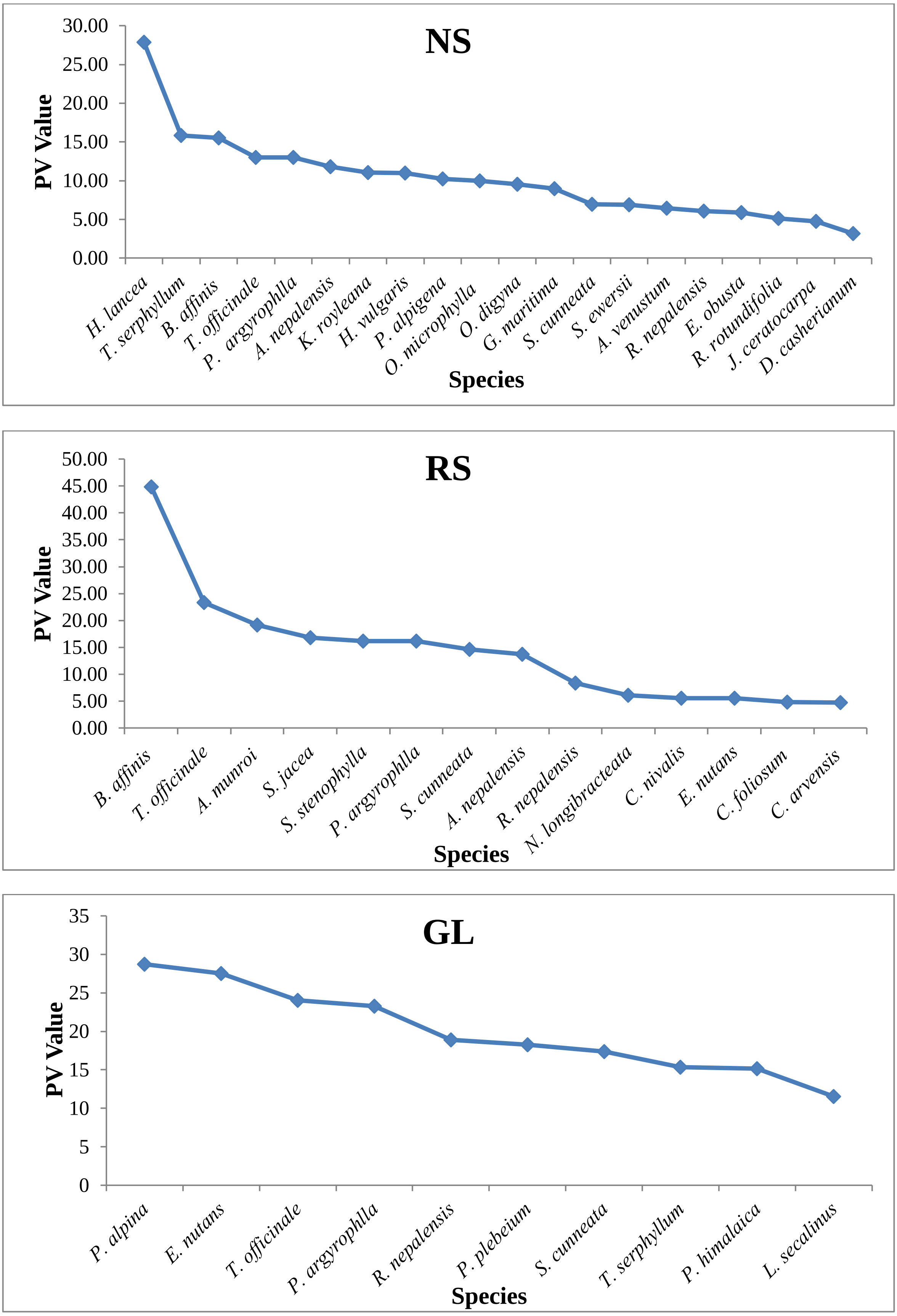
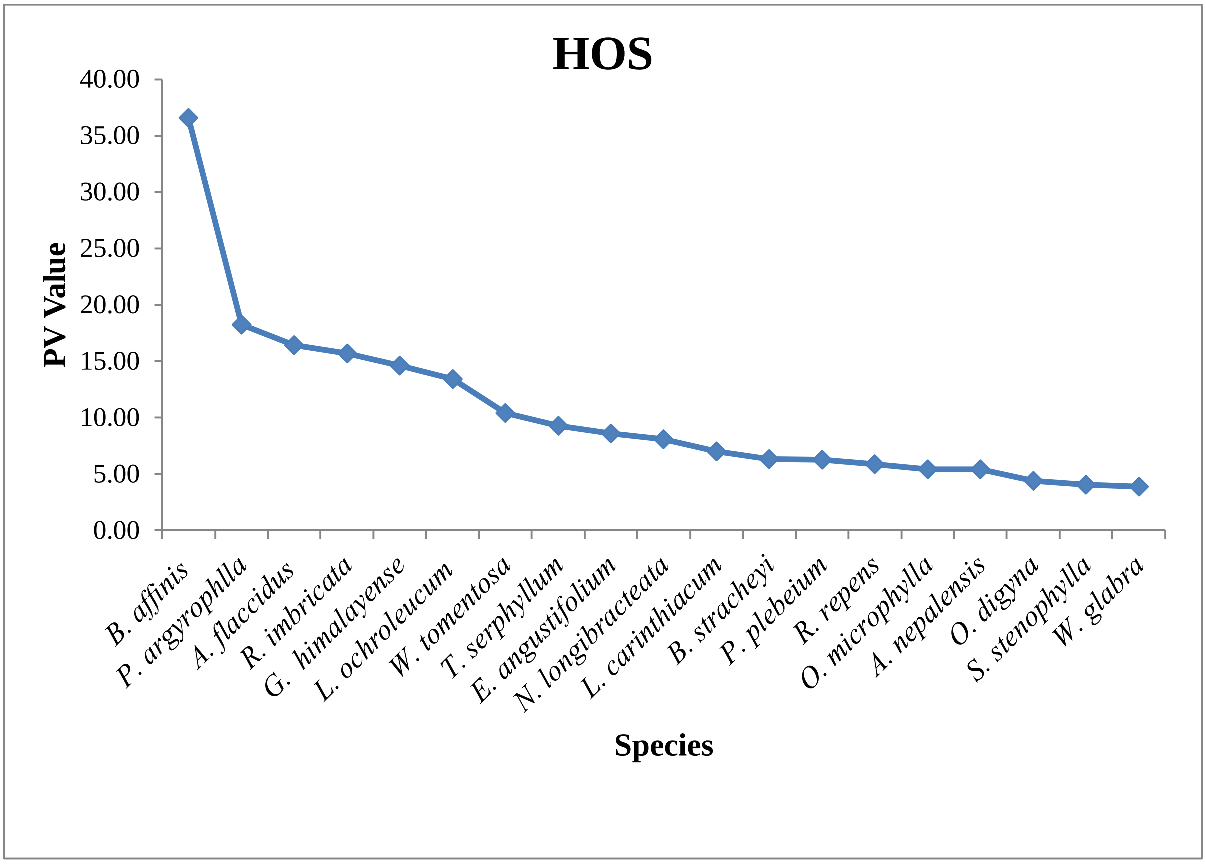
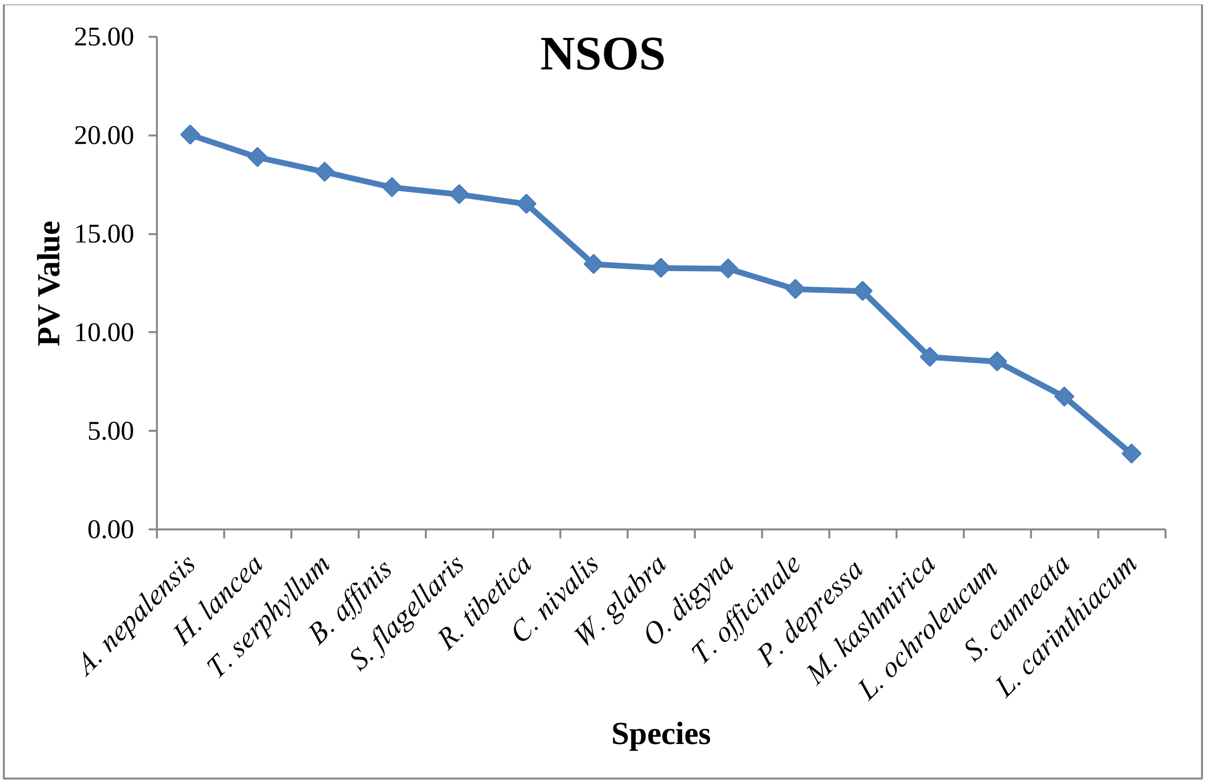
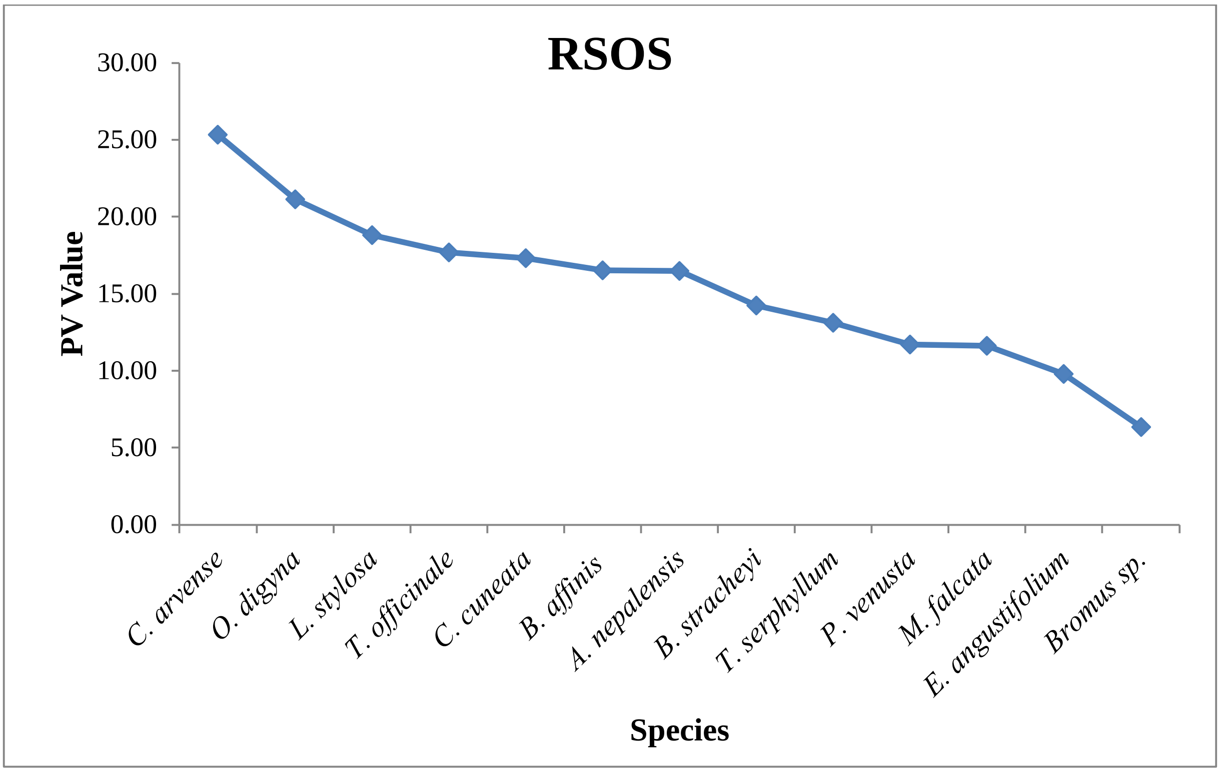


Figure 2.22: Dominance diversity curve of different studied land-forms in CTWS, Himachal Pradesh.


HOS
PV Value
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
B. affinis
P. argyrophlla
A. flaccidus
R. imbricata
G. himalayense
L. ochroleucum
W. tomentosa
T. serphyllum
E. angustifolium
N. longibracteata
L. carinthiacum
B. stracheyi
P. plebeium
R. repens
O. microphylla
A. nepalensis
O. digyna
S. stenophylla
W. glabra
Species


NSOS
PV Value
25.00
20.00
15.00
10.00
5.00
0.00
A. nepalensis
H. lancea
T. serphyllum
B. affinis
S. flagellaris
R. tibetica
C. nivalis
W. glabra
O. digyna
T. officinale
P. depressa
M. kashmirica
L. ochroleucum
S. cunneata
L. carinthiacum
Species



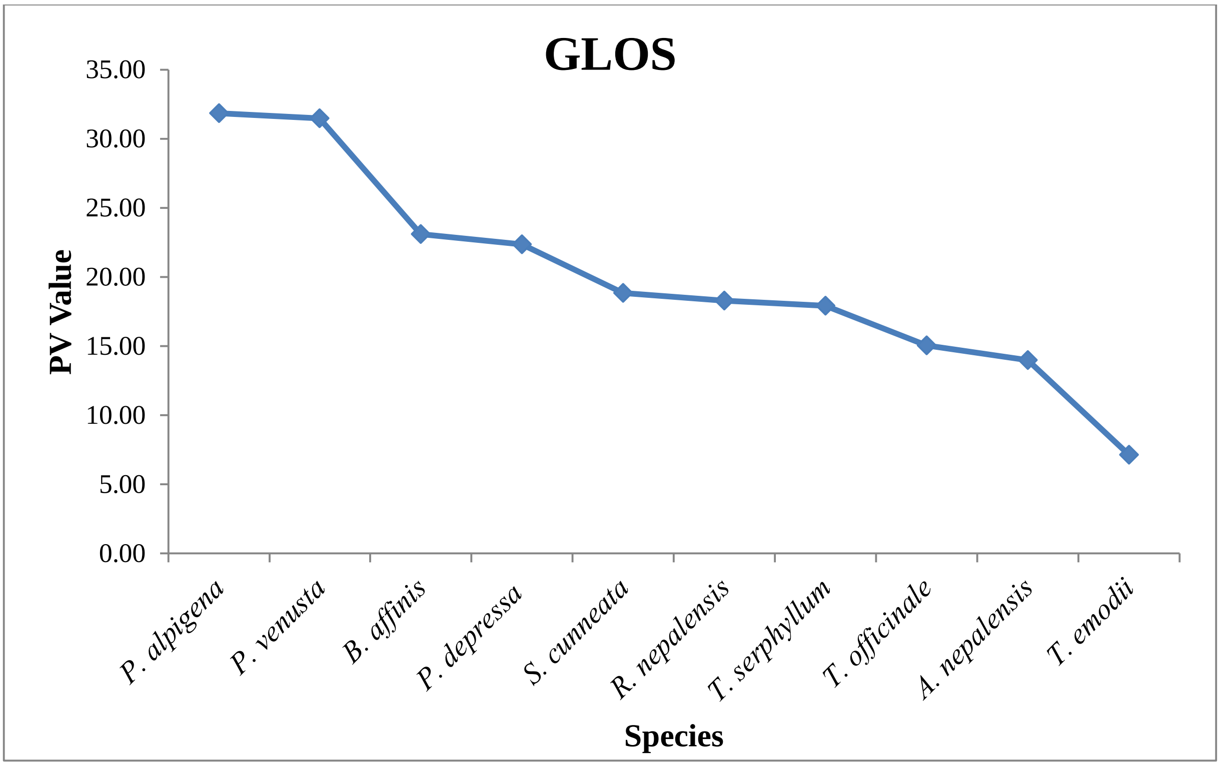


Figure 2.23: Dominance diversity curve of different studied land-forms of outside the CTWS, Himachal Pradesh.

Species richness and diversity

***Poa* community:**

Within this community, the species richness ranged from 15 to 1 with an average value of 6.66 ±4.25. The species diversity ranged from 0 to 2.65 with an average value of 1.33 ± 0.76.

***Potentilla* community:**

Within this community, the species richness ranged from 4 to 11 with an average value of 6.57 ± 0.97. The species diversity ranged from 1.31 to 2.46 with an average value of 0.94 ± 0.13.

***Plantago* community:**

Within this community, the species richness was 6 ± 0. The species diversity was 1.71 ± 0.

***Bistorta* community:**

Within this community, the species richness ranged from 7 to 12 with an average value of 8.50 ± 0.76. The species diversity ranged from 1.92 to 2.41 with an average value of 2.03 ± 0.08.

***Anaphalis* community:**

Within this community, the species richness ranged from 4 to 7 with an average value of 6 ± 0.57. The species diversity ranged from 1.56 to 2.16 with an average value of 1.88 ± 0.08.

***Taraxacum* community:**

Within this community, the species richness ranged from 7 to 10 with an average value of 8.33 ± 0.42. The species diversity ranged from 1.83 to 2.24 with an average value of 2.09 ± 0.07.

***Waldheimia* community:**

Within this community, the species richness ranged from 2 to 13 with an average value of 7.5 ± 5.5. The species diversity ranged from 0.66 to 2.49 with an average value of 1.58 ± 0.91.

- **Pin Valley National Park (PVNP)**

Four distinct vegetation communities were recognized based on TWINSPAN analysis as shown in Figure. 2.24, where the height along the vertical axis represents the total Chi-squares of divisions. TWINSPAN is a divisive clustering based on splitting first correspondence analysis axis and then, recursively working with each split subset. The stopping point of the group formation was set at height 4, which resulted in the formation of four vegetation communities.

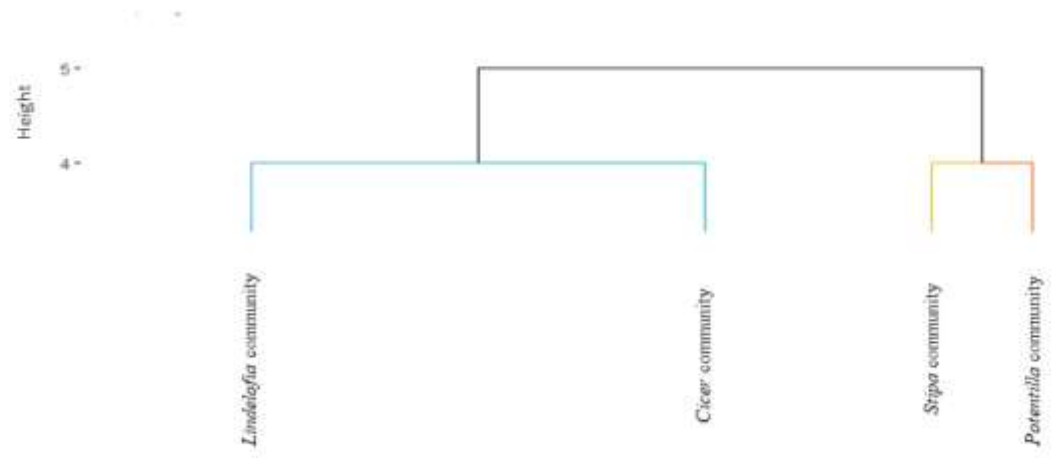


Figure 2.24: Twinspan dendrogram showing four distinct vegetation communities in PVNP, Himachal Pradesh.

Species richness and diversity

***Potentilla* community:**

Within this community, the herb species richness ranged from 6 to 11 with an average value of 8.2±1.15. The species diversity ranged from 1.43 to 1.72 with an average value of 1.69±0.08.

***Stipa* community:**

Within this community, the species richness ranged from 4 to 9 with an average value of 8.0±1.10. The species diversity ranged from 0.49 to 1.83 with an average value of 1.47±0.33.

***Cicer* community:**

Within this community, the species richness ranged from 3 to 10 with an average value of 6.75±1.10. The species diversity ranged from 1.04 to 1.97 with an average value of 1.73±0.09.

***Lindelofia* community:**

Within this community, the species richness ranged from 6 to 9 with an average value of 7.1 ±0.34. The species diversity ranged from 0.47 to 1.99 with an average value of 1.72±0.05.

2.4.3. Forest Land Cover Classification

- **Col. Sher Jung National Park (CSJNP)**

The area statistics of forest land use classes of the Col. Sher Jung National Park has been given below in Table 2.13. It showed that the highest proportion of the area of CSJNP is covered by the Shorea community, which is about 985.30 ha. The bare land covered 160 ha and the waterbody covered the lowest proportion, which is 2.56% of the total area (72.89 ha).

Table 2.13: Area statistics of forest land cover classes of CSJNP, Himachal Pradesh.

Class type	**Area (ha)**	**Percentage (%)**
Shorea community	985.30	34.54
Ficus community	455.39	15.96
Eucalyptus community	373.78	13.10
Terminalia Community	803.94	28.18
Bareland	160.63	5.63
Water	72.89	2.56
Total	2851.95	100

- **Accuracy assessment:**

The accuracy assessment is essential to validate the results of image classification results and a number of methods have been developed for this process. For accuracy assessment validation, an error matrix has been prepared with the help of classified and pre classification satellite imagery, using randomly selected reference points that represent all the classes. The overall accuracy of the classified image was 79% and a kappa coefficient of 0.75 (Table.2.14).

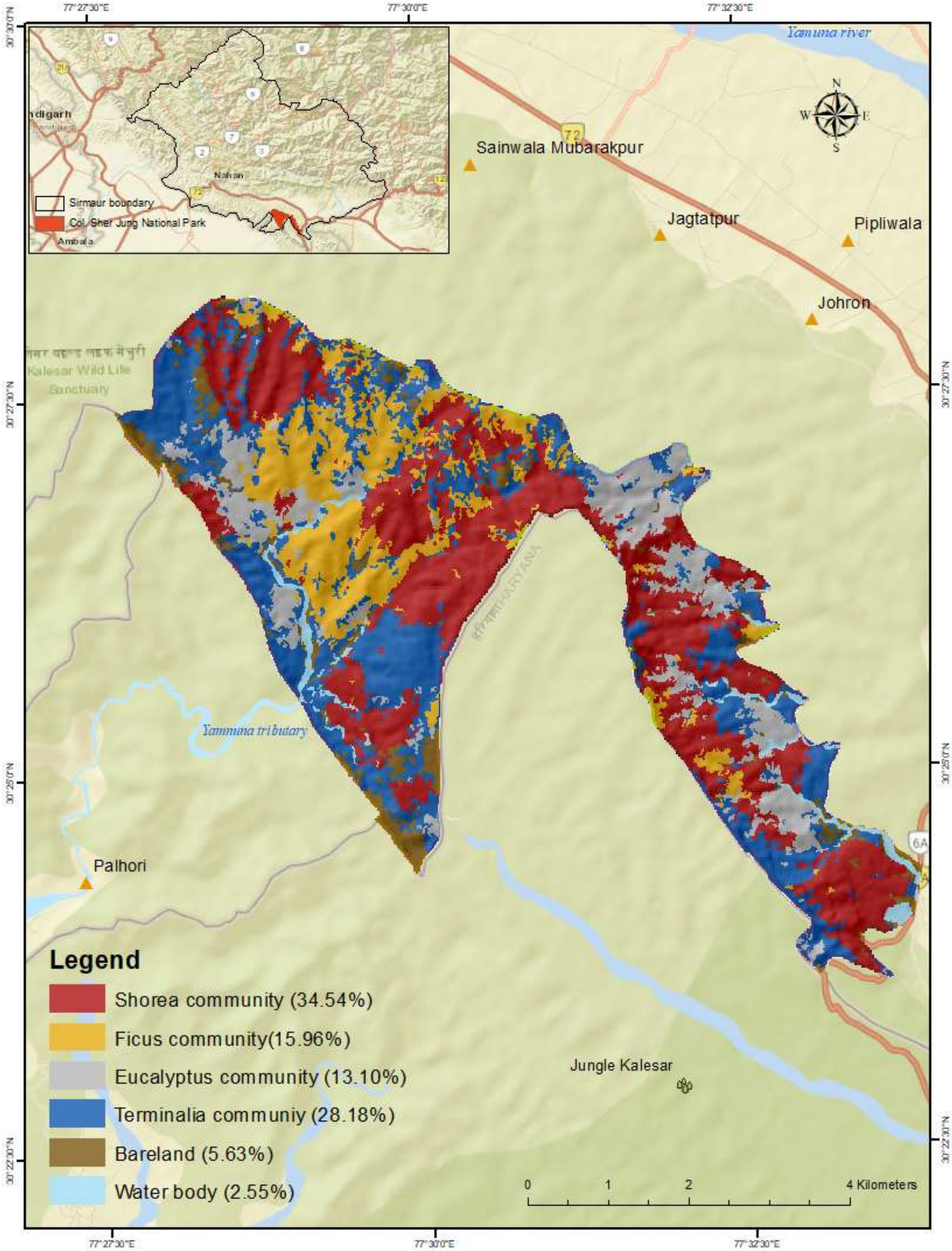


Figure 2.25: Forest land cover map of CSJNP, Himachal Pradesh.

Table. 2.14: Error matrix, overall accuracy and Kappa coefficient for land cover classification of CSJNP, Himachal Pradesh.

Class type	*Shorea* community	*Ficus* community	*Eucalyptus* community	*Terminalia* community	Bareland	Waterbody	Total (User)	Commission error (%)	User accuracy (%)
Shorea community	10	0	1	3	0	0	14	7.14	71.43
Ficus community	3	7	0	0	0	0	10	30	70
Eucalyptus community	0	0	9	2	0	0	11	18.18	81.82
Terminalia Community	1	0	1	8	0	0	10	20	80
Bareland	1	0	0	0	8	0	9	11.11	88.89
Waterbody	0	0	0	0	1	8	9	11.11	88.89
Total (Producer)	15	7	11	13	9	8	63		
Omission error (%)	33.33	0	18.18	23.08	11.11	0			
Producer accuracy (%)	66.67	100	81.82	61.54	88.89	100			
Overall Accuracy	0.7937								
Kappa coefficient	0.7507								

- **Churdhar Wildlife Sanctuary (CWS)**

The area statistics of forest cover classes of the Churdhar Wildlife Sanctuary has been given below in Table (2.15). A total of 10 land cover classes were identified of which Himalayan Moist Temperate Forest (Rai, kharsu) occupied the highest proportion (38.4%) of total area, followed by Himalayan Moist Temperate Forest (Moru, rai) (13.9%) and Himalayan Moist Temperate Forest (Rai, kharsu, tosh) (11.6%). The lowest proportion (0.74%) was covered by Himalayan (Bell rhododendron), while the non-forest area covered 4% of the total area.

Table 2.15: Area statistics of land cover of CWS, Himachal Pradesh.

Class Type	Area (ha)	Percentage (%)
Himalayan Moist temperate Forest (Rai khrarsu)	2432.73	38.42
Himalayan Moist temperate Forest (Kharsu, Silver fir, rai)	683.90	10.80
Himalayan Moist temperate Forest (Rai, Kharsu, Tosh)	740.45	11.69
Himalayan Moist temperate Forest (Rai, kharsu, burans)	425.03	6.71
Himalayan Moist temperate Forest (Moru, rai)	885.87	13.99
Himalayan Moist temperate Forest (Moru, ban)	577.57	9.12
Non-Forest	258.03	4.07
Himalayan Moist Temperate Pasture	170.52	2.69
Dry alpine scrub Juniper	109.83	1.73
Himalayan Moist Alpine scrub (bell rhododendron)	47.47	0.74
Total	6331.43	100

Accuracy assessment

The accuracy assessment is essential to validate the results of image classification results and a number of methods have been developed for this process. For accuracy assessment validation, an error matrix has been prepared with the help of classified and pre classification satellite imagery, using randomly selected reference points that represent all the classes. The overall accuracy of the classified image was 87% and a kappa coefficient of 0.85 (Table 2.16).

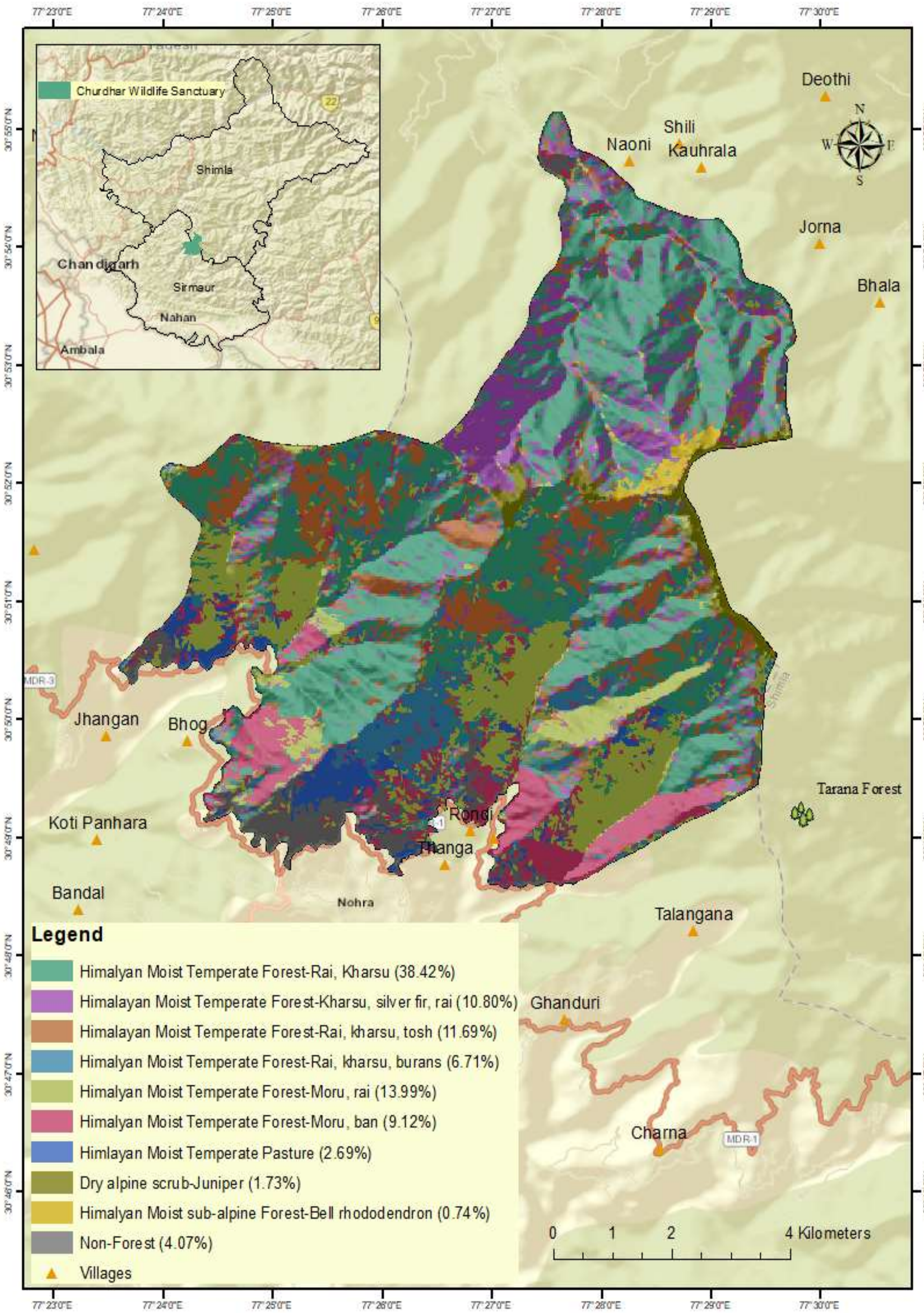


Figure 2.26: Forest land cover map of CWS, Himachal Pradesh.

Table 2.16: Error matrix, Overall accuracy and Kappa statistics for CWS, Himachal Pradesh.

	Himalayan Moist Temperate Forest	Himalayan Moist Temperate Forest	Himalayan Moist Temperate Forest	Himalayan Moist Temperate Forest	Himalayan Moist Temperate Forest	Himalayan Moist Temperate Forest	Non-Forest	Himalayan Moist Temperate Pastur	Dry Alpine scrub (Juniper)	Himalayan Moist alpine scrub(Bell	Total user	Commission error (%)	User accuracy (%)
Himalayan Moist Temperate Forest (Rai, khrarsu)	17	0	0	2	1	1	0	0	0	0	21	19	81
Himalayan Moist Temperate Forest (Kharsu, silver fir, rai)	1	7	0	0	0	1	0	0	0	0	9	23	78
Himalayan Moist Temperate Forest (Rai, kharsu, tosh	1	0	9	0	0	0		0	0	0	10	10	90
Himalayan Moist Temperate Forest (Rai, kharsu, burans)	0	0	0	6	1		1	0	0	0	8	25	75
Himalayan Moist Temperate Forest (Moru, rai)	0	0	0	0	10	1	0	0	0	0	11	9	80
Himalayan Moist Temperate Forest (Moru, ban)	1	0	0	0		8		1	0	0	10	20	100
Non-Forest	0	0	0	0	0	0	5		0	0	5	0	100
Himalayan Moist Temperate Pasture	0	0	0	0	0	0	0	9	0	0	9	0	100
Dry Alpine scrub (Juniper)	0	0	0	0	0	0	0	0	5	0	5	0	100
Himalayan Moist alpine scrub(Bell rhododendron)	0	0	0	0	0	0	0	0	0	6	6	0	6
Total producer	20	7	9	8	12	11	6	10	5	6	94		
Omission error	15	0	0	25	16	27	17	10	0	0			
Producer accuracy (%)	85	100	100	75	84	73	84	90	100	100			
Overall Classification accuracy	0.87												
Kappa coefficient	0.85												

- **Chandratal Wildlife Sanctuary (CTWS)**

The area statistics of forest cover classes of the Chandratal Wildlife Sanctuary has been given below in table (2.17). A total of 10 land cover classes were identified of which *Anaphalis* community occupied the highest proportion (21%) of total area, followed by *Potentilla* community (19.29%) and *Taraxacum* community (11.03%). The water body and snow covered 1.25% and 4.60% of the total area.

Table 2.17: Area statistics for the land cover types of CTWS, Himachal Pradesh.

Class type	**Area (ha)**	**Percentage (%)**
Water body	48.69	1.25
Waldheimia community	279.49	7.18
Bistorta community	686.94	17.65
T*araxacum* community	429.17	11.03
Poa community	215.12	5.53
Plantago community	235.96	6.06
Elymus community	249.02	6.40
Anaphalis community	817.28	21.00
Potentilla community	750.50	19.29
Snow cover	179.04	4.60
Total	3891.25	100.00

Accuracy assessment:

The accuracy assessment is essential to validate the results of image classification results and a number of methods have been developed for this process. For accuracy assessment validation, an error matrix (Table 2.18) has been prepared with the help of classified and pre classification satellite imagery, using randomly selected reference points that represented all the classes. The overall accuracy of the classified image was 83% and a kappa coefficient of 81%.

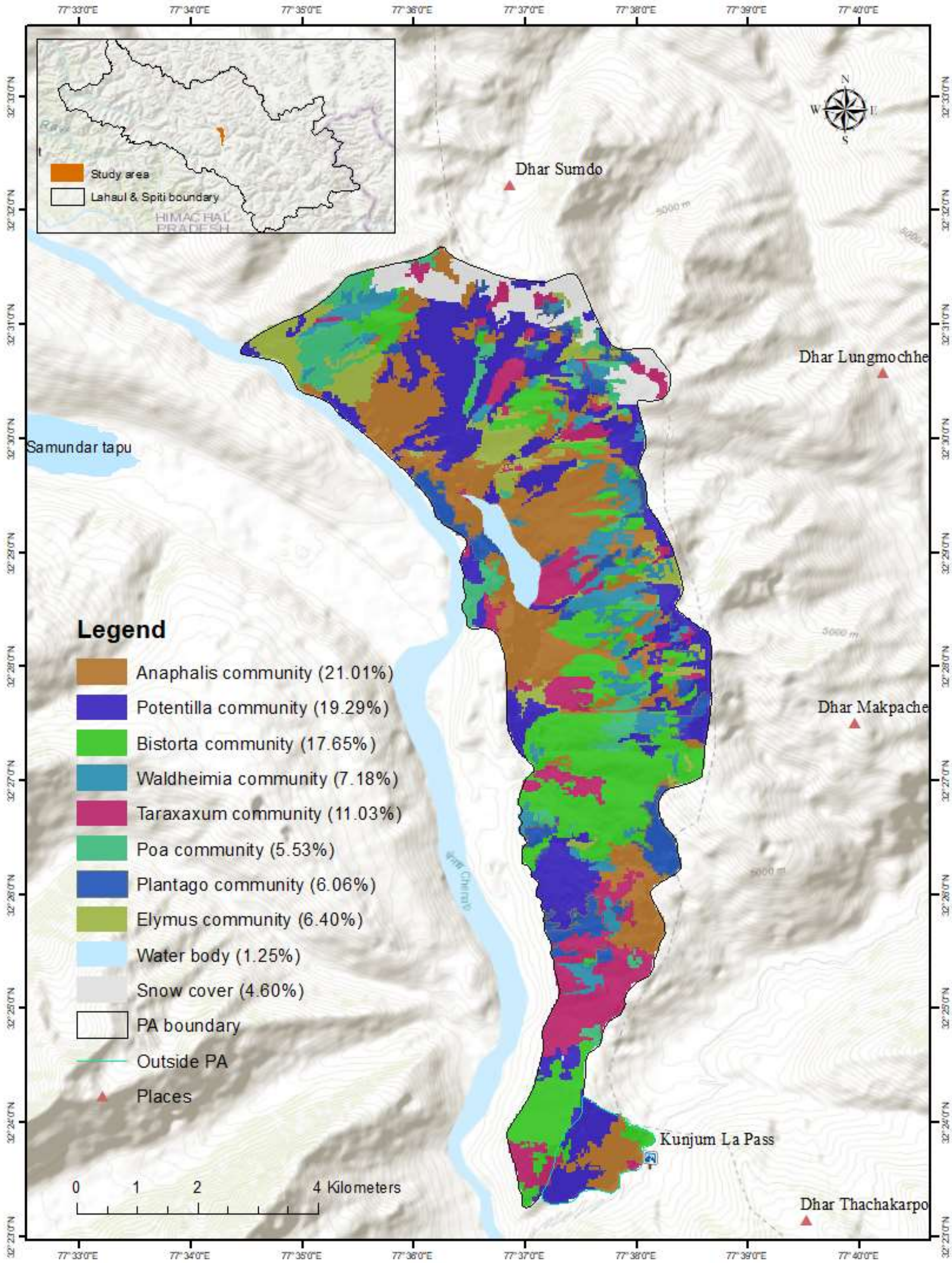


Figure 2.27: Forest land cover map of CTWS, Himachal Pradesh.

Table 2.18: Error matrix, Overall accuracy and Kappa statistics for land cover classification of CTWS, Himachal Pradesh.

Class type	Snow cover	Potentilla community	Anaphalis community	Elymus community	Plantago community	Poa community	Taraxacum community	Bistorta community	Waldheimia community	Water body	Total (user)	Comission error	User accuray (%)
Snow cover	6	0	0	0	0	0	1	0	0	0	7	14.29	85.71
Potentilla community	0	6	1	0	0	1	0	0	0	0	8	25.00	75.00
Anaphalis community	0	1	9	0	1	0	0	0	0	0	11	18.18	81.82
Elymus community	0	0	1	5	0	0	1	0	0	0	7	28.57	71.43
Plantago community	0	0		0	3	0	0	0	0	0	3	0.00	75.00
Poa community	0	0	1	0	0	3	0	0	0	0	4	25.00	88.89
Taraxacum community	0	0	1	0	0	0	8	0	0	0	9	11.11	80.00
Bistorta community	0	0	2	0	0	0		8	0	0	10	20.00	85.71
Waldheimia community	0	0	0	0	0	0	1		6	0	7	14.29	100.00
Water body	0	0	0	0	0	0	0	0	0	5	5	0.00	0.00
Total (producer)	6	7	15	5	4	4	11	8	6	5	71		
Omission error	0.00	14.29	40.00	0.00	25.00	25.00	27.27	0.00	0.00	0.00			
Producer accuracy %	100.00	85.71	60.00	100.00	75.00	75.00	72.73	100.00	100.00	100.00			
Overall Classification accuracy	83.10												
Kappa coefficient	0.81												

- **Pin Valley National Park (PVNP)**

The area statistics of forest cover classes of the PVNP has been given below in Table 2.19. A total of 6 land cover classes were identified of which Bareland occupied the highest proportion (48%) of total area, followed by *Cicer* community (19.29%) and *Stipa* community (11.03%). The snow covered 22.36 of the total area.

Table 2.19: Area statistics for the land cover types of PVNP, Himachal Pradesh.

Land cover type	**Area (ha)**	**Percentage (%)**
Snow cover	16112.52	22.36
Bareland	35104.89	48.72
Lindlefolia community	907.32	1.26
Cicer community	9809.69	13.62
Stipa community	9211.79	12.78
Potentilla community	907.59	1.26
	72053.82	100.00

Accuracy assessment:

The accuracy assessment is essential to validate the results of image classification results and a number of methods have been developed for this process. For accuracy assessment validation, an error matrix has been prepared with the help of classified and pre classification satellite imagery, using randomly selected reference points that represent all the classes. The overall accuracy of the classified image was 83% and a kappa coefficient of 0.79 (Table. 2.20).

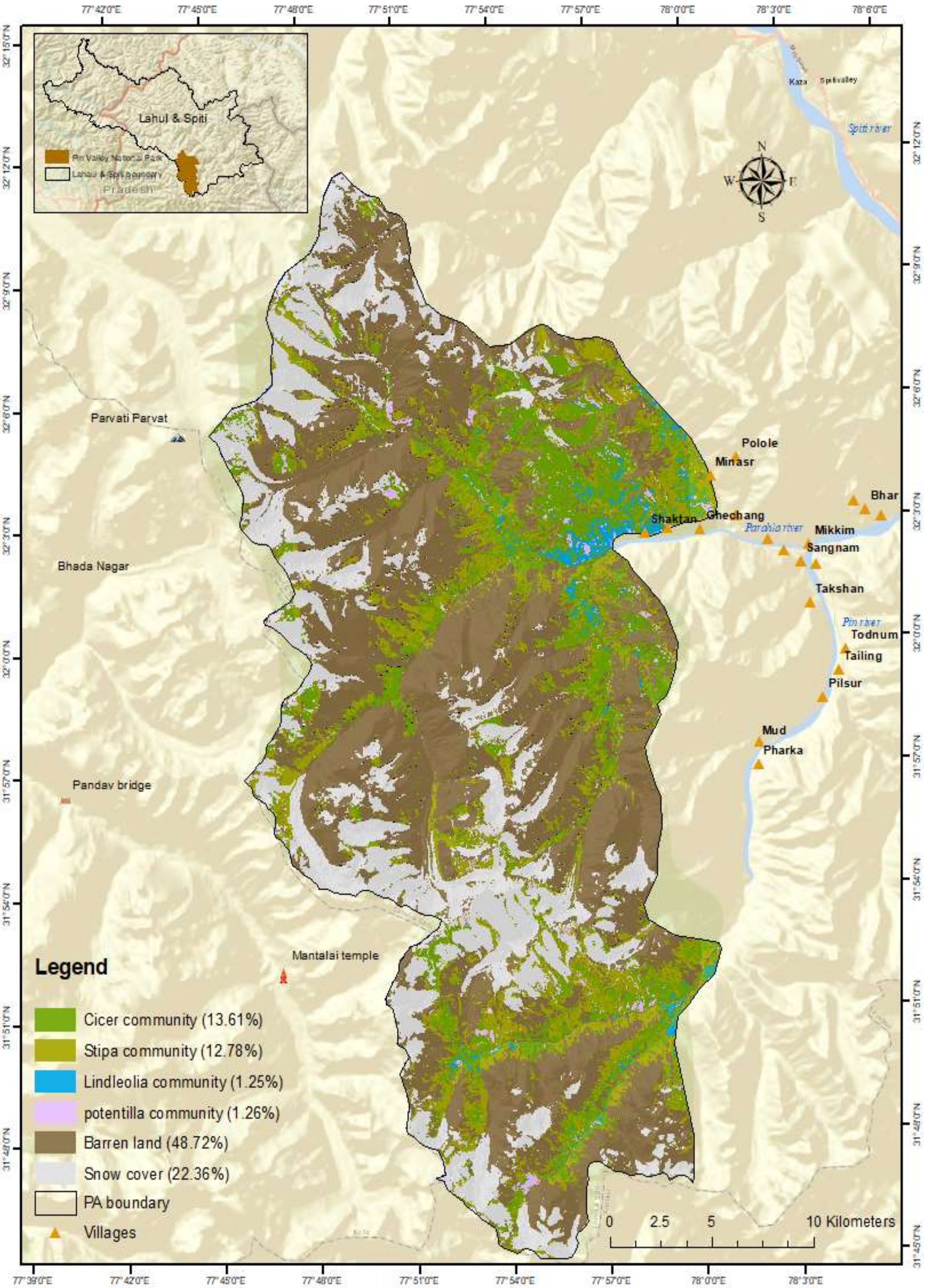


Figure 2.28: Land cover map of PVNP, Himachal Pradesh.

Table 2.20: Error matrix, overall accuracy and Kappa statistics land cover classification of PVNP, Himachal Pradesh.

	Cicer community	*Stipa* community	*Lindelfolia* community	Potentilla community	Barren land	Snow cover	Total (user)	Commission error (%)	User accuracy (%)
Cicer community	16	3	0	0	0	0	19	15.79	84.21
S*tipa* community	3	15	0	2	0	0	20	25	75
Lindelfolia community	1	1	9	0	0	0	11	18.18	81.82
Potentilla community	3	1	2	10	0	0	16	31.25	62.5
Barraen land	1	0	0	0	23	1	25	8	92
Snow cover	0	0	0	1	0	20	21	0	95.24
Total (Producer)	24	20	11	13	23	21	112		
Omission error (%)	33.34	25	18.12	15.38	0	4.76			
Producer accuracy (%)	66.67	75	81.81	76.92	100	95.24			
Overall Accuracy	83.03	0	0	0	0	0			
Kappa coefficient	0.79								

- **Resource utilization in Spiti Valley**

Livestocks are an integral part of farming as these not only substantiated the sources of livelihood, but also ensured sustainable maintenance of soil fertility, through addition of farm yard manure and by providing draft force for farming as well as transport. The observations of the present study demonstrated that, Dzomo contributed highest (36.14%), followed by donkeys (18.88%), Yak contributed 12.05%, Dzo contributed 10.04%, Horse contributed 8.84%, goat contributed 7.27% and sheep contributed minimum 7.23% (Figure 2.29). A decline in population of sheep and goat in Pin valley is observed, due to their conflicts with dogs. The percentage of different goods and services provided by these livestocks in this valley of Himachal is given in Figure 2.30. The barrenness of the land and soil texture demand use of large quantities of farm yard manure (FYM) to raise any crop, which can be obtained only from the livestock as no other compostable material is available.

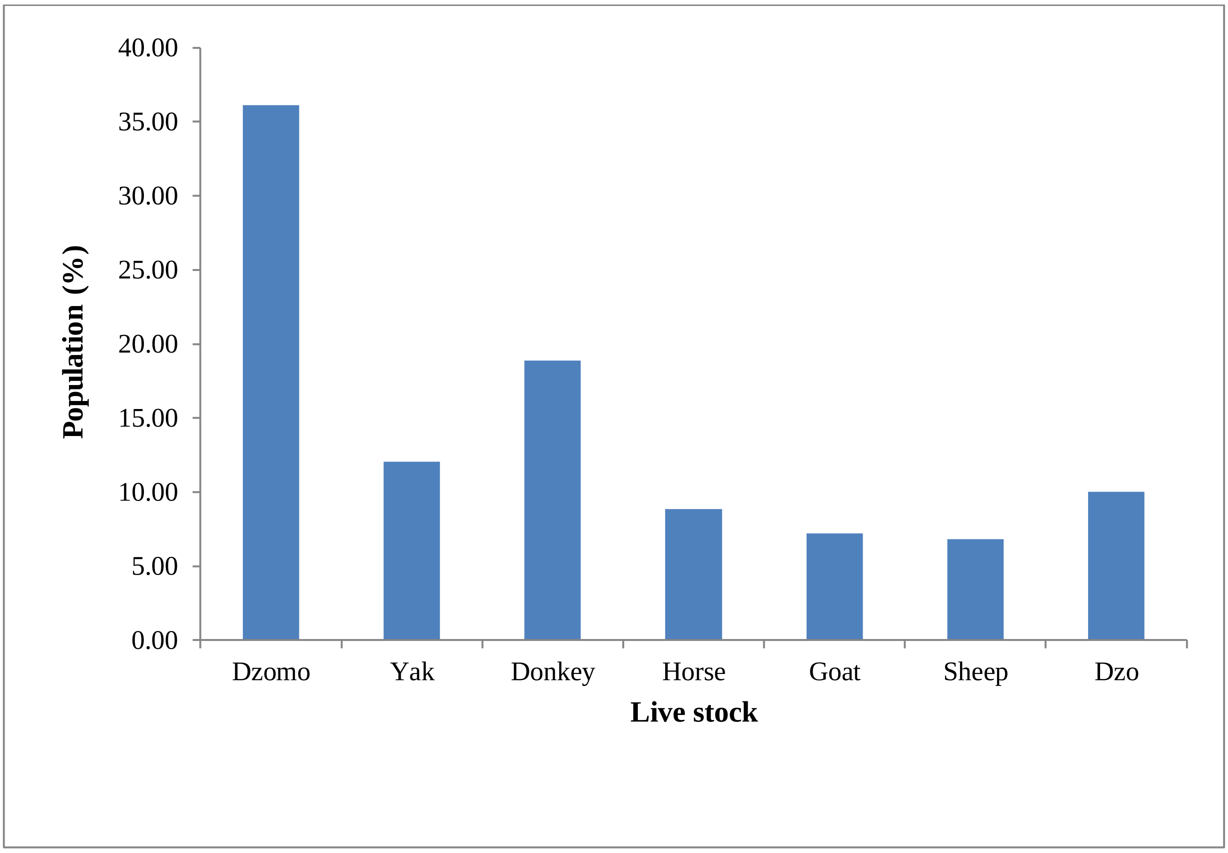


Figure 2.29: Percent contribution of Livestock in Spiti valley, Himachal Pradesh.

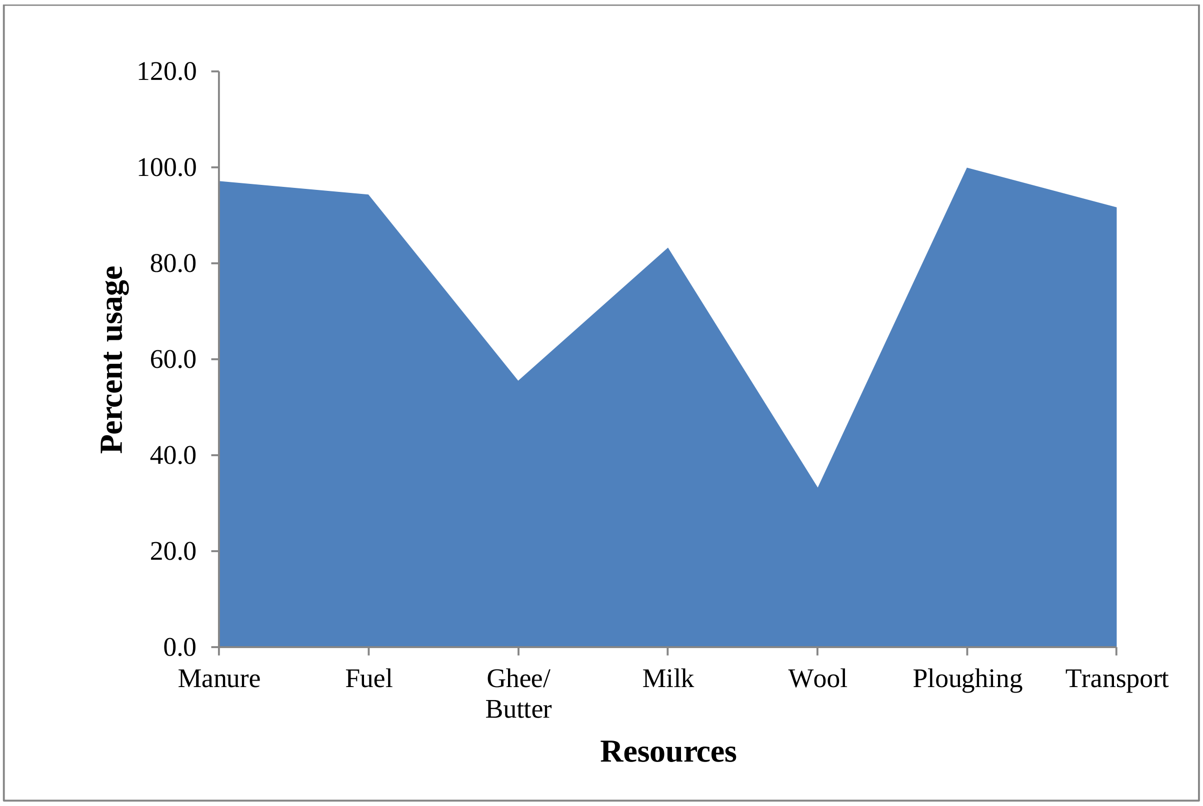


Figure 2.30: Resource contribution by livestock in the Spiti valley, Himachal Pradesh.

Out of 49 plant species belonging to the 27 families, 24 species were used as fodder, 7 species were used for fuel wood, 5 species were used for other purposes by locals. The percent use of different plant species by locals are given in Table 2.21. Fodder availability in cold arid regions is 40-50 per cent of the actual requirement however, in some areas it is more than 50% also. Huge deficit of fodder at village level itself explains the great significance of high-altitude pasture lands. Grazing resources are very much lesser in Spiti valley as compared to the others. The stems of *Cotoneaster microphyllus* were commonly used to groom specially to sweep out the snow during winters, along with the good manure the roots of *Arnebia euchroma*, is also used as hair dye which local women apply it with hair oil. *Elaeagnus angustifolius* which is commonly known as "Teche", used commercially as a seasonal vegetable having a high nutritional value. Leaves of *Mentha longifolia* are used to increase the flavor of tea. *C. mirophyllum* and *S. jacea* are the most preferable fodder species used by locals. The fodder species demand percentage is given in Figure 2.31. There are 6 species that were found to use for more than single purpose, *Aconogonum tortosum* and *Taraxacum offinicale* were used for fodder and medicinal purpose. Myricaria germanica and Salix alba were used for fodder as well as fuel wood while Hippophae *rhamnoides* was used as fodder, fuel wood and other commercial purposes such as jam, juice, tea etc. *Hippophae rhamnoides* have the great importance as this is very famous for different commercial products specially, Seabuckthorn tea is a very popular drink of this valley.

Table.2.21: The percent use of different plant species by locals in Spiti valley, Himachal Pradesh.

S. No.	Species	Family	Percent use
	Fodder		
1	*Aconogonum tortousum*	Polygonaceae	91.67
2	*Artemisia sp.*	Asteraceae	13.89
3	*Bromus sp.*	Poaceae	61.11
4	*Capparis spinaosa* L.	Capparidaceae	55.56
5	*Capsella bursa-pastoris* (L.) Medik.	Brassicaceae	50.00
6	*Carex* sp.	Cyperaceae	75.00
7	*Chenododium botrys* L.	Chenopodiaceae	58.33
8	*Cicer microphyllum*	Fabaceae	97.22
9	*Cyperus* sp.	Cyperaceae	80.56
10	*Elymus* sp.	Poaceae	72.22
11	*Fagopyrum esculentum* Mill.	Polygonaceae	33.33
12	*Festuca rubra*	Poaceae	25.00
13	*Hippophaea rhamnoides* L.	Elaeagnaceae	16.67
14	*Kobresia* sp.	Cyperaceae	58.33
15	*Lepidium sp.*	Brassicaceae	55.56
16	*Lindelofia stylosa*	Boraginaceae	13.89
17	*Myricaria germanica* (L.) Desv.	Tamaricaceae	27.78
18	*Poa annua*	Poaceae	83.33
19	*Polygonum aviculare* L.	Polygonaceae	50.00
20	*Rumex patientia* L.	Polygonaceae	41.67
21	*Salix alba*	Salicaceae	47.22
22	*Salix tetrasperma*	Salicaceae	52.78
23	*Saussurea jacea*	Asteraceae	97.22
24	*Taraxacum officinale* F. H. Wigg.	Asteraceae	66.67
	Fuelwood		
1	*Hippophaea rhamnoides* L.	Elaeagnaceae	80.6

2	*Myricaria germanica* (L.) Desv.	Tamaricaceae	83.3
3	*Populus nigra*	Salicaceae	97.2
4	*Ribes alpestre* L.	Grossulariaceae	55.6
5	*Salix alba*	Salicaceae	41.7
6	*Salix daphnoides*	Salicaceae	27.8
7	*Salix elegans*	Salicaceae	41.7
	Other uses		
1	*Cotoneaster microphyllus*	Leguminosae	Broom
2	*Arnebia euchroma* (Wall. ex G.Don)	Boraginaceae	Hair dye
3	*Elaeagnus angustifolius* L.	Asphodelaceae	Vegetable
4	*Hippophaea rhamnoides* L.	Elaeagnaceae	Commercial use
6	*Mentha longifolia* L.	Lamiaceae	Tea

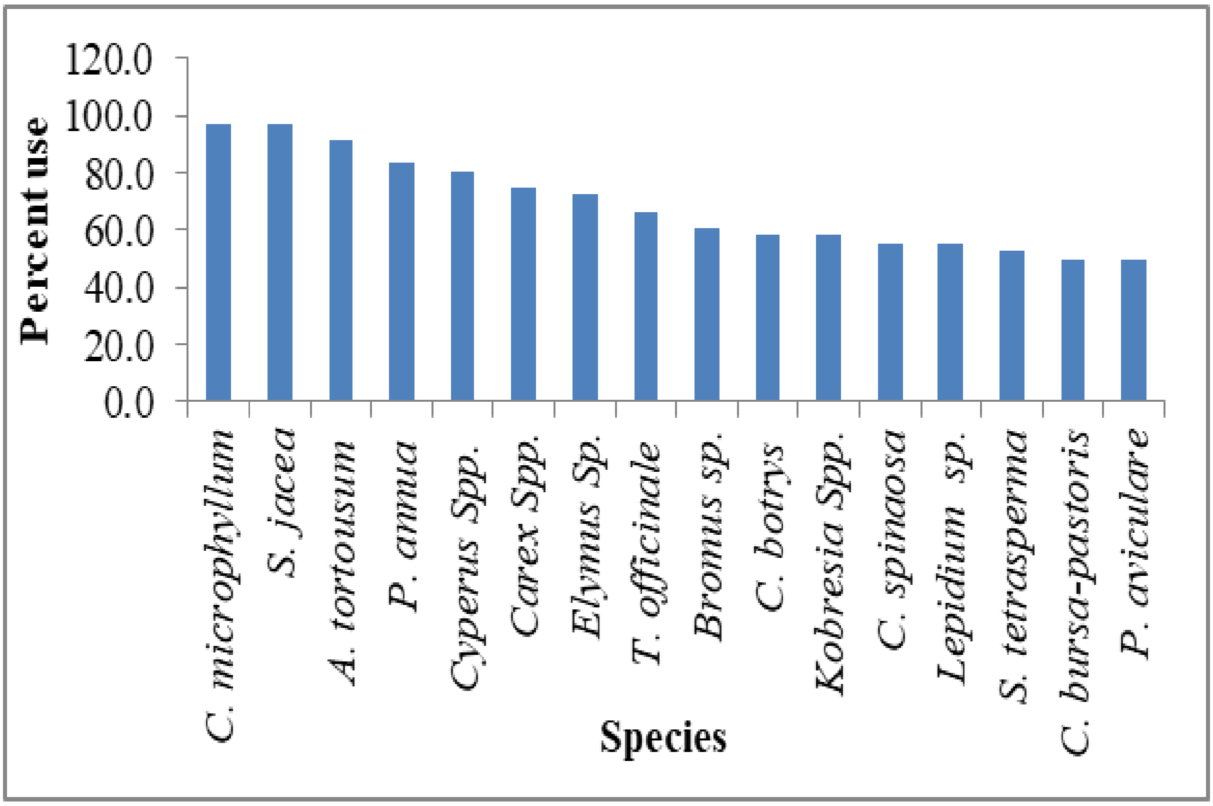


Figure 2.31: Preferential percentage of fodder species in Spiti valley, Himachal Pradesh.

- **Medicinally used plant species**

20 plant species were recorded in which locals have knowledge that these plant species have medicinal properties. The list of medicinally used plant species is given in Table 25. Out of

total observed plants, commonly used plant parts were whole plants (33.333%) followed by roots (25% species) and flowers (16.67%). The percentage contribution of plant parts used is given in Figure 2.32.

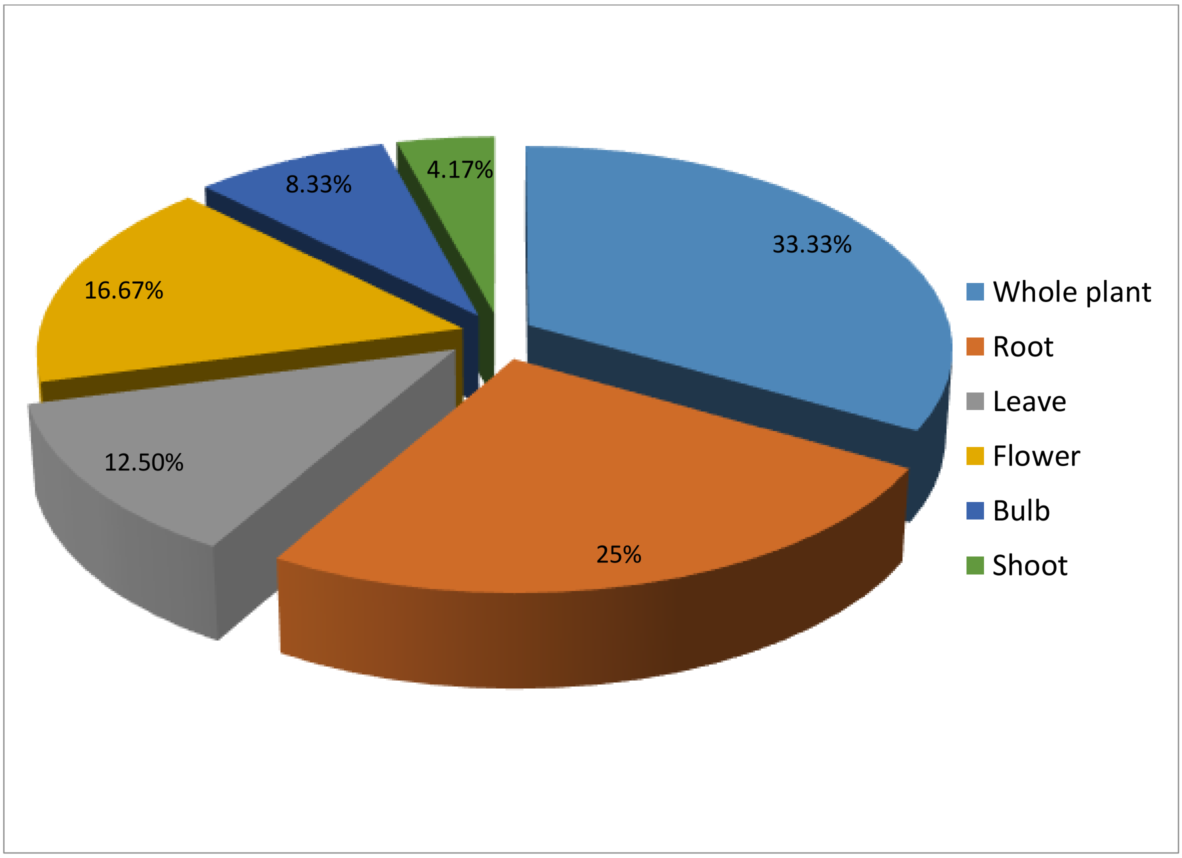
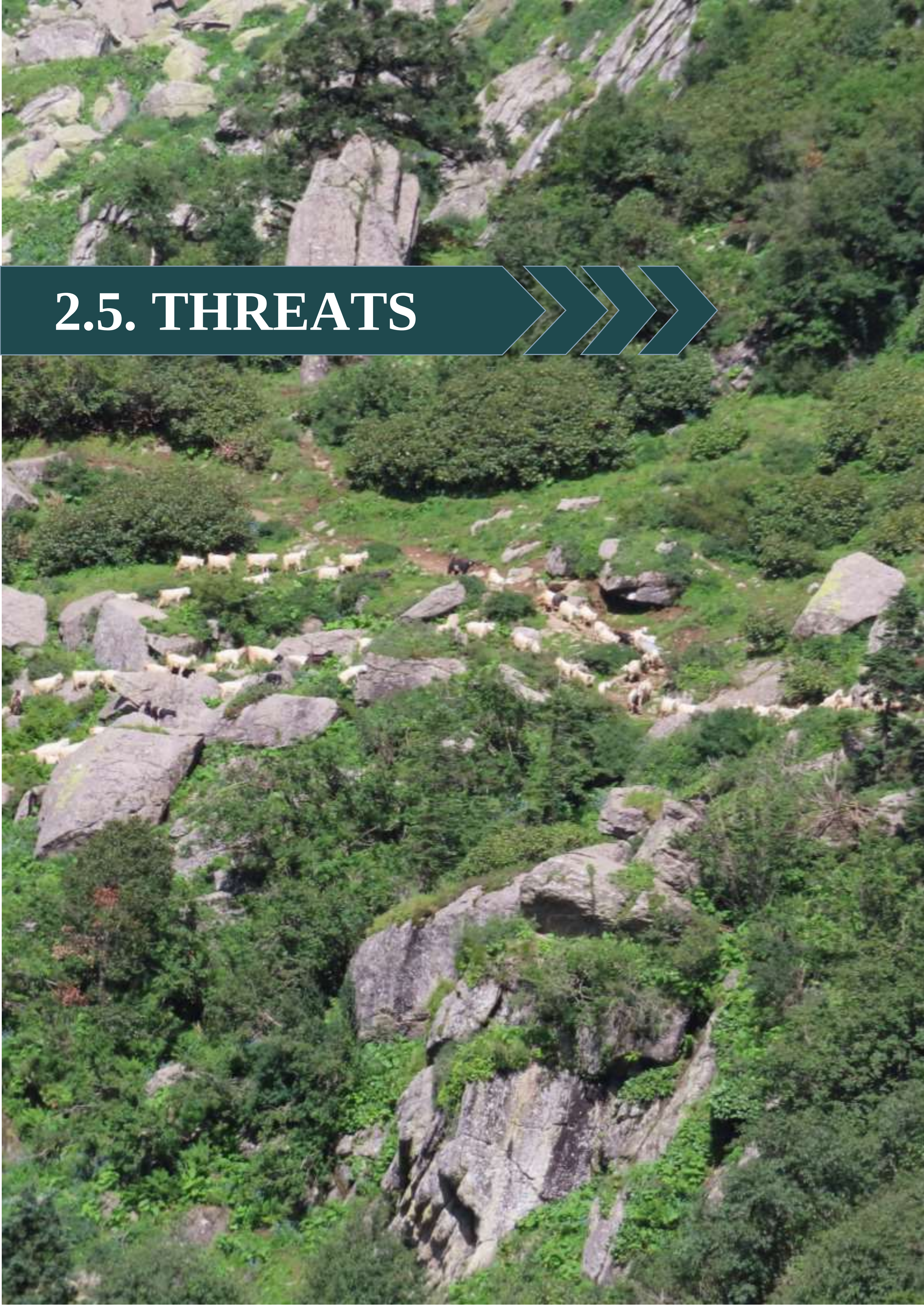


Figure 2.32: The percentage contribution of plant parts used for medicinal purposes in Spiti Valley, Himachal Pradesh.

Table. 2.22: List of ethnomedicinal plants recorded in Spiti valley, Himachal Pradesh.

S.No.	Species	Family	Part used
1	*Aconogonum tortuosum* (D. Don) Hara	Polygonaceae	Roots and shoots
2	*Allium carolianum* DC.	Liliaceae	Bulb and leaves
3	*Allium humile* Kunth*	Liliaceae	Bulbs
4	*Althea rosea* L.	Malvaceae	Flowers and roots
5	*Arnebia euchroma* (Wall. ex G.Don)	Boraginaceae	roots
6	*Bupleurum falcatum* L.	Apiaceae	Whole plant
7	*Chenopodium foliolosum* L.	Chenopodiaceae	Leaves
8	*Ephedra gerardiana* Wallich ex C. A. Meyer	Ephedraceae	Whole plant
9	*Epilobium latifolium* L.	Onagraceae	Whole plant
10	*Eritrichium canum* (Benth.) Kitam.	Boraginaceae	Whole plant
11	*Ferula jaeschkeana* (L.) Vatke	Apiaceae	Roots
12	*Hyssopus officinalis* L.	Lamiaceae	Leaves, flowers
13	*Hyoscyamus niger* L.	Solanaceae	Whole plant
14	*Plantago major* L.	Plantaginaceae	Whole plant
15	*Rosa webbiana* Wall. ex Royle	Rosaceae	Flower
16	*Rhodiola* sp.	Crassulaceae	Rhizome
17	*Saxifraga* sp.	Saxifragaceae	Whole plant
18	*Silene* sp.	Caryophyllaceae	Flower
19	*Taraxacum officinale* F. H. Wigg.	Asteraceae	Root
20	*Thymus linearis* Benth.	Lamiaceae	Whole plant

2.5. THREATS



2.5. Threats

2.5.1. Col. Sher Jung National Park (CSJNP)

Although the National Park is free from the human population and habitation, the local people still hold the right to enter the sanctuary. Illegal grazing and lopping of fodder has been reported from the adjoining villages. Gujjars and migratory grazers are one of the main sources of disturbance in the study area.

Grazing and Overgrazing: rans-nomadic Gujjars are the foremost people residing around the park with their huge livestock and they migrate from the low land plains in the winters to the upper hills of Himachal Pradesh during the summer season, besides there are as many as 50 small villages in its periphery. Such overgrazing and trampling by livestock can lead to environmental degradation and soil erosion.

Illegal grazing and lopping of fodder has been reported from the adjoining villages. Illegal Lopping: Another major threat is illegal lopping. Extensively lopped tree species in the Col. Sher Jung National Park includes *Ficus*, *Desmodium*, *Terminalia* and *Bauhinia*.

Forest Fires: Another major threat prevailing in the region is forest fire (Saini, et al, 2018). Uncontrolled or poorly managed forest fires can cause significant damage to plant populations. Fires can destroy vegetation, including important plant species, and disrupt the natural regeneration process. In spite of the efforts of the forest department in taking preventive measures to reduce the chance of fire, there are incidences of fire on a regular basis.

Illegal Logging and Collection of plants: Unsustainable logging and collection of plants for various purposes, including timber, fuelwood, and ornamental species have been reported in the CSJNP that can have a severe impact on floral diversity. Overexploitation can lead to the depletion or even extinction of certain plant species.

Invasive species: Presence of invasive species pose a serious threat to the native flora and fauna as they have the potential to outcompete the native vegetation and such changes may impact the species dependent on specific native plants for survival. Hence, invasive species can disrupt the ecological processes and change the ecological dynamics of an area. In this study, *Ageratum conyzoides*, *Lantana camara* and *Parthenium hysterophorus* have been recorded in the study area.

2.5.2. Churdhar Wildlife Sanctuary (CWS)

The Churdhar Wildlife Sanctuary, located in Himachal Pradesh, India, is home to diverse floral species. However, there are several threats that can impact the floral diversity of the sanctuary and the protected status, it is still subject to some form of biotic and anthropogenic disturbance.

Livestock Grazing: One of the most notable disturbances in CWS sanctuary is regular livestock grazing that severely undermines the regeneration potential of the concerned forests and subsequent future survival of the affected tree species, some examples being *Acer caesium, Picea smithiana*, and *Prunus cornuta*. The border of the wildlife sanctuary area is surrounded by about 28 villages which are inhabited by natives with large cattle holdings. The continuity of grazing especially during the rainy season causes enormous observed loss from sloppy areas. This overgrazing can lead to the degradation of floral diversity as plants may not have sufficient time to regenerate and reproduce.

Unauthorized collection of plants: Unauthorized collection of plants by Nomadic Gaddis and local people, for medicinal, ornamental, or commercial purposes pose a threat to the floral diversity of Churdhar Wildlife Sanctuary. Some of plants extracted by local people due to their medicinal properties in the CWS include *Fritillaria roylei*, *Swertia ciliata*, *Geranium wallichianum*, *Potentilla atrosaguinea* and *Rhem ausrale*.

Tourism: CWS is a popular tourist place and very often visited by local people for religious purposes during the non-snowfall period (March – mid-November) due to the presence of holy temples situated within the protected area. Tourism affects the environment of a protected area in any destination either directly, indirectly or cumulatively. One of the indirect impacts of tourism is pollution when general environmental rules and regulations are not observed in a protected area. It can be air, water, noise, solid waste, and visuals that can dent the credentials of a protected area as a preferred tourism destination. This can result in the impoverishment and contamination of grounds with toxic pollutants e.g used oils.

Invasive plant species: Presence of invasive species pose a serious threat to the native flora and fauna as they have the potential to outcompete the native vegetation and such changes may impact the faunal species dependent on specific native plants for survival. Hence, invasive species can disrupt the ecological processes and change the ecological dynamics of an area. The presence of invasive species such as Ageratum *conyzoides, Bidens pilosa, Cannabis sativa L., Parthenium hysterophorus L, Galinsoga parviflora Cav., Solanum viarum, Solanum* *pseudocapsicum L., Tagetes minuta L., Datura stramonium L.* and *Erigeron canadensis L.* have been recorded in CWS.

2.5.3. Chandratal Wildlife Sanctuary (CTWS)

During the field surveys, we encountered high grazing pressure and significant tourism activity in the study area.

Grazing Pressure:

The conspicuous presence of high grazing pressure within the wetland areas unveils a crucial concern that transcends mere habitat alteration. The intensive foraging activities of livestock lead to the degradation of vegetation cover, triggering a cascade of ecological consequences.

Tourism:

The influx of tourists brings with it increased human activity that can disrupt the fragile balance of wetland ecosystems. Foot traffic, pollution, and improper waste disposal degrade habitat quality and water cleanliness.

2.5.4. Pin Valley National Park (PVNP)

Collection of Plant Parts: The collection of various plant parts such as rhizomes, tubers, bulbs, leaves, flowers, and roots can be a significant threat to the survival of plant species in Pin Valley National Park. This practice involves harvesting plant materials for various uses, including traditional medicine, food, and commercial purposes. While these practices may have been sustainable when only local communities and traditional healers (amchis) were involved, the increase in population and the involvement of pharmaceutical companies have escalated the pressure on these plant resources (Kala, 2005).

Grazing: Another pressing concern centers around migratory livestock grazing, a widespread form of pastoralism intrinsic to the Himalayas and Trans-Himalayan regions. The park experiences pronounced levels of grazing activity, with both local and migratory herders. The Kinnaur herders embark on extensive seasonal migrations accompanied by their herds of sheep and goats.

2.6. DISCUSSION

2.6. Discussion

2.6.1. Col. Sher Jung National Park (CSJNP)

The results from the study using both the quadrat and transect methods provide valuable insights into the floristic composition and distribution of tree, sapling, seedling, shrub, and herb layers within the study area. A total of 168 plant species were recorded, categorized into different growth forms, including trees, shrubs, herbs, climbers, and ferns. Among these, the majority of species belonged to the herb growth form, followed by trees, shrubs, climbers, and ferns. This indicates a diverse and rich vegetation community, with a dominance of herbaceous species in the study area.

In the present study, a total of 168 plant species were recorded, whereas Naik et al. (2020) reported a slightly higher number of species (184). In both the studies, Poaceae emerged as the dominant family in the study area. The variation in the number of species between the present and previous study (Naik, et al., 2020) especially regarding the number of species within each growth form, can be attributed to differences in the survey periods and seasonal fluctuations. Seasonal fluctuations can influence the presence and abundance of plant species, especially for herbaceous plants, which may exhibit rapid growth and flowering during the rainy season.

Tree Layer

The tree layer analysis revealed that the Garuk beat had the highest species diversity among the studied areas, with the maximum number of tree species observed. This indicates a relatively healthy and diverse forest ecosystem in the Garuk beat. On the other hand, the Danda beat exhibited the lowest number of tree species, suggesting potential ecological disturbances or human impacts in that area. The dominance of *S. robusta* as the primary tree species in most of the beats and transect sites indicates its adaptability to different environmental conditions. *F. racemosa* also showed considerable dominance in certain sites, making it an important species for further ecological studies and conservation efforts.

The sapling layer analysis revealed a consistent dominance of *S. robusta* across most of the sites. This suggests that *S. robusta* is regenerating well and maintaining its population in various habitats. However, some sites showed dominance by *M. philippinensis*, indicating its successful regeneration and establishment in those specific areas (Garuk and Marusidh). The seedling layer results demonstrate varying species dominance across different sites. *M. philippinensis* emerged as a dominant seedling species in several sites, indicating its potential to become a significant component of the future tree layer. However, the dominance of *S. robusta* seedlings in some sites also reflects its successful regeneration and potential for maintaining its presence in the forest.

The presence of *C. opaca, C. infortunatum*, and *C. oppositifolia* as dominant shrub species indicates their adaptability to different environmental conditions. However, the variability in dominant shrub species across different sites suggests localized ecological factors influencing their distribution. The herb layer analysis showed a range of herb species with varying densities across the study area. *A. adenophora* an invasive alien species, emerged as a dominant herb species in multiple sites, suggesting its spread in the forest understory. Additionally, the presence of other dominant herb species like *C. dactylon*, *C. rotundus*, and *E. hirta* highlights the ecological diversity of the forest floor.

The findings of this study contribute to the understanding of plant diversity and distribution patterns at CSJNP. However, certain limitations need to be acknowledged. The survey was conducted during a short time frame (April-May, 2021) and plant diversity might vary across different seasons.

2.6.2. Churdhar Wildlife Sanctuary (CWS)

In the present study, a comprehensive enumeration of 387 species was documented, with a notable dominance of herbaceous species constituting 69%, followed by shrubs (14%), trees (10%), climbers (4%), and ferns (3%). This distribution highlights the prevalence of herbs within the sanctuary's flora. CWS contains several threatened plant species, including *Taxus contorta* (endangered tree), *Fritillaria cirrhosa* (Vulnerable herb), *Trillium govanianum* (Endangerd), and *Dactylorhiza hatagirea* (Endangered) making it a critical habitat for protecting these at-risk plant species.

The previous study (Subramani, et al., 2014) reported a total of 352 floral species, revealing a slightly lower species count compared to the present study. Poaceae emerged as the dominant family in the previous research while in the present study Asteraceae was the richest family. A further scrutiny of the literature revealed the presence of 576 floral species out of which highest proportion covered by herbs (76%), followed by shrubs (12%), trees (7%), climbers (3%) and ferns (2%) in the Churdhar Wildlife sanctuary (Table 2.23).

Table.2.23: A comparative table of tree species found in and around CWS, Himachal Pradesh.

Family	**Present study**	**Past studies**	**Conservation status (IUCN)**
Anacardiaceae	*Rhus chinensis Mill.*	*Rhus chinensis Mill.*	LC
	-	*Toxicodendron wallichii (Hook. f.) Kuntze*	LC
Aqulifoliaceae	*Ilex dipyrena Wall.*	*Ilex dipyrena Wall.*	LC
Betulaceae	*Alnus nepalensis D.Don*	*Alnus nepalensis D.Don*	LC
	Betula utilis D. Don	*Betula utilis D. Don*	LC
	-	*Corylus jacquemontii Decne.*	DD
Cornaceae	-	*Cornus macrophylla Wall.*	LC
Cannabaceae	*Celtis tetrandra Roxb.*	*Celtis tetrandra Roxb.*	LC
Celastraceae	*Euonymous lucidus D.don*	*Euonymous lucidus D.don*	LC
Ericaceae	*Lyonia ovalifolia (Wall.) Drude*	*Lyonia ovalifolia (Wall.) Drude*	LC
	Rhododendron arboreum Sm.	*Rhododendron arboreum Sm.*	LC
	Rhododendron companulatum D.Don	*Rhododendron companulatum D.Don*	NE
Fagaceae	*Quercus floribunda Lindl. ex A.Camus*	*Quercus floribunda Lindl. ex A.Camus*	LC
	Quercus leucotrichophora A.Camus	*Quercus leucotrichophora A.Camus*	NE
	Quercus semecarpifolia Sm.	*Quercus semecarpifolia Sm.*	LC
Juglandaceae	*Juglans regia L.*	*Juglans regia L.*	LC
Lauraceae	*Litsea consimilis (Nees) Nees*	*Litsea consimilis (Nees) Nees*	NE

	Machilus odoratissima Nees	*Machilus odoratissima Nees*	LC
Leguminosae	*Robinia pseudoacacia L.*	*Robinia pseudoacacia L.*	LC
Malvaceae	*Grewia optiva J.R.Drumm. ex Burret*	*Grewia optiva J.R.Drumm. ex Burret*	LC
Meliaceae	*Toona serrata (Royle) M. Roem.*	*Toona serrata (Royle) M. Roem.*	NE
Moraceae	*Ficus neriifolia Sm.*	*Ficus neriifolia Sm.*	LC
	Morus serrata Roxb.	*Morus serrata Roxb.*	NE
Pinaceae	*Abies pindrow (Royle ex D.Don) Royle*	*Abies pindrow (Royle ex D.Don) Royle*	LC
	Abies spectabilis (D. Don) Mirb.	*Abies spectabilis (D. Don) Mirb.*	NT
	Cedrus deodara (Roxb. ex D.Don) G.Don	*Cedrus deodara (Roxb. ex D.Don) G.Don*	LC
	Picea smithiana (Wall.) Boiss.	*Picea smithiana (Wall.) Boiss.*	LC
	Pinus wallichiana A.B. Jacks.	*Pinus wallichiana A.B. Jacks.*	LC
	Taxus contorta Griff.	*Taxus contorta Griff.*	EN
Rosaceae	*Prunus cerasoides Buch.-Ham. ex D.Don*	*Prunus cerasoides Buch.-Ham. ex D.Don*	LC
Rosaceae	*Prunus persica (L.) Batsch*	*Prunus persica (L.) Batsch*	NE
Rosaceae	*Sorbus microphylla Wenz.*	*Sorbus microphylla Wenz.*	NE
Salicaceae	*Populus ciliata Schur*	*Populus ciliata Schur*	NE
	Salix alba L.	*Salix alba L.*	NE
Sapindaceae	*Acer acuminatum Wall. ex D. Don*	*Acer acuminatum Wall. ex D. Don*	LC
	Acer caesium Wall. ex Brandis	*Acer caesium Wall. ex Brandis*	LC

	Acer oblongum Wall. ex DC.	*Acer oblongum Wall. ex DC.*	LC
	-	*Acer pentapomicum Stewart ex Brandis*	LC
	Aesculus indica (Wall. Ex Cambess.) Hook.	*Aesculus indica (Wall. Ex Cambess.) Hook.*	LC
Symplocaceae	*Symplocos cochinchinensis (Lour.) S. Moore*	*Symplocos cochinchinensis (Lour.) S. Moore*	LC

Table. 2.24: A comparative table of shrub species found in and around of CWS, Himachal Pradesh.

Family	**Present Study**	**Past studies**	**Conservation status (IUCN)**
Berberidaceae	*Berberis aristata DC.*	*Berberis aristata DC.*	LC
	Berberis coriaria Royle ex Lindl	*Berberis coriaria Royle ex Lindl*	NE
	Berberis jaeschkeana C.K. Schneid.	*Berberis jaeschkeana C.K. Schneid.*	NE
Buxaceae	*Sarcococca saligna (D.Don) Mull.Arg.*	-	NE
Caprifoliaceae	-	*Leycesteria formosa Wall.*	NE
	Lonicera angustifolia Raf.	*Lonicera angustifolia Raf.*	NE
	-	*Lonicera asperifolia Hook. f. & Thomson*	NE
	Lonicera hispida Pall. Ex Schult.	*Lonicera hispida Pall. Ex Schult.*	NE
	-	*Lonicera hypoleuca Decne.*	NE
	Lonicera obovata Royle ex Hook f. & Thomson	*Lonicera obovata Royle ex Hook f. & Thomson*	NE
	-	*Lonicera orientalis Lam.*	NE

	-	*Lonicera quinquelocularis Hardw.*	NE
	-	*Lonicera webbiana Wall. ex DC.*	NE
Coriariaceae	*Coriaria nepalensis Wall.*	*Coriaria nepalensis Wall.*	NE
Cupressaceae	*Juniperus squamata D.Don*	-	LC
	Juniperus recurva Buch.-Ham.ex D.Don	-	LC
Elaegnaceae	*Elaeagnus parvifolia Wall. ex Royle*	-	NE
Ericaceae	*Cassiope fastigiata D.Don*	-	NE
	Rhododendron anthopogon D. Don	*Rhododendron anthopogon D. Don*	NE
	Rhododendron lepidotum Wall.ex G. Don	*Rhododendron lepidotum Wall.ex G. Don*	NE
Fabaceae	*Phyllodium pulchellum Desv.*	-	LC
	-	*Caragana brevispina Benth.*	NE
	-	*Piptanthus nepalensis (Hook.) D. Don*	NE
	-	*Sophora mollis (Royle) Baker*	NE
Grossulariaceae	*Ribes alpestre Wall.ex Decne.*	*Ribes alpestre Wall.ex Decne.*	NE
	Ribes glaciale Wall.	*Ribes glaciale Wall.*	NE
	-	*Ribes orientale Desf.*	NE
Hypericaceae	*Hypericum choisyanum Wall. ex N.Robson*	*Hypericum choisyanum Wall. ex N.Robson*	NE
Lamiaceae	*Elsholtzia fruticosa (D.Don) Rehdr*	-	NE
	Desmodium elegans Benth.	-	LC

Leguminosae	*Desmodium multiflorum DC.*	-	NE
	Indigofera atropurpurea Hornem.	-	NE
	Indigofera dosua Buck.-Ham.ex D.Don	-	NE
	Indigofera heterantha Wall. Ex Brandis	-	LC
	-	*Indigofera hebepetala Baker*	NE
	Lespedeza gerardiana Wall. Ex Maxim.	-	NE
Moraceae	-	*Ficus sarmentosa Buch. - Ham. ex Sm*	NE
Oleaceae	*Chrysojasminum humile (L.)*	*Chrysojasminum humile (L.)*	NE
Philadelphaceae	-	*Deutzia corymbosa R.Br. ex G.Don*	NE
Phyllanthaceae	*Breynia retusa (Dennst.) Alston*	-	NE
Primulaceae	*Myrsine Africana L.*	*Myrsine Africana L.*	NE
Rosaceae	*Cotoneaster acuminatus Lindl.*	-	NE
	-	*Cotoneaster bacillaris Wall. ex Lindl.*	NE
	-	*Cotoneaster roseus Edgew.*	NE
	Cotoneaster acuminatus Lindl.	-	NE
	Cotoneaster microphyllus Lodd.	*Cotoneaster microphyllus Lodd.*	NE
	Prinsepia utilis Royle	-	NE
	Pyracantha crenulata (D.Don) M. Roem	*Pyracantha crenulata (D.Don) M. Roem*	LC

	Rosa brunonii Lindl.	-	NE
	Rosa macrophylla Lindl.	*Rosa macrophylla Lindl.*	NE
	Rosa moschata Herrm.	-	NE
	Rosa sericea Lindl.	-	NE
	Rubus ellipticus Sm.	*Rubus ellipticus Sm.*	LC
	Rubus niveus Wall.ex G. Don	-	NE
	-	*Sorbaria tomentosa (Lindl.) Rehder*	NE
	Spiraea canescens D.Don	*Spiraea canescens D.Don*	LC
Rubiaceae	*Leptodermis lanceolata Wall.*		NE
	Randia tetrasperma Benth. & Hook. f.	*Randia tetrasperma Benth. & Hook. f.*	NE
	Rhamnus procumbens Edgew	*Rhamnus procumbens Edgew*	NE
	Rhamnus purpurea Edgew.	*Rhamnus purpurea Edgew.*	NE
Rutaceae	*Skimmia laureola (DC.) Sieb. & Zucc. ex Walp.*	*Skimmia laureola (DC.) Sieb. & Zucc. ex Walp.*	NE
	Zanthoxylum aramtum Druce		NE
	-	*Zanthoxylum alatum (DC.)*	NE
Salicaceae	*Salix denticulata Andresson*	*Salix denticulata Andresson*	NE
	Salix lindleyana Wall.ex Andersson	*Salix lindleyana Wall.ex Andersson*	NE
Staphyleaceae	-	*Staphylea emodi Wall.*	NE
Scorphulariaceae	*Buddleja asiatica Lour.*	*Buddleja asiatica Lour.*	NE
Thymealaceae	*Wikstroemia canescens Maxim.*	*Wikstroemia canescens Maxim.*	NE
	Daphne papyracea Wall. Ex G. Don.	*Daphne papyracea Wall. Ex G. Don.*	NE

Urticaceae	*Debregeasia longifolia Wedd.*	-	LC
Viburnaceae	*Viburnum grandiflorum Wall.*	-	NE
	-	*Viburnum mullaha Buch. - Ham. Ex D.Don*	NE

Table. 2.25: A comparative table of herb species found in and around Churdhar Wildlife Sanctuary.

Family	**Present study**	**Past studies**	**Conservataion status (IUCN)**
Acanthaceae	*Justicia procumbens L.*	*Justicia procumbens L.*	NE
	Strobilanthes atropurpurea Nees	*Strobilanthes atropurpurea Nees*	NE
	Strobilanthes Wallichii Nees	*Strobilanthes Wallichii Nees*	NE
Alismataceae	-	*Alisma plantago-aquatica L*	LC
Amaranthaceae	-	*Amaranthus viridis*	NE
	Cyathula capitata Moq.	-	NE
	Dysphania botrys (L.)Mosyakin & Clemants	-	NE
Amaryllidaceae	*Allium humile Kunth*	*Allium humile Kunth*	NE
	-	*Allium victorialis L.*	NE
	-	*Allium wallichii Kunth*	NE
Apiaceae	-	*Acronema hookeri (C.B. Clarke) H. Wolf*	NE

	-	*Angelica glauca Edgew.*	EN
	Bupleurum aitchisonii H. Wolf	*Bupleurum aitchisonii H. Wolf*	NE
	Bupleurum candollei Wall. ex DC.	*Bupleurum candollei Wall. ex DC.*	NE
	Bupleurum falcatum L.	*Bupleurum falcatum L.*	NE
	Centella asiatica (L.) Urb.	-	LC
	Chaerophyllum reflexum Lindl.	*Chaerophyllum reflexum var. acuminatum (Lindl.) Hedge & Lamond*	NE
	Chaerophyllum villosum Wall. ex DC	*Chaerophyllum villosum Wall. ex DC*	NE
	Heracleum candicans Wall. ex DC.	-	NE
	-	*Pleurospermum brunonis Benth. ex C.B. Clarke*	NE
	-	*Pleurospermum candollei Benth. ex C.B. Clarke*	NE
	-	*Pleurospermum stellatum (D. Don) Benth. ex C.B. Clarke*	NE
	Selinum vaginatum C.B. Clarke	*Selinum vaginatum C.B. Clarke*	NE
	-	*Seseli libanotis (L.) Koch*	NE
	Arisaema caudatum Engl.	-	NE

Araceae	*Arisaema intermedium Blume*	*Arisaema intermedium Blume*	NE
	-	*Arisaema flavum (Forssk.) Schot*	NE
	Arisaema jacquemontii Blume	-	LC
	Arisaema tortuosum (Wall.) Schott	-	NE
	-	*Arisaema utile Hook. f. ex Engl. H*	NE
	Remusatia pumila (D. Don) H. Li & A.Hay	*Remusatia pumila (D. Don) H. Li & A.Hay*	NE
	Sauromatum venosum (Dryand. ex Aiton) Kunth	-	LC
Asparagaceae	*Asparagus racemosus Willd.*	-	NE
	Maianthemum purpureum (Wall.) LaFrankie	-	NE
	Ophiopogon intermedius D.Don	*Ophiopogon intermedius D.Don*	NE
Asteraceae	*Achillea millefolium L.*	*Achillea millefolium L.*	LC
	Ageratina adenophora (Spreng.) R.M.King & H. Rob.	*Ageratina adenophora (Spreng.) R.M.King & H. Rob.*	NE
	Ageratum conyzoides (L.) L.	*Ageratum conyzoides (L.) L.*	NE
	Anaphalis nepalensis (Spreng.) Hand.- Mazz.	*Anaphalis nepalensis (Spreng.) Hand.- Mazz.*	NE
	Anaphalis royleana DC.	*Anaphalis royleana DC.*	NE

	Anaphalis triplinervis (Sims) Sims ex C.B. Clarke	*Anaphalis triplinervis (Sims) Sims ex C.B. Clarke*	NE
	-	*Anaphalis margaritacea (L.) Benth. & Hook. f.*	NE
	Ainsliaea latifolia (D.Don) Sch. Bip	*Ainsliaea latifolia (D.Don) Sch. Bip*	NE
	-	*Ainsliaea aptera DC.*	NE
	Artemisia indica Willd.	*Artemisia indica Willd.*	NE
	-	*Artemisia scoparia Waldst. & Kit.*	NE
	Aster thomsonii C.B.Clarke	-	NE
	-	*Aster molliusculus (Lindl. ex DC.) C.B.Clarke*	NE
	-	*Baccharoides anthelmintica (L.) Moench*	NE
	Bidens pilosa L.	-	NE
	Bidens tripartita L.	*Bidens tripartita L.*	LC
	-	*Carpesium cernuum L*	NE
	-	*Cephalorrhynchus macrorhizus (Royle) Tuisl*	NE
	Cirsium wallichii var. glabratum (Hook.f.) Wendelbo	*Cirsium wallichii var. glabratum (Hook.f.) Wendelbo*	NE

	Duhaldea cuspidata (DC.) Anderb.	-	NE
	Duhaldea nervosa Wall. ex DC.	-	NE
	-	*Eclipta prostrata (L.) L.*	LC
	Erigeron alpinus L.	*Erigeron alpinus*	NE
	Erigeron annuus L.	*Erigeron annuus L.*	NE
	Erigeron bonariensis L.	*Erigeron bonariensis L.*	NE
	Erigeron emodi I.M. Turner	*Erigeron emodi I.M. Turner*	NE
	Erigeron multiradiatus (Lindl. Ex DC.)	*Erigeron multiradiatus (Lindl. Ex DC.)*	NE
	Galinsoga parviflora Cav.	*Galinsoga parviflora Cav.*	NE
	Gerbera gossypina (Royle) Beauv.	*Gerbera gossypina (Royle) Beauv*	NE
	Gnaphalium affine D. Don	*Gnaphalium affine D. Don*	NE
	Himalaiella heteromalla (D.Don)	-	NE
	Jacobaea analoga Veldkamp	*Jacobaea analoga Veldkamp*	NE
	Lactuca brunoniana (Wall. ex DC.) C.B. Clarke	*Lactuca brunoniana (Wall. ex DC.) C.B. Clarke*	NE
	Lactuca saligna L.	-	NE
	Ligularia amplexicaulis DC.	*Ligularia amplexicaulis DC.*	NE
	Melanoseris macrorhiza (Royle) N.Kilian	*Melanoseris macrorhiza (Royle) N.Kilian*	NE

	Myriactis nepalensis Less.	-	NE
	-	*Saussurea auriculata (DC.) Sch. Bip*	NE
	Saussurea piptathera Edgew.	*Saussurea piptathera Edgew.*	NE
	Saussurea taraxacifolia Wall. ex DC	*Saussurea taraxacifolia Wall. ex DC*	NE
	Scorzonera virgata DC.	-	NE
	Senecio graciliflorus DC.	-	NE
	Senecio kunthianus Wall. ex DC	*Senecio kunthianus Wall. ex DC*	NE
	Senecio rufinervis DC.	*Senecio rufinervis DC.*	NE
	Sigesbeckia orientalis L.	-	NE
	Tagetes minuta (L.)	*Tagetes minuta (L.)*	NE
	Tanacetum longifolium Wall. ex DC.	*Tanacetum longifolium Wall. ex DC.*	NE
	Taraxacum officinale (L.) Weber ex F.H. Wigg.	*Taraxacum officinale Webb*	NE
Balsaminaceae	*Impatiens amplexicaulis Edgew*	*Impatiens amplexicaulis Edgew*	NE
	-	*Impatiens arguta Hook.f. & Thomson*	NE
	-	*Impatiens brachycentra Kar. & Kir*	NE
	Impatiens glandulifera Royle H	*Impatiens glandulifera Royle H*	NE

	-	*Impatiens glauca Hook.f. & Thomson*	NE
	Impatiens laxiflora Edgew.	*Impatiens laxiflora Edgew.*	NE
	-	*Impatiens racemosa DC*	NE
	Impatiens bicolor Royle	-	NE
	Impatiens scabrida DC.	-	NE
	Impatiens sulcata Wall.	*Impatiens sulcata Wall.*	NE
Begoniaceae	*Begonia picta Sm.*	*Begonia picta Sm.*	NE
Boraginaceae	*Cynoglossum microglochin var. nervosum (Benth. ex C.B. Clarke) Y.J. Nasir*	*Cynoglossum microglochin var. nervosum (Benth. ex C.B. Clarke) Y.J. Nasir*	NE
	-	*Cynoglossum officinale L.*	NE
	Cynoglossum wallichii var. glo chidiatum (Wall. ex Benth.) Kazmi	-	NE
	Cynoglossum uncinatum Royle ex Benth.	*Cynoglossum uncinatum Royle ex Benth.*	NE
	Lindelofia longiflora (Benth.) Baill.	*Lindelofia longiflora (Benth.) Baill*	NE
	-	*Mertensia racemosa Benth. ex C.B. Clarke*	NE
	-	*Myosotis sylvatica Ehrh. ex Hoffm*	NE

Brassicaceae	*Arabis amplexicaulis Edgew.*	*Arabis amplexicaulis Edgew.*	NE
	-	*Arabis pterosperma Edgew*	NE
	Capsella bursa-pastoris (L.) Medik.	-	NE
	Cardamine impatiens L.	*Cardamine impatiens L.*	NE
	-	*Cardamine macrophylla Willd.*	NE
	Lepidium sativum L.	*Crucihimalaya stricta Al-Shehbaz, O'Kane & R.A. Prince*	NE
	-	*Thlaspi arvense L.*	NE
	-	*Thlaspi cochleariforme DC.*	NE
Campanulaceae	*Campanula argyrotricha Wall. Ex A. DC.*	*Campanula argyrotricha Wall. Ex A. DC.*	NE
	-	*Campanula latifolia L.*	NE
	Campanula pallida Wall.	-	NE
Cannabaceae	*Cannabis sativa L.*	*Cannabis sativa L.*	NE
Caprifoliaceae	*Dipsacus inermis Wall.*	-	NE
	Morina longifolia Wall. ex DC.	*Morina longifolia Wall*	NE
	-	*Valeriana hardwickii Wall.*	NE
Carophyllaceae	*Gypsophila cerastoides D.Don*	-	NE
	Silene viscosa (L.) Pers.	*Silene viscosa (L.) Pers.*	NE

	Silene vulgaris (Moench) Garcke	*Silene vulgaris (Moench) Garcke*	LC
	Silene indica Roxb. ex Otth	*Silene indica (Roxb.) Roxb. ex Otth H*	NE
	Silene himalayensis (Rohrb.) Majumdar	-	NE
	-	*Silene setaesperma Majum dar*	NE
	-	*Silene indica (Roxb.) Roxb. ex Otth var. edgeworthii (Bacquet) Y.J. Nasi*	NE
	-	*Myosoton aquaticum (L.) Moench*	NE
	-	*Arenaria festucoides Benth.*	NE
	-	*Lepyrodiclis holosteoides (C.A. Mey.) Fenzl ex Fisch. & C.A. Mey*	NE
	-	*Stellaria monosperma Buch. - Ham. ex D. Don*	NE
	Stellaria himalayensis Majumdar	-	NE
		Stellaria media (L.) Vill.	NE
Celastraceae	*Parnassia nubicola Wall. ex Royle*	-	NE
Gesneriaceae	-	*Chirita bifolia D. Don*	NE

	Commelina benghalensis L.	*Commelina benghalensis L.*	LC
	Cyanotis cristata (L.) D.Don	-	NE
Crassulaceae	*Hylotelephium ewersii (Ledeb.) H. ohba*	*Hylotelephium ewersii (Ledeb.) H. ohba*	NE
	-	*Rhodiola heterodonta (Hook. f. & Thomson) Boriss.*	NE
	Rhodiola himalensis (D. Don) S.H. Fu	*Rhodiola himalensis (D. Don) S.H. Fu*	NE
	-	*Rhodiola tibetica (Hook f. & Thomson) S. H. Fu*	NE
	-	*Rhodiola wallichiana (Hook.) S.H. Fu*	NE
	Rosularia adenotricha (Wall. Ex Edgew.) C.A. Jansson	*Rosularia adenotricha (Wall. Ex Edgew.) C.A. Jansson*	NE
	Sedum multicaule Wall. ex Lindl	-	NE
	Sedum oreades (Decne.) Raym.-Hamet	-	NE
	Sedum trifidum Hook. f. & Thomson	-	NE
Cyperaceae	-	*Carex flicina Nees*	NE
	-	*Carex haematostoma Nees*	NE
	Carex inanis Kunth	*Carex hebecarpa C.A. Mey. subsp.*	NE

		ligulata (Nees) T. Koyama	
	Carex nubigena D.Don ex Tilloch & Taylor	*Carex nubigena D.Don ex Tilloch & Taylor*	NE
	Carex obscura Nees	*Carex obscura Nees*	NE
	-	*Carex wallichiana Spreng.*	NE
	-	*Carex haematostoma Nees*	NE
	-	*Carex hebecarpa C.A. Mey. subsp. ligulata (Nees) T. Koyama*	NE
	Carex nivalis Boott	*Carex nivalis Boott*	NE
	-	*Carex remota L.*	NE
	Cyperus niveus Retz.	*Cyperus niveus Retz.*	NE
	Eleocharis congesta D. Don	*Eleocharis congesta D. Don*	LC
	-	*Eleocharis palustris (L.) Roem. & Schult.*	LC
	-	*Kobresia capillifolia (Decne.) C.B. Clarke*	NE
	-	*Kobresia duthiei C.B. Clarke*	NE
	-	*Kobresia laxa Nees*	NE
	Kobresia nepalensis (Nees) Kük.	*Kobresia nepalensis (Nees) Kük.*	NE
	-	*Kobresia pygmaea(C.B. Clarke) C.B. Clarke)*	NE

	Schoenoplectiella juncoides	*Schoenoplectiella juncoides (Roxb.) Lye*	NE
Droseraceae	-	*Drosera peltata Thunb.*	NE
Euphorbiaceae	-	*Euphorbia maddenii Boiss.*	NE
	-	*Euphorbia parviflora L.*	NE
	-	*Euphorbia stracheyi Boiss.*	NE
	Euphorbia wallichii Hook.f.	*Euphorbia wallichii Hook.f.*	NE
Fabaceae	*Chamaecrista nomame (Sieber) H. Ohashi*	*Chamaecrista nomame (Sieber) H. Ohashi*	LC
	Desmodium triflorum (L.) DC.	-	NE
	-	*Hedysarum microcalyx Baker*	NE
	-	*Lathyrus emodi (Fritsch) Ali*	NE
	-	*Trifolium dubium Sibth.*	NE
	Trifolium pratense L.	*Trifolium pratense L.*	LC
	Trifolium repens L.	*Trifolium repens L.*	NE
	-	*Trigonella gracilis Benth.*	NE
Gentianaceae	-	*Comastoma tenellum (Rottb.) Toyok*	NE
	Gentiana algida Pall.	*Gentiana algida Pall.*	NE

	Gentiana argentea Royle ex D.Don	*Gentiana argentea Royle ex D.Don*	NE
	-	*Gentianopsis paludosa (Hook.f.) Ma*	NE
	Halenia elliptica D.Don	*Halenia elliptica D.Don*	NE
	-	*Jaeschkea canaliculata (Royle ex G.Don) Knobl.*	NE
	-	*Swertia alternifolia Royle*	NE
	Swertia ciliata (D.Don ex G. Don) B.L. Burtt	*Swertia ciliata (D.Don ex G. Don) B.L. Burtt*	NE
	Swertia cordata (G. Don) Wall. ex C.B. Clarke	-	NE
	-	*Swertia cuneata Wall. ex D.Don*	NE
	Swertia speciosa D.Don	*Swertia speciosa D.Don*	NE
Geraniaceae	-	*Erodium cicutarium (L.) L' Her*	NE
	Geranium himalayense Klotzsch	*Geranium himalayense Klotzsch*	NE
	Geranium nepalense Sweet	*Geranium nepalense Sweet*	NE
	-	*Geranium robertianum L.*	NE
	Geranium wallichianum D.Don ex Sweet	*Geranium wallichianum D.Don ex Sweet*	LC

Haemodoraceae	-	*Aletris pauciflora (Klotzsch) Hand.-Mazz.*	NE
Hypericaceae	-	*Hypericum perforatum L*	NE
Hypoxidaceae	*Hypoxis aurea Lour.*	*Hypoxis aurea Lour.*	NE
Iridaceae	-	*Iris kemaonensis Wall. ex D.Don*	NE
Juncaceae	-	*Juncus concinnus D.Don*	NE
	Juncus himalensis Klotzsch	*Juncus himalensis Klotzsch*	NE
	Juncus thomsonii Buchenau	-	NE
Lamiaceae	*Ajuga bracteosa Wall. ex Benth.*	*Ajuga bracteosa Wall. ex Benth.*	NE
	Ajuga parviflora Benth.	-	NE
	Clinopodium vulgare L.	*Clinopodium vulgare L.*	NE
	Coleus barbatus (Andrews) Benth. ex G.Don	-	NE
	Craniotome furcata (Link) Kuntze	-	NE
	-	*Elsholtzia ciliata (Thunb.) Hyl.*	NE
	Elsholtzia eriostachya (Benth.) Benth.	-	NE
	Elsholtzia strobilifera (Benth.) Benth.	-	NE
	-	*Lamium album L.*	NE
	-	*Leonurus cardiaca L.*	NE
		Mentha longifolia (L.) Huds.	LC

	Micromeria biflora (Buch-Ham. ex D.Don) Benth.	*Micromeria biflora (Buch-Ham. ex D.Don) Benth.*	NE
	Nepeta connata Royle ex Benth.	*Nepeta connata Royle ex Benth.*	NE
	-	*Nepeta laevigata (D.Don) Hand.-Mazz.*	NE
	Nepeta podostachys Benth.	-	NE
	Origanum vulgare L.	-	NE
	Phlomoides bracteosa (Royle ex Benth.)	-	NE
	Phlomoides macrophylla (Benth.) Kamelin & Makhm.	*Phlomoides macrophylla (Benth.) Kamelin & Makhm.*	NE
	Prunella vulgaris L.	-	LC
	Salvia cana Wall. ex. Benth	-	NE
	Salvia nubicola Wall. ex Sweet	-	NE
	Scutellaria scandens D. Don	*Scutellaria scandens D. Don*	NE
	Stachys melissifolia Benth.	*Stachys melissifolia Benth.*	NE
	Teucrium quadrifarium Buch-Ham. Ex D.Don	*Teucrium quadrifarium Buch. -Ham. Ex D.Don*	NE
	Thymus serphyllum L.	*Thymus serphyllum L.*	NE
Liliaceae	-	*Cardiocrinum giganteum (Wall.) Makino*	NE
	-	*Clintonia udensis var. alpina (Kunth ex Baker) H. Hara*	NE

	-	*Disporum cantoniense (Lour.) Mer*	NE
	Fritillaria cirrhosa D.Don	-	VU
	-	*Gagea lutea (L.) Ker Gawl.*	NE
	-	*Lloydia serotina (L.) Rchb.*	NE
	-	*Paris polyphylla Sm.*	VU
	Polygonatum cirrhifolium (Wall.) Royle	*Polygonatum cirrhifolium (Wall.) Royle*	NE
	Polygonatum verticillatum (L.) All.	*Polygonatum verticillatum (L.) All.*	NE
Lythraceae	-	*Rotala rotundifolia (Buch.-Ham. ex Roxb.) Koehne*	LC
Malvaceae	*Malva neglecta Wallr.*	*Malva neglecta Wallr.*	NE
Melanthiaceae	*Trillium govanianum Wall. ex D.Don*	*Trillium govanianum Wall. ex D.Don*	EN
Myrsinaceae	-	*Myrsine semiserrata Wall.*	LC
Onagraceae	*Circaea alpina L.*	*Circaea alpina L.*	NE
	Epilobium brevifolium D. don	*Epilobium brevifolium D. don*	NE
	-	*Epilobium cylindricum D. Don*	NE
	-	*Epilobium latifolium L.*	LC

	Epilobium laxum Royle	*Epilobium laxum Royle*	NE
	Epilobium royleanum Hausskn. H	*Epilobium royleanum Hausskn. H*	NE
	Oenothera rosea L'Her. ex Aiton	-	NE
Orobanchaceae	*Leptorhabdos parviflora (Benth.) Benth.*	*Leptorhabdos parviflora (Benth.) Benth.*	NE
	-	*Pedicularis bicornuta Klotzsch*	NE
	Pedicularis gracilis Wall. ex Benth	*Pedicularis gracilis Wall. ex Benth*	NE
	Pedicularis hoffmeisteri Klotzsch	*Pedicularis hoffmeisteri Klotzsch*	NE
	-	*Pedicularis longiflora Rudolph var. tubiformis (Klotzch) Tsoong*	NE
	Pedicularis pectinata Wall. Ex Benth.	*Pedicularis pectinata Wall. Ex Benth.*	NE
	Pedicularis punctata Decne.	*Pedicularis punctata Decne.*	NE
	-	*Pedicularis pyramidata Royle ex Benth.*	NE
	Pedicularis siphonantha D.Don	*Pedicularis siphonantha D.Don*	NE
Orchidaceae	*Calanthe tricarinata Lindl.*	*Calanthe tricarinata Lindl.*	NE

	Dactylorhiza hatagirea (D.Don) Soó	*Dactylorhiza hatagirea (D.Don) Soó*	EN
	Epipactis gigantea Douglas ex Hook.	*Epipactis gigantea Douglas ex Hook*	LC
	Peristylus elisabethae (Duthie) R.K. Gupta	*Peristylus elisabethae (Duthie) R.K. Gupta*	NE
	-	*Goodyera biflora (Lindl.) Hook.f*	NE
	Goodyera fusca (Lindl.) Hook. f.	*Goodyera fusca (Lindl.) Hook. f.*	NE
	Goodyera repens (L.) R.Br.	*Goodyera repens (L.) R.Br.*	NE
	-	*Habenaria commelinifolia (Roxb.) Wall. ex Lindl.*	NE
	-	*Habenaria intermedia D. Don*	NE
	-	*Habenaria marginata Colebr.*	NE
	-	*Habenaria pectinata D.Don*	NE
	-	*Herminium monorchis (L.) R.Br.*	NE
	-	*Malaxis acuminata D.Do*	NE
	-	*Malaxis muscifera Sol. ex Sw.*	VU
	-	*Platanthera clavigera Lindl.*	NE

	Platanthera edgeworthii (Hook. f. ex Collett) R.K. Gupta	*Platanthera edgeworthii (Hook. f. ex Collett) R.K. Gupta*	NE
	Ponerorchis chusua (D.Don) Soó	*Ponerorchis chusua (D.Don) Soó*	NE
	Satyrium nepalense D.Don	*Satyrium nepalense D.Don*	NE
Oxalidaceae	*Oxalis acetosella L.*	*Oxalis acetosella L.*	NE
	Oxalis corniculata L.	*Oxalis corniculata L.*	NE
Papaveraceae	-	*Argemone mexicana L.*	NE
	Corydalis cornuta Royle	*Corydalis cornuta Royle*	NE
	Corydlais filiformis Royle	-	NE
	Corydalis govaniana Wall.	-	NE
	-	*Corydalis thyrsiflora Prain*	NE
	-	*Corydalis vaginans Royle*	NE
	Meconopsis aculeata Royle	*Meconopsis aculeata Royle*	NE
Phytolaccaceae	*Phytolacca acinosa Roxb.*	*Phytolacca acinosa Roxb.*	NE
Plantaginaceae	-	*Hemiphragma heterophyllum Wall.*	NE
	Plantago lanceolata L.	*Plantago lanceolata L.*	NE
	Plantago major L.	*Plantago major L.*	LC
	-	*Veronica alpina L. subsp. pumila (All.) Dostal*	NE

	Veronica biloba schreb. ex L.	*Veronica biloba L.*	NE
	-	*Veronica melissifolia Desf. ex Poir*	NE
	-	*Wulfeniopsis amherstiana (Benth.) D.Y. Hong*	NE
Poaceae	*Agrostis munroana Aitch. & Hemsl.*	*Agrostis munroana Aitch. & Hemsl.*	NE
	Agrostis pilosula Trin.	*Agrostis pilosula Trin.*	NE
	-	*Agrostis stolonifera L.*	LC
	Andropogon munroi C.B.Clarke	*Andropogon munroi C.B.Clarke*	NE
	Arundinella bengalensis (Spreng.) Druce	*Arundinella bengalensis (Spreng.) Druce*	NE
	-	*Arundinella nepalensis Trin.*	NE
	Brachiaria villosa (Lam.) A. Camus	*Brachiaria villosa (Lam.) A. Camus*	NE
	-	*Bromus ramosus Huds.*	NE
	-	*Calamagrostis emodensis Griseb.*	NE
	-	*Calamagrostis pseudophragmites (Haller) Koeler*	NE
	Thamnocalamus spathiflorus (Trin.) Munro	*Thamnocalamus spathiflorus (Trin.) Munro*	NE

	Chrysopogon serrulatus Trin.	*Chrysopogon serrulatus Trin.*	NE
	Cymbopogon distans (Nees ex Steud.) Will.Watson	*Cymbopogon distans (Nees ex Steud.) Will.Watson*	NE
	Cynodon dactylon (L.) Pers.	*Cynodon dactylon (L.) Pers.*	NE
	Dactylis glomerata L.	*Dactylis glomerata L.*	NE
	Drepanostachyum falcatum (Nees) Keng f.	*Drepanostachyum falcatum (Nees) Keng f.*	NE
	Digitaria cruciata (Nees) A. Camus	*Digitaria cruciata (Nees) A. Camus*	NE
	Echinochloa colona (L.) Link	*Echinochloa colona (L.) Link*	LC
	-	*Echinochloa crusgalli (L.) P. Beauv.*	NE
	-	*Eragrostis pilosa (L.) P. Beauv.*	NE
	Eulalia mollis (Griseb.) Kuntze	*Eulalia mollis (Griseb.) Kuntze*	NE
	-	*Festuca kashmiriana Stapf*	NE
	-	*Festuca valesiaca Schleich. Ex Gaudin*	NE
	Koeleria macrantha (Ledeb.) Schult.	*Koeleria macrantha (Ledeb.) Schult.*	NE
	-	*Muhlenbergia himalayensis Hack. Ex Hook. F.*	NE

	Phacelurus speciosus (Steud.) C.E.Hubb.	*Phacelurus speciosus (Steud.) C.E.Hubb.*	NE
	Phleum alpinum L.	*Phleum alpinum L.*	LC
	-	*Phleum himalaicum Mez.*	NE
	Poa alpina L.	*Poa alpina L.*	NE
	Poa annua L.	*Poa annua L.*	LC
	-	*Poa nemoralis L.*	NE
	-	*Poa stapfiana Bor*	NE
	Saccharum rufipilum Steud.	*Saccharum rufipilum Steud. H*	NE
	-	*Saccharum spontaneum L*	LC
	-	*Setaria palmifolia (J. Koenig) Stapf*	NE
	Setaria pumila (Poir.) Roem. & Schult.	*Setaria pumila (Poir.) Roem. & Schult*	NE
	-	*Sinarundinaria falcata (Nees) C.S. Chao & Renvoize*	NE
	Stipa roylei (Nees) Duthie	*Stipa roylei (Nees) Duthie*	NE
	Thamnocalamus spathiflorus (Trin.) Munro	*Thamnocalamus spathiflorus (Trin.) Munro*	NE
	Themeda anathera (Nees ex Steud.)	*Themeda anathera (Nees ex Steud.)*	NE
	-	*Trisetum aeneum (Hook.f.) R.R. Stewart*	NE

	-	*Trisetum clarkei (Hook.f.) R.R. Stewart*	NE
Poaceae	-	*Trisetum spicatum (L.) K. Richt.*	NE
Podophyllaceae	*Podophyllum hexandrum Royle*	*Podophyllum hexandrum Royle*	NE
Polemonicaceae	*Polemonium caeruleum L*	*Polemonium caeruleum L*	NE
Polygalaceae	-	*Polygala crotalarioides Buch. -Ham. Ex DC.*	NE
	-	*Polygala hottentota C. Presl.*	NE
Polygonaceae	*Aconogonon rumicifolium (Royle ex Bab.) H.Hara*	*Aconogonon rumicifolium (Royle ex Bab.) H.Hara*	NE
	Bistorta affinis (D. Don) Greene	*Bistorta affinis (D. Don) Greene*	NE
	-	*Bistorta emodi (Meisn.) H. Hara*	NE
	-	*Polygonum aviculare L.*	LC
	Fagopyrum esculentum Moench	*Fagopyrum esculentum Moench*	NE
	Polygonum delicatulum Meisn.	*Polygonum delicatulum Meisn.*	NE
	Polygonum filicaule Wall. ex Meisn.	-	NE
	Persicaria amplexicaulis (D.Don) Ronse Decr.	*Persicaria amplexicaulis (D.Don) Ronse Decr.*	NE

	Persicaria capitata (Buch. - Ham. ex D.Don) H.Gross	-	NE
	Persicaria chinensis (L.) H. Gross	-	NE
	Persicaria hydropiper (L.) Delarbe	-	LC
	Persicaria nepalensis (Meisn) H. Gross	*Persicaria nepalensis (Meisn) H. Gross*	NE
	Persicaria orientalis (L.) Spach	-	NE
	-	*Polygonum paronychioides C.A. Mey*	NE
	-	*Persicaria vivipara (L.) Ronse Decr.*	NE
	-	*Persicaria wallichii Greuter & Burdet*	NE
	Rheum australe D. Don	*Rheum australe D. Don*	NE
	Rumex hastatus D. Don	*Rumex hastatus D. Don*	NE
	Rumex nepalensis Spreng.	*Rumex nepalensis Spreng.*	NE
Primulaceae	-	*Anagallis arvensis (L.)*	NE
	Androsace sarmentosa Wall.	*Androsace sarmentosa Wall.*	NE
	-	*Androsace sempervivoides Jacquem. ex Duby*	NE
	-	*Cortusa brotheri Pax ex Lipsky*	NE

	-	*Lysimachia ferruginea Edgew*	NE
	Primula denticulata Sm.	*Primula denticulata Sm.*	NE
	Primula gracilipes Craib	-	NE
	-	*Primula petiolaris Wall*	NE
	Primula reidii Duthie	*Primula reidii Duthie*	NE
Ranunculaceae	*Anemone rivularis Buch.-Ham. ex DC.*	*Anemone rivularis Buch.-Ham. ex DC*	NE
	Anemonastrum obtusilobum (D.Don) Mosyakin	-	NE
	Anemone tetrasepala Royle	-	NE
	-	*Anemone vitifolia Buch.-Ham. ex DC.*	NE
	Aquilegia pubiflora Wall. ex Royle	*Aquilegia pubiflora Wall. ex Royle*	NE
	Caltha palustris L.	-	LC
	-	*Delphinium denudatum Wall. ex Hook. f. &*	NE
	Delphinium vestitum Wall. Ex Royle	*Delphinium vestitum Wall. ex Royle*	NE
	Ranunculus distans D.Don	-	NE
	Ranunculus pulchellus C.A. Mey	*Ranunculus pulchellus C.A. Mey*	NE
	-	*Rannunculs sceleratus L.*	NE
	Thalictrum foliolosum DC.	*Thalictrum foliolosum DC.*	NE
	Thalictrum reniforme Wall.	*Thalictrum reniforme Wall.*	NE

	-	*Aconitum laeve Royle*	NE
	-	*Actaea spicata*	NE
	-	*Ranunculus adoxifolius Hand.-Mazz*	NE
	-	*Ranunculus trichophyllus Chaix ex Vill.*	NE
	-	*Thalictrum alpinum L.*	NE
	-	*Trollius acaulis Lindl*	NE
Rosaceae	*Agrimonia pilosa Ledeb.*	*Agrimonia pilosa Ledeb.*	NE
	Duchesnea indica (Jacks.) Focke	*Duchesnea indica (Jacks.) Focke*	NE
	Fragaria nubicola (Lindl. ex Hook.f.) Lacaita.	-	NE
	Filipendula vestita (Wall. ex G.Don) Maxim	*Filipendula vestita (Wall. ex G.Don) Maxim*	NE
	Geum elatum Wall. Ex G. Don	-	NE
	Potentilla atrosanguinea G.Lodd. ex D.Don	-	NE
	-	*Potentilla fruticosa L. var. arbuscula (D. Don) Maxim.*	NE
	Potentilla indica (Andrews) Th.Wolf	*Potentilla indica (Andrews) Th.Wolf*	NE
	Potentilla lineata Trevir.	*Potentilla lineata Trevir.*	NE

	Potentilla nepalensis Hook.	*Potentilla nepalensis Hook.*	NE
	-	*Potentilla supina L.*	LC
	Sibbaldia cuneata Edgew.	-	NE
Rubiaceae	-	*Argostemma verticillatum L.*	NE
	Galium aparine L.	*Galium aparine L.*	NE
	-	*Neanotis hirsuta*	NE
	Rubia cordifolia L.	*Rubia cordifolia L.*	NE
Saxifragaceae	*Astilbe rivularis Buch. -Ham. ex D.Don*	*Astilbe rivularis Buch. -Ham. ex D.Don*	NE
	Bergenia ciliata (Haw.) Sternb.	*Bergenia ciliata (Haw.) Sternb.*	LC
	Bergenia stracheyi (Hook.f. & Thomson) Engl.	*Bergenia stracheyi (Hook.f. & Thomson) Engl.*	NE
	-	*Saxifraga brachypoda D.Don*	NE
	-	*Saxifraga brunonis Wall. ex Ser*	NE
	Saxifraga granulifera Harry Sm.	-	NE
	-	*Saxifraga moorcroftiana (Ser.) Wall. ex Sternb*	NE
	-	*Saxifraga mucronulata Royle*	NE
	-	*Saxifraga pallida Wall. ex Ser*	NE
	Saxifraga parnassifolia D.Don	-	NE
	-	*Saxifraga sibirica L.*	NE

Scrophulariaceae	*Scrophularia himalensis ex. Benth*	-	NE
	Verbascum thapsus L.	*Verbascum thapsus L.*	NE
Solanaceae	-	*Datura metel (L.)*	NE
	Datura stramonium (L.)	*Datura stramonium (L.)*	NE
	Nicandra physalodes (L.)	-	NE
	Solanum nigrum L.	*Solanum nigrum L.*	NE
	Solanum villosum Mill.	-	NE
	-	*Solanum viarum Dunal*	NE
	-	*Solanum pseudocapsicum L*	NE
	-	*Solanum virginianum L.*	NE
		Withania somnifera (L.)	DD
Urticaceae	*Girardinia diversifolia (Link) Friis*	-	NE
	Gonostegia hirta (Blume) Miq.	-	NE
	Lecanthus peduncularis (Royle) Wedd.	*Lecanthus peduncularis (Royle) Wedd.*	NE
	Pilea scripta (Buch. – Ham. Ex D.Don)	-	NE
	Pilea umbrosa Wedd. Ex Blume	-	NE
	-	*Pouzolzia sanguinea (Blume) Merr.*	NE
	Urtica dioica L.	-	LC
Violaceae	-	*Viola betonicifolia Sm.*	NE
	Viola biflora L.	*Viola biflora L*	NE

	Viola canescens Wall.	-	NE
	Viola pilosa Blume	*Viola pilosa Blume*	NE
Zingiberaceae	-	*Curcuma aromatica Salisb.*	NE
	-	*Cautleya spicata (Sm.) Baker*	LC
	Hedychium spicatum Sm.	*Hedychium spicatum Sm.*	NE
	Roscoea alpina Royle	*Roscoea alpina Royle*	NE
	Roscoea purpurea Sm.	*Roscoea purpurea Sm.*	NE
	-	*Tribulus terrestris L.*	LC

Table 2.26: A comparative table of Climber species found in and around CWS, Himachal Pradesh.

Family	Present study	Past studies	IUCN Status
Apocynaceae	-	*Pergularia roylei (Wight) D. Dietr*	NE
Araliaceae	*Aralia parasitica (D. Don) Buch. -Ham. ex Bosse**	-	NE
	Hedera nepalensis K.Koch	*Hedera nepalensis K.Koch*	NE
Celastraceae	-	*Euonymus echinatus Wall*	NE
Convolvulaceae	*Cuscuta reflexa Roxb*	*Cuscuta reflexa Roxb*	LC
Cucurbitaceae	*Solena amplexicaulis (Lam.) Gandhi*	*Solena amplexicaulis (Lam.) Gandhi*	NE
Dioscoreaceae	*Dioscorea deltoidea Wall. ex Griseb.*	*Dioscorea deltoidea Wall. ex Griseb.*	NE
Fabaceae	-	*Vicia tenera Benth.*	NE

Moraceae	*Ficus hederacea Roxb.*	*Ficus hederacea Roxb.*	NE
Oleaceae	*Jasminum dispermum Wall.*	*Jasminum dispermum Wall.*	NE
Ranunculaceae	*Clematis barbellata Edgew.*	*Clematis barbellata Edgew.*	NE
	Clematis montana Buch. -Ham. ex DC.	*Clematis montana Buch. -Ham. ex DC.*	NE
Smilacaceae	*Smilax aspera L*	*Smilax aspera L*	LC
	-	*Smilax elegans Wall. ex Kunt*	NE
Vitaceae	*Parthenocissus semicordata (Wall.) Planch.*	*Parthenocissus semicordata (Wall.) Planch.*	NE
	Tetrastigma serrulatum (Roxb.) Planch.	*Tetrastigma serrulatum (Roxb.) Planch.*	NE

Table. 2.27: A comparative table of ferns and fern-allie found in and around CWS, Himachal Pradesh.

Family	**Present Study**	**Past studies**	**Conservation status (IUCN)**
Pteridaceae	*Adiantum capillus-veneris L.*	*Adiantum capillus-veneris L.*	LC
	Adiantum caudatum L.	*Adiantum caudatum L.*	NE
	Adiantum venustum D. Don	*Adiantum venustum D. Don*	NE
Aspleniaceae	*Asplenium dalhousiae Hook.*	*Asplenium dalhousiae Hook.*	NE
	Asplenium ensiforme Wall. ex Hook. & Grev.	*Asplenium ensiforme Wall. ex Hook. & Grev.*	NE

Athyriaceae	*Athyrium foliolosum T. Moore ex R. Sim*	*Athyrium foliolosum T. Moore ex R. Sim*	NE
Dennstaedtiaceae	*Pteridium aquilinum (L.) Kuhn*	*Pteridium aquilinum (L.) Kuhn*	LC
Dryopteridaceae	*Dryopteris barbigera (T. Moore ex Hook.) Kuntze*	*Dryopteris barbigera (T. Moore ex Hook.) Kuntze*	NE
	Polystichum bakerianum (Atk. ex C.B. Clarke) Diels	*Polystichum bakerianum (Atk. ex C.B. Clarke) Diels*	NE
Polypodiaceae	*Drynaria mollis Bedd.*	*Drynaria mollis Bedd.*	NE
Pteridaceae	*Onychium japonicum (Thunb.) Kunze*	*Onychium japonicum (Thunb.) Kunze*	NE
	Onychium lucidum (D.Don) Spreng.	*Onychium lucidum (D.Don) Spreng.*	NE
	Pteris cretica L.	*Pteris cretica L.*	NE

Among the seven identified communities, the *Abies mixed* community had the highest average tree species richness, followed by the *Quercus* - *Alnus* community (Table). On the other hand, the *Quercus* - *Alnus* community had the highest average shrub species richness, followed by the Abies community. The highest sapling and seedling were observed in the Picea mixed community (Table). This could suggest a favorable environment for sapling and seedling establishment in the Picea mixed community, possibly due to light soil moisture availability and suitable microhabitat conditions.

2.6.3. Chandratal Wildlife Sanctuary (CTWS)

The results from the study conducted in Chandratal Wildlife Sanctuary provide valuable insights into the distribution and abundance of plant species within the protected area and its surroundings.

The past study (Dey, et al., 2021) documented a total of 125 herb species, whereas the present study recorded 62 species. Asteraceae emerged as the dominant family in both studies. However, Brassicaceae, Caryophyllaceae, and Gentianaceae were prominent families in the past study, while Fabaceae and Polygonaceae gained prominence in the present study. The past study's four-year duration allowed for a comprehensive assessment of the herbaceous flora. In contrast, the present study's shorter two-month time frame captured a specific period encompassing late summer to early autumn. The difference in the number of species and composition could be attributed to the longer duration and more extensive surveys carried out in the previous study.

The relative density values for different land-forms within the protected area vary significantly, indicating the specific habitat preferences. For instance, *Kobresia royleana* showed the highest relative density in AF land-form, while *Plantago depressa* dominated in AL land-form. Similarly, *Hygrophila lancea* was most abundant in NS land-form, *Bistorta affinis* in RS land-form, and *Poa alpigena* in GL land-form. This indicates that different plant species thrive in different microhabitats within the sanctuary, adapting to the specific environmental conditions of each land-form.

The relative frequency values complement the relative density results, offering additional insights into the prevalence of different species in different land-forms. The results suggest that certain species, such as *Poa alpigena* in GLOS land-form, exhibit a high relative frequency, indicating their wide distribution across the landscape. The dominance diversity curves provide a graphical representation of the species dominance in each land-form. Notably, different dominant species emerge for each land-form, reinforcing the ecological significance of these microhabitats.

Among the six identified communities, the *Bistorta* community had the highest average species richness (8.50 ± 0.76), followed by the *Taraxacum* community (8.33 ± 0.42). On the other hand, the *Plantago* community had the lowest species richness, with a value of 6 ± 0. Regarding species diversity, the Taraxacum community showed the highest average diversity (2.09 ± 0.07), followed by the *Bistorta* community (2.03 ± 0.08).

2.6.4. Pin Valley National Park (PVNP)

Among the four identified communities, *Potentilla* community exhibited the highest average species richness while the *Cicer* community showed lowest average species richness. The results of the present study provide valuable insights into the utilization of livestock and plant resources in Spiti Valley, Himachal Pradesh, and their significant contributions to the local livelihoods and the overall ecosystem. Dzomo, donkeys, yaks, Dzo, horses, goats, and sheep are the primary livestock species in the region, each contributing to the local economy in varying proportions. The high percentage contribution of Dzomo underscores its significance as a valuable livestock species in the valley. However, it is concerning to observe a decline in the population of sheep and goats, attributed to conflicts with dogs. The livestock's multi-functional role emphasizes their integral place in the agricultural practices and economic sustainability of the local community. The high significance of high-altitude pasture lands is evident in the context of fodder availability. The cold arid regions face a 40-50% deficit in fodder, making the high-altitude pastures crucial for meeting the fodder demands of the villages of Spiti valley. However, it is also worth noting that grazing resources in the Spiti valley are comparatively limited, which emphasizes the need for sustainable grazing management practices to balance livestock grazing and preserve the local ecosystem. The traditional knowledge and resourcefulness of the local community are showcased in their use of specific plant species for various purposes (table). Such practices reflect the close relationship between the community and the natural resources available in the valley.

The medicinal use of certain plant species further emphasizes their significance in traditional healthcare practices. Local people have knowledge of plant species with medicinal properties, and different plant parts, such as roots, shoots, bulbs, leaves, flowers, and rhizomes, are used for medicinal purposes. The earlier study (Singh et al., 2012) was conducted over a more extended period of four years that reported a higher number of medicinal plants (50 species). The present study indicates a relatively higher preference for using the whole plant (33.33%) and roots (25.0% species) compared to the previous study, which reported a higher use of leaves (31%) flowers (17%) as medicinal parts. The conservation and sustainable utilization of these medicinal plant species are crucial to maintain the traditional healthcare knowledge of the community and preserve biodiversity.

2.7. CONCLUSION

2.7. Conclusion

2.7.1. Col. Sher Jung National Park (CSJNP)

S. robusta was the dominant tree species in all the beats and transects studied, except transects T2 and T5, where M. philippensis was the dominant species. In the shrub layer, C. oppositifolia was dominant in Garuk and Danda beats, *C. infortunatum* in Kaludev beat and *C. opaca* in Marusidh beat. *A. adenophora* was the dominant herb in Garuk beat, *A. lanceolatus* in Kaludev and Marusidh beats and *C. dactylon* in Danda beat. Col. Sher Jung National Park mainly comprises Sal forest with three associated species, namely *S. robusta- S. cumini, S. robusta-M. Philippensis* and *S. robusta–T. tomentosa* forest types. *S. robusta - M. philippensis* forest site favours the increased diversity compared to the other forest sites. Based on the shape of the population structure of individual tree species in different sites, tree species can be categorised into various groups. The first group was composed of species that exhibited many individuals only in seedling size classes but none in higher size classes. Such species viz., *C. tomentosa* and *P. emblica* at site-1, while *P. emblica* at site-2 indicatedthat these species were new to the area and may become established in due course of time. All sites showing J shaped curve belong to this category, which revealed overall fair regeneration.

2.7.2. Churdhar Wildlife Sanctuary (CWS)

This study presents valuable insights into the composition, structure, and diversity of vegetation communities in Churdhar Wildlife Sanctuary (CWS). Notably, it provides the first-time documentation of shrub species diversity patterns in the area. The study highlights that the Picea mixed community exhibits the highest average total tree density, while *Cedrus - Pinus* community shows the highest average total shrub density. A literature review including present study in CWS has unveiled the presence of a total of 576 taxa of floral species. This emphasizes the sanctuary's status as a stronghold of plant diversity, making it imperative to preserve its rich floral elements. Despite its protected status, the study area is still subject to certain forms of disturbances. Regular livestock grazing at high altitudes and over-extraction of medicinal plants are notable threats. Addressing these concerns becomes crucial to safeguard the repository of unique and rare medicinal plants thriving in the high-altitude regions of this sanctuary.

2.7.3. Chandratal Wildlife Sanctuary (CTWS)

In this study eight distinct distinct vegetation communities were identified of which geographically highest proportion of CTWS was occupied by *Anaphalis* community, followed by *Potentilla* and *Bistirta* community. Within the protected area, alluvial fan landform exhibited the highest species diversity (23 species), followed closely by around the lake and near the stream (20 species each), with roadside landform recording 14 species. The grassland landform within the protected area had the least species diversity, with only 10 species recorded. Outside the protected area, the hill outside landform showcased the highest species diversity, with 19 species, followed by near the stream outside with 15 species, and roadside outside with 13 species. Similarly, the grassland outside landform had the least species diversity, with only 10 species. These findings highlight the importance of the Chandratal Wildlife Sanctuary in conserving floral diversity, with the protected area showing higher species richness compared to the non-protected area. The study sheds light on the distribution of plant species across different landforms, providing valuable information for conservation planning and management strategies to preserve the biodiversity of this ecologically sensitive region.

2.7.4. Pin Valley National Park (PVNP)

The present study highlights the vital role of livestock and plant resources in sustaining the livelihoods and culture of the people in Spiti Valley. The results highlight the need for conservation measures to protect livestock species facing conflicts and address the challenges of fodder availability. The utilization of plant resources for various purposes, including medicinal use, showcases the richness of traditional knowledge and the potential for economic opportunities from the valley's natural resources. Sustainable management practices and conservation efforts are essential to maintain the delicate balance between human activities and the fragile ecosystem of Spiti Valley.

CHAPTER 3
HERPETOFAUNA

3.1. INTRODUCTION

3.1. INTRODUCTION

The herpetofauna, which encompasses amphibians and reptiles, plays a crucial role in ecological systems by serving as a vital linkage between terrestrial and aquatic ecosystems (Boutilier et al., 1997). These organisms occupy a significant position in the food chain, serving as both predators and prey (Roy, 2002; Daniels, 2005). The herpetofauna category includes two distinct classes: amphibians and reptiles. Amphibians are ectothermic vertebrates characterized by smooth skin, and they lead a dual existence, inhabiting both terrestrial and aquatic environments (Amphi-meaning "on both sides" and -bios meaning "life"). The three extant orders of amphibians are Anura (comprising tailless and limbless creatures such as toads and frogs), Caudata (including salamanders and newts), and Gymnophiona (consisting of caecilians, limbless amphibians that resemble snakes) (Negi & Banyal, 2016). Amphibians face the highest level of threat among all vertebrate groups worldwide (Saodhi et al., 2008; Stuart et al., 2004). Reptiles, on the other hand, are ectothermic vertebrates that rely on lungs for respiration and possess scales covering their bodies. Unlike amphibians, reptiles lack an aquatic larval stage and exhibit either oviparity (egg-laying) or viviparity (Negi & Banyal, 2016; Singh & Banyal, 2013).

3.1.1. REPTILES

Reptiles, encompassing a global species richness of approximately 11,341, constitute a significant component of biodiversity, comprising snakes, lizards, turtles, and crocodiles. Their presence in ecosystems plays a pivotal role in maintaining ecological processes such as nutrient cycling and seed dispersal. Reptiles exhibit distinctive characteristics, including scaly skin, a tetrapod limb structure, and the capacity to lay shelled eggs on land. Through their roles as predators, prey, and seed dispersers, reptiles contribute significantly to the functioning of diverse ecosystems, exhibiting remarkable adaptations that enable their survival in a wide range of habitats spanning from arid deserts to lush rainforests. Moreover, reptiles serve as valuable model organisms in scientific research across various disciplines, including evolutionary biology, physiology, and ecology. They offer unique insights into fundamental biological processes and provide a platform for investigating evolutionary adaptations and ecological interactions. Additionally, reptiles exhibit diverse reproductive strategies, encompassing land-based egg laying, viviparity (live-bearing), and a range of parental care behaviors.

Despite their significant ecological and evolutionary contributions, numerous reptile species are currently confronted with the threat of extinction primarily stemming from habitat loss, climate change, and anthropogenic impacts. It is imperative to implement conservation efforts aimed at addressing these threats in order to safeguard reptile diversity and uphold the integrity of ecosystems. Habitat loss, climate change, and illegal wildlife trade are among the various challenges posing substantial risks to reptile populations, resulting in a global decline in their numbers.

Consequently, it becomes imperative to comprehensively understand their biological characteristics, behavioral patterns, and ecological requirements to effectively conserve and manage reptile species. Scientific investigations focusing on reptiles play a pivotal role in elucidating crucial aspects such as their distribution patterns, population dynamics, and habitat preferences, which are fundamental for formulating robust conservation strategies. By gaining insights into the aforementioned aspects, researchers can develop targeted approaches to mitigate the threats faced by reptiles and foster their long-term survival. Furthermore, the scientific study of reptiles contributes to broader scientific knowledge by unraveling their evolutionary history, biogeography, and physiological adaptations. These investigations deepen our understanding of these captivating creatures and enhance our comprehension of the intricate workings and dynamics of ecosystems.

3.1.2. AMPHIBIANS

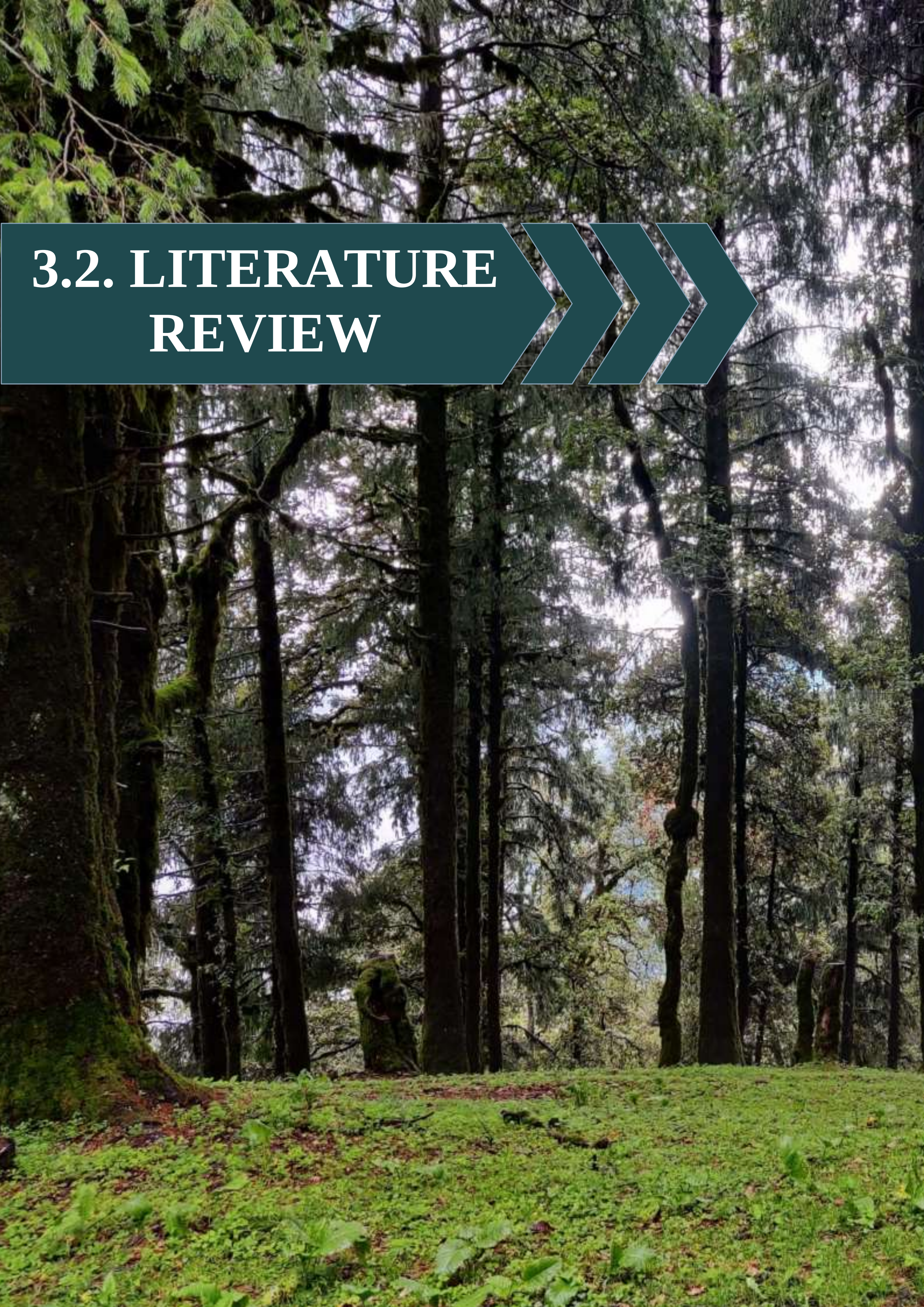
Amphibians, despite their ecological significance, are facing unprecedented threats worldwide, rendering them the most endangered group of vertebrates. Their populations have experienced significant declines primarily due to habitat loss and fragmentation, climate change, pollution, and the emergence of infectious diseases (Bovo et al., 2018). Unfortunately, conservation efforts aimed at mitigating these threats are impeded by inadequate knowledge regarding the distribution and ecological characteristics of amphibian species. India, being a mega-diverse nation, holds considerable importance in terms of reptile and amphibian diversity, with Himachal Pradesh, despite covering a mere 1.7% of the country's total area, playing a significant role in contributing to this diversity (Saikia et al., 2007). The Western Himalayas, located within the boundaries of Himachal Pradesh, host a diverse array of species, despite being largely overlooked in terms of herpetofauna surveys. Consequently, the region presents an invaluable opportunity for studying and conserving amphibians.

Amphibians exhibit a wide range of habitat preferences, occupying diverse aquatic and terrestrial ecosystems. However, their survival is significantly threatened by environmental modifications, including habitat loss, alterations in temperature patterns, and fluctuations in salinity levels. The vulnerability of amphibians to environmental changes is particularly pronounced during their larval stages. During this phase, their permeable skin and inadequate osmoregulatory mechanisms render them highly susceptible to variations in their surroundings, especially when reliant on freshwater and high humidity in the aquatic larval environment (Shoemaker and Nagy, 1977; Viertel, 1999). Amphibians also display heightened sensitivity to increasing water temperatures, which can compromise their thermal tolerance and subsequently impact their ecological performance (Wu and Kam, 2005; Duarte et al., 2012). Given their pronounced responsiveness to environmental variability, amphibians have been widely recognized as valuable ecological indicators (Chaudhary, 1998; Shrestha, 2001; Roy, 2002; Daniels, 2005; Negi and Banyal, 2016; Boruah, 2020). Researchers have utilized various environmental factors to model the occupancy and detection probabilities of frog species (Gooch et al., 2006; Adams et al., 2011; Amburgey et al., 2014; Annich et al., 2019). Moreover, several studies have demonstrated the influence of salinity on the diversity and distribution of amphibians across different life stages (Ferraro and Burgin, 1993; Roberts et al., 1999; Chinathamby et al., 2006; Chuang et al., 2022).

3.1.3. NEED OF STUDY

Accurately estimating animal abundance within a specific area is critical for effective ecosystem management (Skalski and Robson, 1992). However, traditional techniques such as catching, marking, and recapturing individual animals or tagging are often time-consuming, labour-intensive, and expensive. Radio telemetry is a highly accurate but cost-intensive technique used to study anurans movement, habitat use, and ecology. Acoustic sampling is also reliable but can only be used on vocal-male populations, leading to biased estimations. Conversely, photographic identification using natural colour patterns has been demonstrated to be a robust and inexpensive method for individual identification of amphibians such as in *Leiopelma archeyi*, *Melanophryniscus cambaraensis*, *Anaxyrus baxteri*, *Salamandrina perspicillata*, *Triturus dobrogicus, and Amolops formosus*. These natural colour patterns can aid in identifying individuals and provide valuable insights into population dynamics and species ecology. The assessment of animal populations and their dispersal patterns yields valuable insights into habitat characteristics, community composition, ecological conditions, and ecosystem management (Hellawell, 1991; Downes et al., 2002; Patel and Das, 2020). Variation in animal abundance and density can serve as indicators of habitat quality, with higher densities observed in habitats associated with favorable conditions (Mackenzie, 2006). Occupancy models offer a robust framework for analyzing population structure and documenting the habitat requirements and preferences of amphibians (Schmidt and Pellet, 2005; Ahmed et al., 2020). By leveraging data derived from repeated observations at multiple sites, these models generate unbiased estimates of occupancy and elucidate associated factors. Detection probability, which can vary across sites and survey characteristics such as habitat type, weather conditions, observer experience, and sampling techniques, is a key parameter considered in occupancy modeling (MacKenzie et al., 2002; Strain et al., 2017; Ahmed et al., 2020). Various occupancy models can be effectively employed to monitor amphibian populations and elucidate population trends by discerning differences in habitat preference and species presence (e.g., Schmidt and Pellet, 2005; Mattfeldt et al., 2009; Rhinehart et al., 2009). These models allow for the quantification of occupancy dynamics, providing crucial information on the distribution and habitat utilization of amphibians. Furthermore, they offer insights into the factors influencing occupancy patterns and can assist in identifying priority areas for conservation efforts. By integrating occupancy modeling techniques into amphibian monitoring programs, researchers can derive a comprehensive understanding of population dynamics and effectively inform conservation and management strategies.

3.2. LITERATURE REVIEW



3.2. LITERATURE REVIEW:

Out of the 19 orders of reptiles that have existed, only four persist in present times. These surviving orders are Crocodilia, comprising species such as crocodiles, garials, caimans, and alligators, with a total of 23 species. Sphenodontia is another surviving order, represented by two species found exclusively in New Zealand. Squamata, encompassing lizards, snakes, and worm lizards, is the most diverse order, with an estimated 9,150 species. The final surviving order is Testudines, which includes turtles, terrapins, and tortoises, with a species count exceeding 300 (Singh & Banyal, 2013).

The global status of reptiles indicates that one-fifth of the reptilian species face threats. These threats arise from various factors, including habitat loss and fragmentation, climate change, pollution, and emerging diseases (Bovo et al., 2019). The decline in reptile populations can be attributed to the deterioration and destruction of their habitats, which disrupts their natural ecosystems. Climate change further exacerbates these issues by altering temperature and precipitation patterns, impacting reptilian physiology and reproductive behaviors. Pollution, resulting from human activities, introduces harmful substances into reptile habitats, causing adverse effects on their health and overall population viability. Additionally, emerging diseases pose a significant challenge to reptiles, as they may lack the immune defenses necessary to combat novel pathogens. Understanding the threats faced by reptiles is crucial for effective conservation strategies. By addressing habitat degradation, mitigating the impacts of climate change, reducing pollution levels, and implementing measures to control the spread of diseases, conservation efforts can be targeted towards safeguarding reptilian biodiversity. Furthermore, research and monitoring initiatives play a crucial role in identifying and addressing these threats, thus aiding in the preservation of reptile populations and their ecological contributions.

The declining populations of amphibians and reptiles worldwide have garnered substantial attention within the scientific community. Research indicates that approximately 28% of reptile species and 30% of amphibian species are currently under threat (Vences et al., 2002). Consequently, there is a pressing need to compare and evaluate the relative efficacy, advantages, disadvantages, and potential sampling biases associated with various techniques used for assessing herpetofauna populations on a global scale. Among vertebrates, amphibians constitute the smallest group, accounting for only 6.6% of the total vertebrate biodiversity on Earth (Lagler, 1962). The global amphibian and reptile faunas consist of 8,053 and 11,341 species, respectively (amphibiaweb.org; Uetz et al., 2020). In the context of India, the identified amphibian species currently number 417 (AmphibiaWeb, 2018; Frost, 2017), while reptiles encompass approximately 700 species (Uetz et al., 2017; Palot, 2015; Aengals et al., 2011). Considering the alarming decline observed in amphibian and reptile populations, it is imperative to continue monitoring these species and employ the most effective techniques available for their study. Robust monitoring methodologies are essential for accurately assessing population trends, identifying factors contributing to population declines, and implementing appropriate conservation measures. By utilizing scientifically sound and efficient techniques, we can better understand the status of amphibians and reptiles, ultimately aiding in their long-term conservation and the preservation of global biodiversity.

Himachal Pradesh, situated in the western Himalayan region, encompasses a mere 1.7% of India's total geographical area. Despite its relatively small size, this state contributes significantly to the reptilian and amphibian biodiversity of the country, accounting for approximately 11% and 5% of their respective families (Saikia & Sharma, 2007). While the Western Ghats and Northeastern India are renowned for their exceptional diversity, the eastern and western Himalayan regions have also been the focus of herpetofauna research. However, the Western Himalayas, including Himachal Pradesh, have received relatively limited attention in surveys, with only a few published studies dedicated to exploring the region's fauna.

In the early 1900s, Himachal Pradesh witnessed the discovery of several new species, stimulating further investigation into its reptile and amphibian populations. Subsequently, various studies have documented the distribution, habits, and habitats of diverse reptile and amphibian species within the state. For instance, Acharji and Kripalani (1950) compiled a list of herpetofauna in the Kangra and Kullu valleys, while Mahajan and Agrawal (1976) published a comprehensive inventory of 27 reptile species in the Simla district. Subsequent investigations by Waltner (1991), Lal (1991), Mukherji (1991), Dutta (1999), and Mehta (2000) further augmented our knowledge of herpetofaunal diversity and distribution in the region.

Nevertheless, despite these commendable efforts, the western Himalayas, and particularly Himachal Pradesh, remain relatively underexplored in terms of herpetofauna diversity. Consequently, there is a pressing need for more comprehensive and systematic research initiatives to enhance our understanding of the reptilian and amphibian populations in this region. Such investigations would not only contribute to the broader scientific knowledge of herpetofauna but also aid in formulating effective conservation strategies for the unique biodiversity of the western Himalayas, thereby ensuring its long-term preservation.

A comprehensive review of available literature and reports pertaining to the herpetofauna of Himachal Pradesh has yielded valuable insights into the reptile and amphibian diversity within the state. The exhaustive analysis encompassed the examination of numerous sources, allowing for an enhanced understanding of the herpetofaunal composition in the region. The compiled findings revealed the presence of 79 reptile species, encompassing 52 genera distributed across 17 families (Table 3.1). Furthermore, the review identified 21 distinct amphibian species, representing 14 genera spanning 6 families. Among the reptiles, the family Colubridae emerged as the most dominant, exhibiting a notable presence with 27 species distributed across 19 genera (Table 3.2). This family encompasses a diverse array of colubrid snakes, highlighting their significant representation within the reptilian fauna of Himachal Pradesh.

Conversely, within the amphibian taxa, the family Dicroglossidae stood out as the most prominent, featuring nine species encompassing six genera. The prevalence of Dicroglossidae in the region emphasizes its ecological significance and contributes to the overall diversity of amphibians within Himachal Pradesh. The identification of these dominant families, along with their respective genera and species, provides valuable insights into the taxonomic distribution and richness of reptiles and amphibians within Himachal Pradesh. This comprehensive assessment serves as a foundational resource for future studies and conservation efforts aimed at understanding and preserving the herpetofauna biodiversity of the region.

The rigorous review and cross-validation process undertaken in this study has identified a number of species within the reptilian and amphibian taxa of Himachal Pradesh that exhibit uncertain distribution records (Table 3.3). These species, totaling 18 within the reptile category, belong to 14 genera spanning 7 families, highlighting potential discrepancies in their reported presence within the region. The reptilian species of uncertain distribution in Himachal Pradesh include *Laudakia dayana, Altiphylax stoliczkai, Hemidactylus malcolmsmithi, Hemidactylus reticulatus, Hemidactylus triedrus, Argyrogena fasciolata, Gonyosoma prasinus, Hebius modestus, Oligodon albocinctus, Oligodon taeniatus, Oligodon cyclurus, Philothamnus hoplogaster, Platyceps rhodorachis, Rhabdophis nuchalis, Sinomicrurus macclellandi, Duberria lutrix, Pseudaspis cana,* and *Trimeresurus purpureomaculatus*.

Similarly, within the amphibian category, 6 species were identified as having doubtful distribution records within Himachal Pradesh. These species belong to 5 genera spanning 3 families. The amphibian species with uncertain distribution within the region are *Bufotes viridis, Minervarya syhadrensis, Sphaerotheca breviceps, Fejervarya limnocharis, Amolops afghanus,* and *Amolops himalayanus*. The inclusion of these doubtful species highlights the existence of discrepancies and uncertainties in their documented occurrence within the study area. The lack of concrete evidence regarding their presence or absence necessitates further investigation and verification to ascertain their true distribution range within Himachal Pradesh. These findings underline the importance of comprehensive field surveys, targeted research, and subsequent validation in order to provide accurate and reliable data on the herpetofauna diversity of the region. Such verification efforts are essential for refining our understanding of species distribution patterns, informing conservation initiatives, and advancing our knowledge of the reptilian and amphibian biodiversity within Himachal Pradesh.

Abbreviation used in Table for the presence of species:

1. Great Himalayan National Park
2. Pin Valley National Park
3. Simbalbara Wildlife Sanctuary
4. Renuka Wetland
5. Prashar Lake
6. Rakchham-Chhitkul Wildlife Sanctuary

Table 3.1: Reptilian diversity of Himachal Pradesh based on literature review with their reference and location encounter from any protected areas.

S. No.	Family	Genus	*Scientific name*	1	2	3	4	5	6	Reference
1	Agamidae	*Calotes*	*Calotes versicolor*	x	x	✓	✓	x	x	Sharma & Sidhu 2016, Thakur & Matta 2015
2		*Japalura*	*Japalura major*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
3		*Laudakia*	*Laudakia agrorensis*	x	x	x	x	x	x	Mahajan & Agarwal 1976
4			*Laudakia dayana*	x	x	x	x	x	✓	Negi & Banyal 2016
5			*Laudakia tuberculata*	✓	x	✓	✓	✓	x	Sharma & Sidhu 2016, Singh et al. 2015
6		*Sitana*	*Sitana ponticeriana*	x	x	✓	x	x	x	Sharma & Sidhu 2016, Mehta et al. 2009, Saikia et al. 2007
7	Anguidae	*Dopasia*	*Dopasia gracilis*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
8	Gekkonidae	*Cyrtodactylus*	*Cyrtodactylus lawderanus*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
9			*Cyrtodactylus chamba*	x	x	x	x	x	x	Agarwal 2018

10			*Cyrtodactylus fasciolatum*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
11		*Altiphylax*	*Altiphylax stoliczkai*	✓	x	x	x	x	x	Dutta 1999
12		*Hemidactylus*	*Hemidactylus. cf. kushmorensis*	x	x	✓	✓	x	x	Sharma & Sidhu 2016, Mehta et al. 2009, Saikia et al. 2007
13			*Hemidactylus flaviviridis*	x	x	✓	✓	x	x	Sharma & Sidhu 2016, Mehta et al. 2009, Saikia et al. 2007
14			*Hemidactylus malcolmsmithi*	x	x	x	x	x	x	Agarwal 2018
15			*Hemidactylus reticulatus*	x	x	x	x	x	x	Mahajan & Agarwal 1976
16			*Hemidactylus triedrus*	x	x	x	x	x	x	Mahajan & Agarwal 1976
17	Lacertidae	*Ophisops*	*Ophisops jerdonii*	x	x	✓	x	x	x	Sharma & Sidhu 2016, Mehta et al. 2009, Saikia et al. 2007
18	Scincidae	*Ablepharus*	*Ablepharus pannonicus*	x	x	x	x	x	x	Sharma & Sidhu 2016
19		*Ablepharus*	*Ablepharus himalayanus*	✓	x	x	x	✓	✓	Borkin et al. 2018, Negi and Banyal 2016, Saikia 2013
20			*Ablepharus ladacensis*	x	✓	x	x	x	x	Borkin et al. 2018, Sharma & Sidhu 2016, Saikia et al. 2008
21		*Eurylepis*	*Eurylepis taeniolatus*	x	x	✓	x	x	x	Sharma & Sidhu 2016, Mehta et al. 2009, Saikia et al. 2007
22		*Eutropis*	*Eutropis carinata*	x	x	x	✓	x	x	Sharma & Sidhu 2016, Thakur and Mattu 2015, Saikia et al. 2007
23			*Eutropis dissimilis*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007

24			*Eutropis macularia*	x	x	✓	x	x	x	Sharma & Sidhu 2016, Mehta et al. 2009, Saikia et al. 2007
25		*Riopa*	*Riopa punctata*	x	x	✓	✓	x	x	Sharma & Sidhu 2016, Thakur and Mattu 2015
26	Varanidae	*Varanus*	*Varanus bengalensis*	x	x	✓	✓	x	x	Sharma & Sidhu 2016, Mehta et al. 2009, Saikia et al. 2007
27			*Varanus flavescens*	x	x	x	✓	x	x	Sharma & Sidhu 2016, Thakur and Mattu 2015, Saikia et al. 2007
28	Boidae	*Eryx*	*Eryx conicus*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
29			*Eryx johnii*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
30	Colubridae	*Herpetoreas*	*Herpetoreas platyceps*	✓	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007, Dutta 1999,
31		*Amphiesma*	*Amphiesma stolatum*	x	x	✓	x	x	x	Sharma & Sidhu 2016, Mehta et al. 2009, Saikia et al. 2007
32		*Argyrogena*	*Argyrogena fasciolata*	x	x	x	x	x	x	Mahajan & Agarwal 1976
33		*Boiga*	*Boiga multifasciata*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
34			*Boiga trigonata*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
35		*Coelognathus*	*Coelognathus helena*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
36			*Coelognathus radiatus*	x	x	x	x	x	x	Varma & Anthony 2020
37		*Elaphe*	*Orthriophis hodgsoni*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia 2013
38		*Fowlea*	*Fowlea Piscator*	x	x	✓	x	x	x	Sharma & Sidhu 2016, Mehta et al. 2009
39			*Fowlea sanctjohannis*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
40		*Gonyosoma*	*Gonyosoma prasinus*	x	x	x	x	x	x	Mahajan & Agarwal 1976

41		*Hebius*	*Hebius modestus*	x	x	x	x	x	x	Mahajan & Agarwal 1976
42		*Liopeltis*	*Liopeltis rappi*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
43		*Lycodon*	*Lycodon aulicus*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
44			*Lycodon striatus*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
45			*Lycodon mackinnoni*	x	x	x	x	x	x	Nawani et al (2021) Santra 2018
46		*Oligodon*	*Oligodon albocinctus*	x	x	x	x	x	x	Mahajan & Agarwal 1976
47			*Oligodon arnensis*	x	x	x	x	x	x	Sharma & Sidhu 2016, Mahajan & Agarwal 1976
48			*Oligodon taeniatus*	x	x	x	x	x	x	Mahajan & Agarwal 1976
49			*Oligodon cyclurus*	x	x	x	x	x	x	Mahajan & Agarwal 1976
50			*Oligodon churahensis*	x	x	x	x	x	x	Mirza et al. 2021
51		*Philothamus*	*Philothamnus hoplogaster*	x	x	x	x	x	x	Das et al. 1998
52		*Platyceps*	*Platyceps rhodorachis*	x	x	x	x	x	x	Ramesh et al. 2005
53		*Ptyas*	*Ptyas mucosa*	✓	x	✓	✓	✓	✓	Sharma & Sidhu 2016, Mehta et al. 2009, Dutta 1999
54		*Rhabdophis*	*Rhabdophis nuchalis*	x	x	x	x	x	x	Mahajan & Agarwal 1976
55		*Sibynophis*	*Sibynophis collaris*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
56			*Sibynophis sagittarius**	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
57		*Spalerosophis*	*Spalerosophis atriceps**	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
58		*Trachischium*	*Trachischium laeve*	x	x	x	x	x	x	Annandale 1907
59	Elapidae	*Bungarus*	*Bungarus caeruleus*	x	x	x	x	x	x	Mahajan & Agarwal 1976
60		*Naja*	*Naja naja*	x	x	✓	x	x	x	Mehta et al. 2009

61			*Naja oxiana*	x	x	x	x	x	x	Sharma & Sidhu 2016
62			*Sinomicrurus nigriventer*	x	x	x	x	x	x	
63	Lamprophiidae	*Duberria*	*Duberria lutrix*	x	x	x	x	x	x	Das et al. 1998
64	Psammophiidae	*Psammophis*	*Psammophis condanarus*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007, Anderson 1871
65			*Psammophis leithii*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
66	Pseudaspididae	*Pseudaspis*	*Pseudaspis cana*	x	x	x	x	x	x	Das et al. 1998
67	Pythonidae	*Python*	*Python molurus*	x	x	✓	x	x	x	Sharma & Sidhu 2016, Mehta et al. 2009, Saikia et al. 2007
68	Typhlopidae	*Argyrophis*	*Argyrophis diardii*	x	x	x	x	x	x	Saikia et al. 2010
69		*Indotyphlops*	*Indotyphlops porrectus*	x	x	x	✓	x	x	Thakur and Matta 2015, Mehta 2000
70			*Indotyphlops braminus*	x	x	✓	x	x	x	Sharma & Sidhu 2016, Mehta et al. 2009, Saikia et al. 2007
71	Viperidae	*Daboia*	*Daboia russelii*	x	x	x	✓	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
72		*Echis*	*Echis carinatus*	x	x	x	✓	x	x	Sharma & Sidhu 2016, Thakur and Matta 2015, Mehta 2000
73		*Gloydius*	*Gloydius himalayanus*	✓	x	x	✓	x	✓	Sharma & Sidhu 2016, Negi and Banyal 2016, Saika 2013
74		*Trimeresurus*	*Trimeresurus septentrionalis*	x	x	x	x	x	✓	Sharma & Sidhu 2016, Negi and Banyal 2016
75			*Trimeresurus gramineus*	x	x	x	x	x	x	Scalter 1891
76	Geoemydidae	*Batagur*	*Batagur kachuga*	x	x	x	✓	x	x	Sharma & Sidhu 2016, Mehta 2000
77		*Melanochelys*	*Melanochelys trijuga*	x	x	✓	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2010

78		*Pangshura*	*Pangshura smithii*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007
79	Trionychidae	*Lissemys*	*Lissemys punctata*	x	x	x	x	x	x	Sharma & Sidhu 2016, Saikia et al. 2007, Mehta 2000

Table 3.2: Amphibian Diversity Himachal Pradesh based on literature review with their reference and location encounter from any protected areas.

S. No.	**Family**	**Genus**	***Scientific name***	**1**	**2**	**3**	**4**	**5**	**6**	**References**
1	Bufonidae	*Bufotes*	*Bufotes latastii*	x	x	x	x	x	x	Sharma & Sidhu 2016
2			*Bufotes viridis*	x	✓	x	x	x	x	Thakur & Matta 2015, Saikia et al. 2008, Mehta 2005
3		*Duttaphrynus*	*Duttaphrynus himalayanus*	✓	x	x	x	x	✓	Negi & Banyal 2016, Sharma & Sidhu 2016
4			*Duttaphrynus melanostictus*	x	x	✓	✓	✓	x	Sharma & Sidhu 2016, Singh et al. 2015
5		*Firouzophrynus*	*Firouzophrynusstomaticus*	✓	x	✓	✓	x	x	Sharma & Sidhu 2016, Thakur & Mattu 2015
6	Dicroglossidae	*Euphlyctis*	*Euphlyctis cyanophlyctis*	x	x	✓	✓	x	x	Sharma & Sidhu 2016, Thakur & Matta 2015
7		*Fejervarya*	*Fejervarya limnocharis*	x	x	x	✓	x	x	Tilak & Mehta 1983
8		*Hoplobatrachus*	*Hoplobatrachus tigerinus*	x	x	✓	✓	x	x	Sharma & Sidhu 2016
9		*Minervarya*	*Minervarya syhadrensis*	x	x	✓	x	x	x	Sharma & Sidhu 2016

10			*Minervarya teraiensis*	x	x	x	x	x	x	Sharma & Sidhu 2016
11		*Nanorana*	*Nanorana liebigii*	x	x	x	x	x	x	Sharma & Sidhu 2016, Thakur & Matta 2015, Singh and Banyal 2013
12			*Nanorana minica*	x	x	x	✓	x	x	Sharma & Sidhu 2016, Thakur & Matta 2015, Mehta 2005
13			*Nanorana vicina*	✓	x	x	x	x	x	Sharma & Sidhu 2016, Mehta 2005
14		*Sphaerotheca*	*Sphaerotheca breviceps*	x	x	✓	✓	x	x	Sharma & Sidhu 2016
15	Megophryidae	*Scutiger*	*Scutiger occidentalis*	x	x	x	x	x	x	Litvinchuk et al. 2018
16	Microhylidae	*Microhyla*	*Microhyla ornata*	x	x	✓	✓	x	x	Sharma & Sidhu 2016, Thakur & Matta 2015, Mehta 2005
17		*Uperodon*	*Uperodon systoma*	x	x	✓	x	x	x	Sharma & Sidhu 2016, Thakur & Matta 2015, Mehta 2005
18	Ranidae	*Amolops*	*Amolops afghanus*	x	x	x	x	x	x	Inger and Dutta 1986
19			*Amolops formosus*	✓	x	x	x	x	x	Dutta 1999
20			*Amolops himalayanus*	x	x	x	x	x	x	Sharma & Sidhu 2016, Thakur & Matta 2015, Singh & Banyal 2013
21	Rhacophoridae	*Polypedates*	*Polypedates maculatus*	x	x	x	x	x	x	Sharma & Sidhu 2016, Thakur & Matta 2015

Table 3.3: Showing Doubtful records of Reptiles and amphibians from Himachal Pradesh

S. No.	Family	Genus	*Scientific Name*	Type locality	Location	Authors
1	Agamidae	*Laudakia*	*Laudakia dayana*	Haridwar, Uttranchal; Ladakh Range, Kashmir. 3000m	Rakchham-Chhitkul WLS	Negi & Banyal 2016
2	Gekkonidae	*Altiphylax*	*Altiphylax stoliczkai*	Bei Karoo, nördlich von Dras, Kashmir. (India (Jammu and Kashmir, Karoo/Dras, Ladakh), W China, Pakistan)	GHNP	Dutta 1999
3		*Hemidactylus*	*Hemidactylus malcolmsmithi*	India (Punjab)	Chamba	Agarwal et al. 2018
4			*Hemidactylus reticulatus*	Kollegal, Mysore State. (Andhra Pradesh, Kerala, Telangana, Tamil Nadu)	Shimla	Aggarwal & Mahajan 1976
5			*Hemidactylus triedrus*	Nellore District, Andhra Pradesh	Shimla	Aggarwal & Mahajan 1977
6	Colubridae	*Argyrogena*	*Lycodon fasciolatus*	India. (UP to Tamil nadu)	Shimla	Aggarwal & Mahajan 1978
7		*Gonyosoma*	*Gonyosoma prasinum*	Assam. Khasi Hills, Meghalaya (any part of north-eastern India)	Shimla	Aggarwal & Mahajan 1979
8		*Heblius*	*Hebius modestus*	Khasi Hills, India (Meghalaya; Arunachal Pradesh)	Shimla	Aggarwal & Mahajan 1980
9		*Oligodon*	*Oligodon albocinctus*	Cherrapungi, Assam. (Nepal, Bangladesh, Bhutan, India (Assam, Sikkim; Mizoram, Arunachal Pradesh Nagaland), Myanmar)	Shimla	Aggarwal & Mahajan 1981
10			*Oligodon taeniatus*	Cambodia (Thailand, Laos, Cambodia, S Vietnam)	Shimla	Aggarwal & Mahajan 1982

11			*Oligodon cyclurus*	Bankok, Thailand (India (Assam, Mizoram, Nagaland), Bhutan, Myanmar (= Burma), Thailand, Laos, Cambodia, Vietnam, Nepal, Bangladesh)	Shimla	Aggarwal & Mahajan 1983
12		*Philothamnus*	*Philothamnus hoplogaster*	Durban, South Africa. (Zimbabwe, S Mozambique, Zimbabwe, Tanzania, Kenya, Malawi, E/S Democratic Republic of the Congo (Zaire), Rwanda, Burundi, Zambia, Republic of South Africa)	Shimla	Das et al. 1998
13		*Platyceps*	*Platyceps rhodorachis*	Persia, Arabian Peninsula; Shiraz, Iran (Africa, Middle East, Asia, NW India (Jammu and Kashmir))	Luhri	Rames et al. 2015
14		*Rhabdophis*	*Rhabdophis nuchalis*	Ichang, Upper Yangtse-Kiang (NE India (Nagaland), Myanmar)	Shimla	Aggarwal & Mahajan 1983
15	Pseudoxyrhophiidae	*Duberria*	*Duberria lutrix*	Republic of South Africa, Swaziland, Zimbabwe, Mozambique, Tanzania	Shimla	Das et al. 1998
16	Pseudaspididae	*Pseudaspis*	*Pseudaspis cana*	Namibia, Botswana, Zimbabwe, Angola, Zambia, Malawi, Tanzania, Mozambique, Republic of South Africa	Shimla	Das et al. 1998
17	Elapidae	*Sinomicrurus*	*Sinomicrurus macclellandi*	Assam, India. (Assam, Sikkim, Darjeeling; Arunachal Pradesh, Mizoram, Nagaland), Nepal, Bangladesh, Bhutan)		Saikia et al. 2010
18	Viperidae	*Trimeresurus*	*Trimeresurus purpureomaculatus*	Singapura. (Bangladesh, Burma, S Thailand, W Malaysia, Indonesia)	Shimla	Sclater 1891

19	Bufonidae	*Bufotes*	*Bufotes viridis*	Austria.	Pin Valley	Saikia et al. 2008
20	Dicroglossidae	*Minervarya*	*Minervarya syhadrensis*	Satara and Poon districts and the Naasik district, India.	Simbalbara	Mehta et al, 2009
21		*Sphaerotheca*	*Sphaerotheca breviceps*	Tamil Nadu. Eastern Nepal (Sunsari District), central India to Maharashtra and to Jharkhand and West Bengal.	Simbalbara, Renuka Wetland	Mehta 2000, Mehta et al. 2009
22		*Fejervarya*	*Fejervarya limnocharis*	Java, Indonesia. Cambodia, Indonesia, Laos, Malaysia, Myanmar, Thailand. Bangladesh, Brunei, India, Singapore, Vietnam.	Renuka Wetl&, Shimla	Mehta et al. 2009
23	Ranidae	*Amolops*	*Amolops afghanus*	Afghanistan in error. Kachin state, northern Myanmar (Kachin), and Yunnan Province, China; likely also in adjacent northeastern India; records for other nations (e.g., Nepal)	Kufri	Inger & Dutta 1986
24			*Amolops himalayanus*	Darjeeling", India. Northeastern India.	Shimla, Kufri	Mehta 2005

- **OBJECTIVES OF THE PROJECT**

1. To undertake a detailed assessment of the state's biodiversity in select areas to improve scientific conservation and management of biodiversity
2. To do a threat assessment and ranking for the biodiversity (both flora and fauna)
3. To develop biodiversity assessment design or methodology for Himachal Pradesh through establishing baseline and monitoring indicator for long term monitoring.

These objectives are further divided into various themes and sub-tasks to carry out the work for achieving desired outputs viz.

'Updating the baseline information important components of biodiversity of the state'

1. To undertake a detailed assessment of the state's biodiversity in select areas to improve scientific conservation and management of biodiversity

- Task a: To prepare a checklist and potential distribution maps of available information and documentation of biodiversity in the state with respect to important flora and fauna.
- Task b: To determine the abundance and diversity of important species in representative protected areas – Important taxa are taken for consideration.

'Design a robust assessment method for important taxa of the state'

2. Task a: Design, identify and rank various threats to key species.
3. To develop biodiversity assessment design or methodology for Himachal Pradesh through establishing baseline and monitoring indicator for long term monitoring

- Task a: Establish a baseline for the monitoring of flora and fauna in the state.
- Task b: Develop a monitoring protocol of key taxa in the state.

❖ HERPETOFAUNA OBJECTIVES

- To Prepare a checklist of the Herpetofauna from the selected protected areas of Himachal Pradesh.
- To know the abundance of anurans, chelonians, lizards and snakes in these selected protected areas.
- To assess the diversity and distribution of the Anurans in the Col. Sher Jung National Park and Churdhar Wildlife Sanctuary.
- To know about an indicator and endemic species of Himalayan ecosystem and know about its population and ecology from the conservation perspectives.
- To show the altitudinal changes in the Herpetofauna distribution through the selected protected areas in Himachal Pradesh.

3.3. FIELD SURVEY

3.3. FIELD SURVEY

3.3.1. METHODOLOGY

The present study aimed to conduct a comprehensive survey of the herpetofauna across different landscapes and altitudinal gradients in Himachal Pradesh. To achieve this, an initial assessment of various waterholes and flowing streams was conducted to identify the most suitable habitats for amphibians. Subsequently, specific locations with long streams and waterholes were selected as focal sites for in-depth sampling and analysis of amphibian distribution. To ensure efficient detection and accurate representation of herpetofauna populations, a stratified random sampling approach was employed. This involved dividing the study area into distinct strata based on specific habitat characteristics. Within each stratum, multiple sampling techniques were utilized, including the Visual Encounter Survey (VES), belt transects, and pool sampling for smaller stationary water bodies. The VES method allowed for systematic visual observations of herpetofauna species, enabling the recording of their presence and abundance. Belt transects, which involved the establishment of linear sampling units across selected habitats, provided valuable data on species composition and distribution along specific transect lines. Additionally, pool sampling was employed to investigate the presence of herpetofauna in smaller water bodies such as ponds or pools. In addition to the planned sampling methods, opportunistic encounters were also documented to supplement the data. These opportunistic encounters involved recording any unplanned observations of reptiles during the course of the study, providing further insights into the herpetofauna present in the sampled areas. By employing a combination of stratified random sampling, the Visual Encounter Survey technique, belt transects, pool sampling, and opportunistic encounters, this study aimed to generate detailed and scientifically robust information on the diversity and distribution of herpetofauna across various landscapes and altitudinal gradients in Himachal Pradesh.

3.3.2. VISUAL ENCOUNTER SURVEY

Visual encounter survey (VES) is a widely used method for studying herpetofauna populations, allowing researchers to directly observe and document the presence and abundance of amphibians and reptiles in their natural habitats (Heyer et al., 1993). This survey technique involves systematically searching a designated area and visually detecting individuals of the target species.

During a VES, trained observers traverse predetermined transects or survey plots, carefully scanning the environment for herpetofauna (Figure 3.1). The surveys can be conducted during the day or at night, depending on the species' activity patterns (Crump, 1986). Observer walk slowly and thoroughly search various microhabitats, such as vegetation, rocks, logs, and water bodies, where herpetofauna are likely to be found. When a species is encountered, observers approach it cautiously to gather relevant information, including species identification, individual count, size, behavior, and microhabitat characteristics. These data are recorded in a standardized manner using field notebooks, data sheets, or electronic devices. Photographs, audio recordings, or genetic samples may also be collected to supplement the records and aid in species verification. To enhance the survey's effectiveness, environmental conditions such as temperature, humidity, and time of day are often taken into consideration, as they can influence the detectability and activity of herpetofauna. Additionally, conducting repeated surveys over multiple seasons or years provides valuable insights into population dynamics, species richness, and habitat preferences.

Figure 3.1: One of the stream and nearby vegetation habitat selected for Visual Encounter Survey (VES) of Herpetofauna during the survey period.

3.3.3. BELT TRANSECT

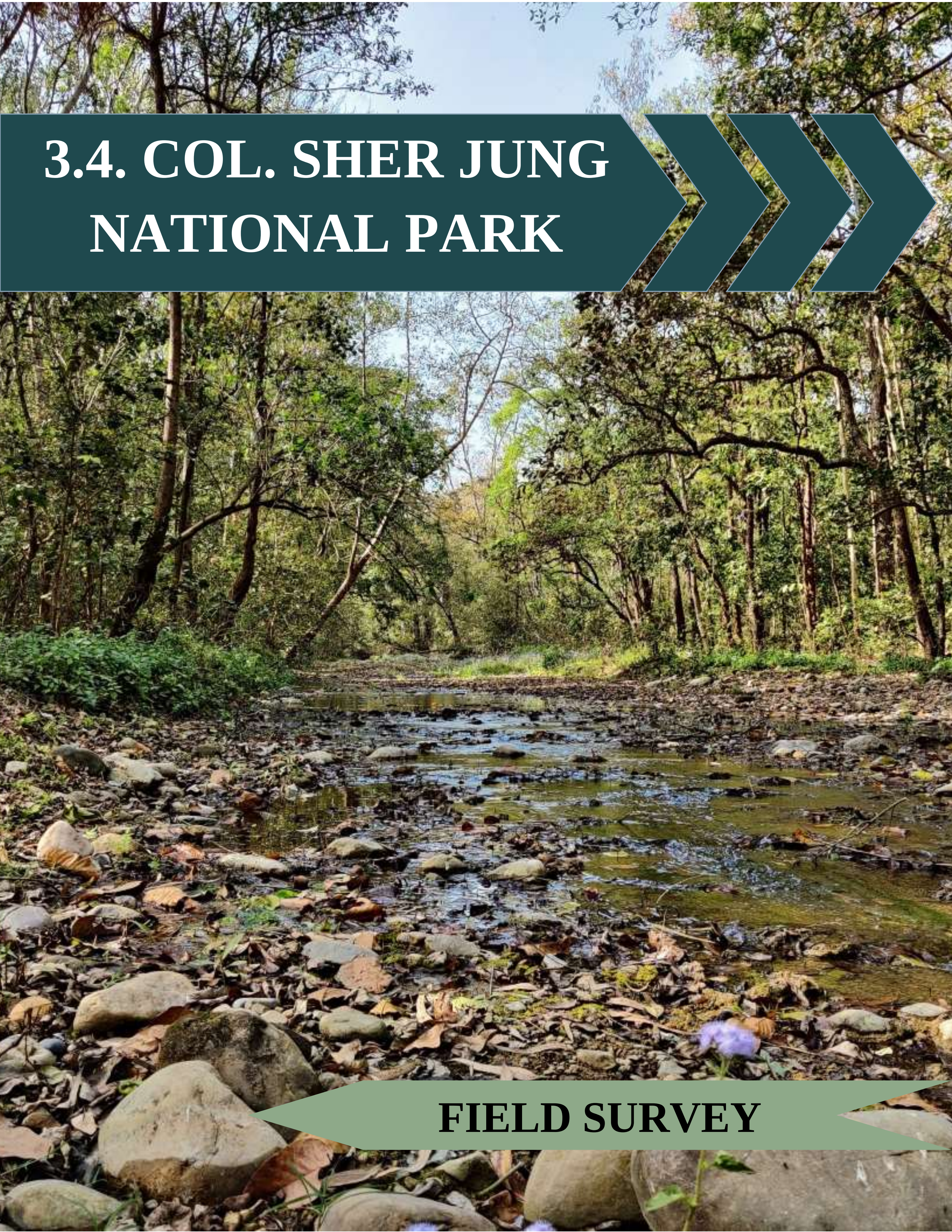
It is a commonly used method for studying herpetofauna populations, particularly in terrestrial habitats. It involves establishing a linear sampling area, usually marked by a physical belt or tape, within which observations and data collection are conducted. Belt transects allow for systematic sampling and documentation of herpetofauna along a defined path, providing valuable information on species presence, abundance, and habitat associations. To conduct a belt transect survey, researchers establish a transect line and place the belt or tape on the ground, perpendicular to the transect line. The width of the belt can vary depending on the target species and study objectives. Observers then walk along the transect line, slowly scanning the area on both sides of the belt to detect and identify herpetofauna individuals.

3.3.4. QUADRATE SAMPLING

It is a commonly employed technique for studying herpetofauna populations, particularly in aquatic habitats such as wetlands and ponds. It involves the systematic sampling of discrete quadrates within the larger habitat to assess the presence, abundance, and diversity of herpetofauna species (Jaeger and Inger, 1994) (Figure 3.2). This method allows researchers to focus their efforts on specific habitat patches that may exhibit unique ecological characteristics or provide suitable conditions for particular species. To conduct a quadrate sampling survey, researchers identify and select a representative sample of patches within the study area. These patches can be defined based on vegetation type, water depth, microhabitat features, or other relevant criteria. The number and size of patches sampled may vary depending on the study objectives and available resources.

Figure 3.2: Quadrate sampling laying across the streams for Herpetofauna Survey.

3.4. COL. SHER JUNG NATIONAL PARK

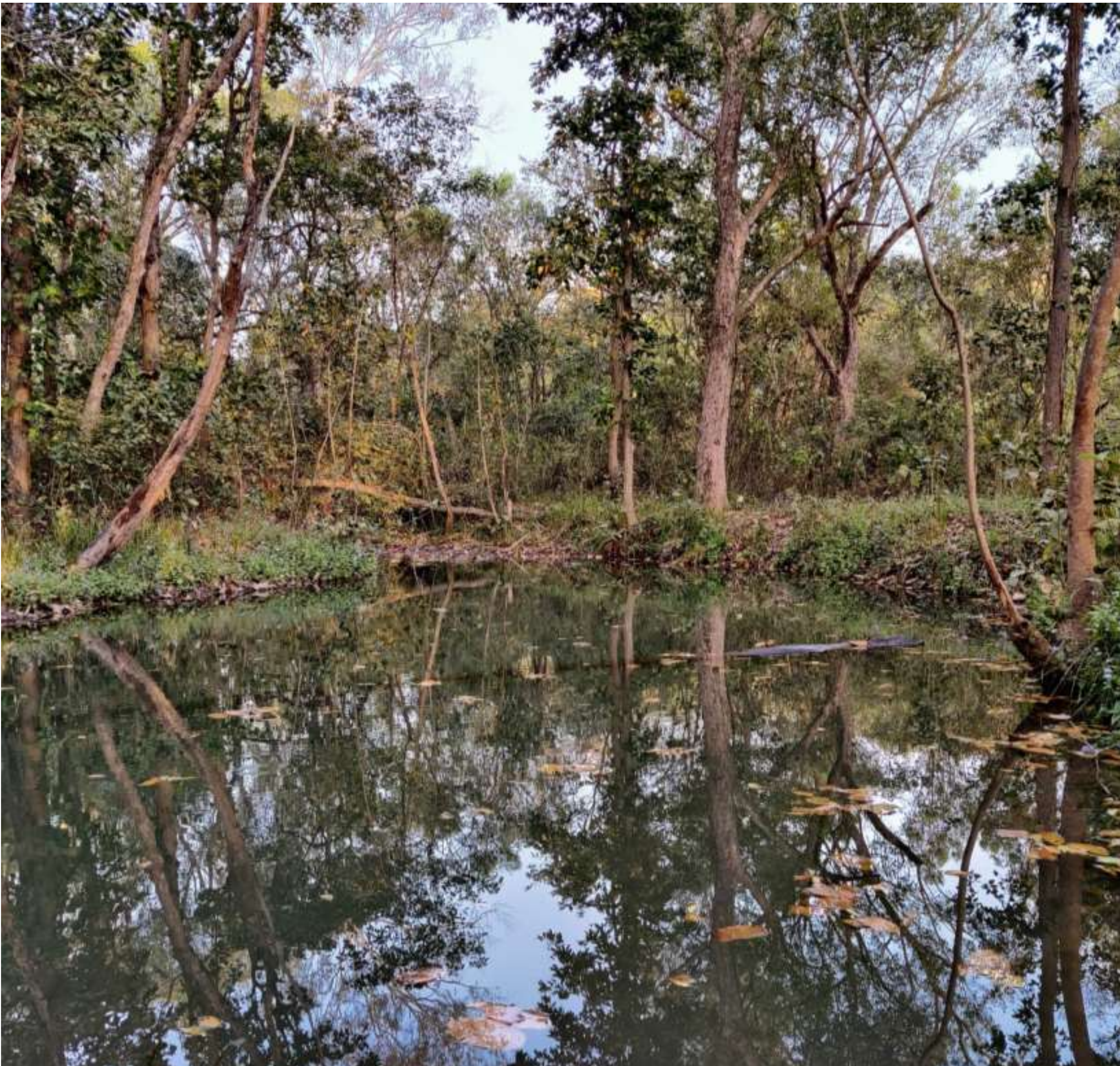


FIELD SURVEY

3.4. COL. SHER JUNG NATIONAL PARK

FIELD SURVEY

The present study aimed to conduct a herpetofauna survey in the foothills of the Shivalik range. To achieve this goal, we first surveyed numerous waterholes and flowing streams to determine the most suitable habitats for amphibians. We selected different habitats and stream patches in various areas as the key locations for the amphibians and reptiles survey. Some of the major waterholes present in the park were also used for the survey. Two areas were selected for the selective reptile survey based on a preliminary survey. After the selection of sites, we used a stratified random sampling approach using both nocturnal and diurnal Visual encounter survey (VES) (Time constrained) (Crump et al., 1994) to know the diversity and distribution of the herpetofauna in the study area. We also laid 78 belt transects (20m x 4m) in selected locations in the study area to know the efficiency of the detection and compare it with VES. The survey was carried out from March to May 2021 and from March to May 2022 in Col. Sher Jung National Park (Figure 3.3). The whole national park was surveyed majorly based on 15 VES sites out of which 8 sites were common for both VES and belt transects with a total manhour of 413 and 218 hours respectively. Subsequently, we selected thirteen major locations, consisting of long streams and waterholes, for detailed sampling and distribution of amphibians. To ensure the efficiency of detection, we used a stratified random sampling approach employing quadrate sampling (Jaeger and Inger, 1994) to the long streams and pools in the study area. The site was surveyed based on 78 quadrates of 20m x 4m. The survey was conducted from 15 March to 20 May 2022 (Figure 3.4). The frogs were detected by direct sighting or glitters of eyes using a waterproof flashlight. Six water parameters, namely temperature, pH, salinity, TDS, conductivity, and ORP, were collected at each sampling location using Aquasol AM-AL-01 Multiparameter Handheld Meter. Subsequently, these parameters were utilized to assess the association between anuran species and estimate their abundance. We also recorded the opportunistic encounters for herpetofauna for the presence of different species in the park. The comparison between the VES and belt transect was also observed to show the difference in the abundance of herpetofauna on the same sites. We divided the study area into six major habitats based on different parameters after ground-truthing to get a better knowledge of the distribution of different species in the area and the importance of habitat for herpetofauna. The six habitats were Eucalyptus dominated mixed forest- areas with no water source and dry forest, Riparian area with dense canopy- flowing streams and pools with canopy cover, Riparian area with open canopy- flowing streams and water pools with least or no canopy, Sal dominated mixed forest- areas with few waterholes and pool, Moist streams bed- areas with moist ground and canopy cover and Dry riverbed with no canopy- seasonal streams with no water during the survey period.



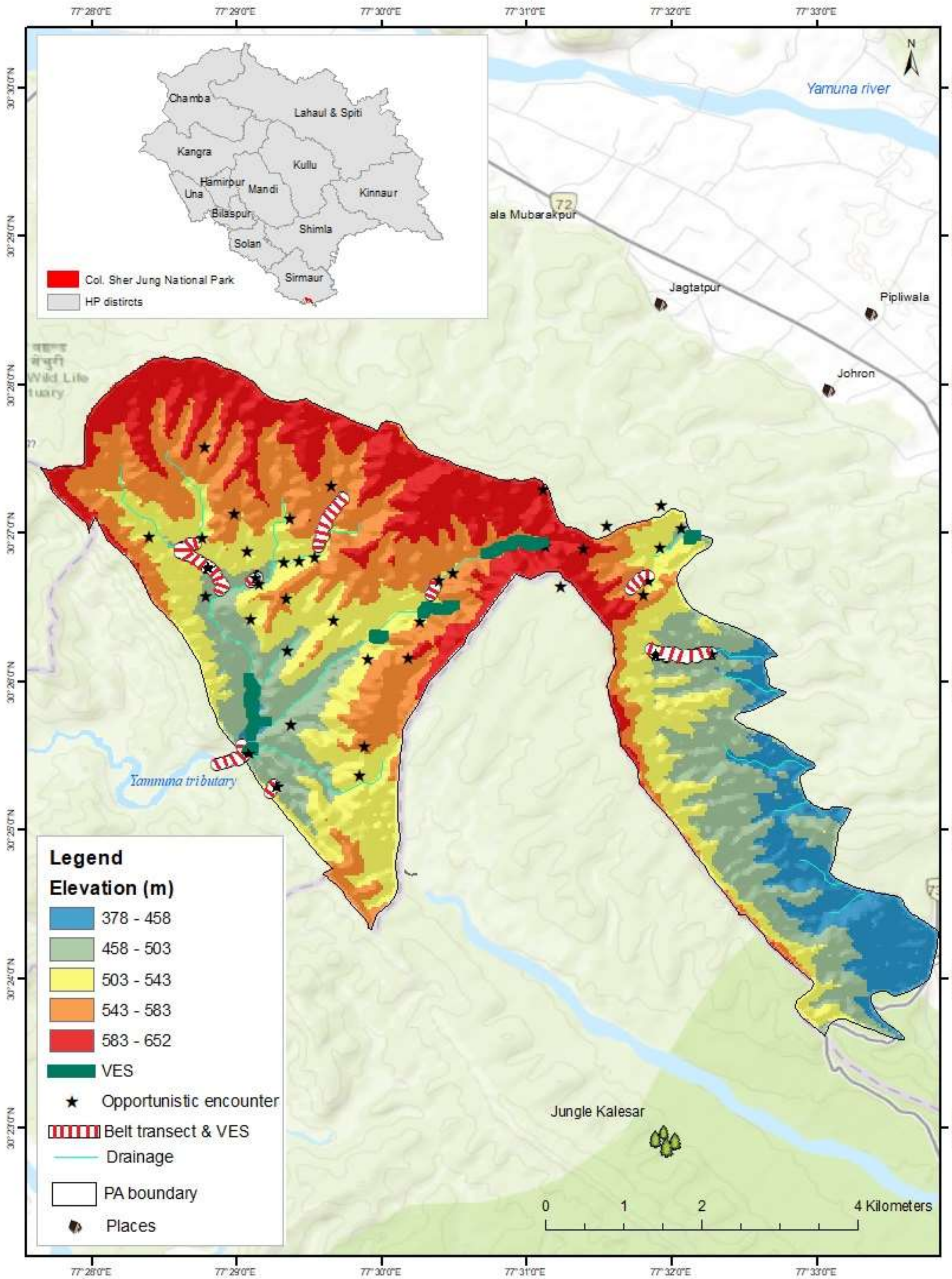


Figure 3.3: Map of Col. Sher Jung National Park showing the Visual encounter survey sites, belt transects and opportunistic encounters of Herpetofauna.

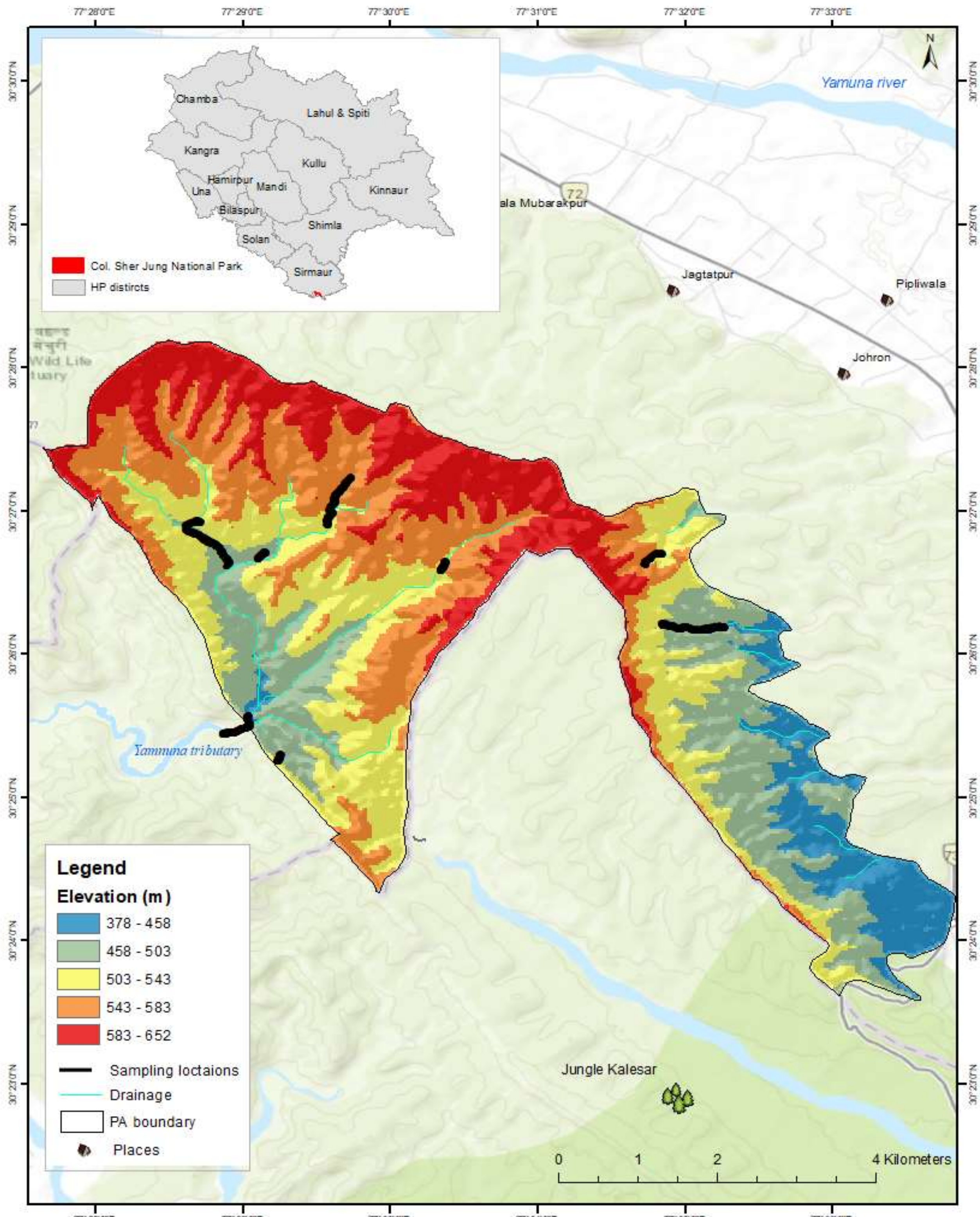


Figure 3.4: A map of the study area (Col. Sher Jung National Park) shows 13 survey sites along with 78 sampling locations for the amphibian survey.

3.4.1. DATA ANALYSIS:

We prepared a checklist for the species diversity in the study area. The number of species in each group of herpetofauna was noted for VES, belt transect and opportunistic encounters. We plotted a doughnut chart to see the difference between different sampling methods using OriginPro 2022 (64-bit) SR1 version 9.9.0.225. We also plotted the species accumulation curve to check the adequacy of the sampling in different habitats using PAST 4.04. The encounter rate for the species was also calculated to see the most dominant and least dominant species of the park. The standard deviation between the two methods VES and Belt transect was calculated to show the difference between the two-sampling technique. An abundance map for different species in different habitats was prepared to know the distribution pattern in the study area using OriginPro 2022 (64-bit) SR1 version 9.9.0.225.

3.4.2. ABUNDANCE

We used the N-mixture model (Royle, 2004) of the “unmarked” package (Fisk and Chandler, 2011) to estimate the abundance of the species and its association with the site-specific covariates. N-mixture works on the repeated count data and hierarchical model approach to estimate the abundance of the species in the sampling sites. The models were fitted using the maximum likelihood methods. From the count data of our NVES, a matrix containing the number of encounters per event on each site was generated to estimate abundance. The pcount function in the "unmarked" package was used to characterize N-mixture models by setting the mixture to Poisson distribution. As the mean and variance of the data had relatively little volatility, the Poisson distribution "P" was employed. We modelled abundance using six water covariates viz: temperature, salinity, pH, conductivity, TDS and ORP. All six covariates were added to the abundance component of the N-mixture model. For *Amolops formosus* in Churdhar wildlife sanctuary Flow of water was also used as abundance component and detection component for further analysis. An automated model selection in the MuMIn package (Barton, 2015) was used to generate sets of abundance models. We fitted number of models using the predicted covariates and the best models was selected based on the AICc (Akaike information criterion) value. As our sample size was small, we used AICc score of the model as the lower-case ‘c’ indicates that the value has been calculated from the AIC test corrected for small sample sizes. Models with the smallest AICc value and highest Akaike weight were considered to be the best models (Burnham and Anderson, 1998). Further, model averaging was done for the top models as the ΔAICc value was <2.

3.4.3. OCCUPANCY

To evaluate the influence of covariates on the detection and occupancy of all encountered species, we employed likelihood-based occupancy modelling (Long et al., 2011; Shannon et al., 2014; MacKenzie et al., 2017). Single-season occupancy models were used in software R, and packages Unmarked and MuMIn (Fiske and Chandler, 2019) were used to estimate detection rates (p) and site occupancy (ψ) for surveys conducted at all 78 locations. The model employs multiple occasions on a collection of survey sites to construct a likelihood estimate using a series of probabilistic arguments. False-negative surveys were corrected by estimating the probability of detection, providing a more precise assessment of site occupancy values (MacKenzie et al., 200017). All continuous variables were normalised using z-scores prior to analysis, and the correlation between various sites and survey covariates was checked. The best model was selected based on the Akaike Information Criteria (AIC), with a minimum value indicating a balance between fit (likelihood) and the least number of parameters (Akaike, 1974; Burnham and Anderson, 2002).

3.5. RESULTS

3.5. RESULTS

3.5.1. DIVERSITY:

The survey resulted in the presence of 28 species of Herpetofauna. We encountered 21 species of reptiles belonging to 18 genera (Figure 3.13) of 10 families and 7 species of amphibians belonging to 6 genera of 3 families (Table 3.4). The most dominant family for reptiles was Colubridae with 5 species and for amphibians Dicroglossidae with 4 species. We encountered 20 species (71.42%) of the herpetofauna from VES, 11 species (39.28%) during belt transect and 18 species (64.28%) during opportunistic sampling. VES resulted in the highest number of species followed by the opportunistic encounter and then by belt transect. The opportunistic encounter resulted in very few encounters of amphibians whereas VES had the highest encounter along with the highest number of individuals. Of total encounters during VES 40% (8 species) were lizards, 35% (7 species) were amphibians, 10% (2 species) were Chelonia and 15% (3 species) were snakes. Belt Transects resulted in 63.63% (7 species) amphibians, 18.18% (2 species) lizards, 9.09% (1 species) Chelonia and 9.09% (1 species) snakes' encounters. In Opportunistic encounters, we found 55.56% (10 species) of snakes, 27.78% (5 species) of lizards, 11.11% (2 species) of Chelonia and 5.56% (1 species) of amphibians (Figure 3.6). In VES the most dominant group was lizards, in the Belt transect it was amphibians and in Opportunistic encounter it was snakes. This comparison showed how three different sampling designs were adequate for sampling different groups of herpetofauna.

Table 3.4: Checklist of Herpetofauna diversity of Col. Sher Jung National Park

Reptiles			
S.no.	**Family**	**Genus**	**Species**
1	Agamidae	*Sitana*	*Sitana sp.*
2		*Calotes*	*Calotes versicolor*
3	Colubridae	*Ptyas*	*Ptyas mucosa*
4		*Boiga*	*Boiga trigonata*
5			*Boiga forsteni*
6		*Sibynophis*	*Sibynophis sagittarius*
7		*Fowlea*	*Fowlea piscator*
8	Elapidae	*Bungarus*	*Bungarus sp.*
9		*Naja*	*Naja naja*
10	Gekkonidae	*Hemidactylus*	*Hemidactylus flaviviridis*
11			*Hemidactylus cf. brookii*
12	Pythonidae	*Python*	*Python molurus*
13	Scincidae	*Eutropis*	*Eutropis macularia*
14			*Eutropis carinata*
15		*Ablepharus*	*Ablepharus spp.*
16		*Riopa*	*Riopa punctata*
17	Typhlopidae	*Argyrophis*	*Argyrophis diardii*
18		*Indotyphlops*	*Indotyphlops braminus*
19	Varanidae	*Varanus*	*Varanus bengalensis*
20	Trionychidae	*Lissemys*	*Lissemys punctata*
21	Geoemydidae	*Melanochelys*	*Melanochelys trijuga*
Amphibians			
1	Bufonidae	*Duttaphrynus*	*Duttaphrynus melanostictus*
2			*Duttaphrynus stomaticus*
3	Dicroglossidae	*Fejervarya*	*Fejervarya spp.*
4		*Hoplobatrachus*	*Hoplobatrachus tigerinus*
5		*Sphaerotheca*	*Sphaerotheca breviceps*

6		*Euphlyctis*	*Euphlyctis cyanophlyctis*
7	Microhylidae	*Microhyla*	*Microhyla sp.*

The encounter rate for the group of taxa of herpetofauna was calculated (Figure 3.5). The species along with the number of individuals encountered during the VES and belt transect was recorded (Table 3.5). The encounter rate of the different species of the study area was calculated (Figure 3.7). The most dominant species was *Fejervarya* sp. with 2149 individuals in VES with an encounter rate of 5.2 individuals per hour followed by *Euphylctis cyanophlyctis* (1344) *and Duttaphrynus melanostictus* (762) with an encounter rate of 3.25 and 1.84 individuals per hour respectively. The least dominant species were *Eutropis dissimilis* (0.0048), *Lissemys punctata* and *Calotes versicolor* (0.0072) individuals per hour with only 2, 3 and 3 individuals respectively during the whole survey. For the Belt transect, the most dominant species was also *Fejervarya* sp. with 1269 individuals and an encounter rate of 5.82 individuals per hour. The least dominant species was *Melanochelys trijuga* with only one individual during the belt transects.

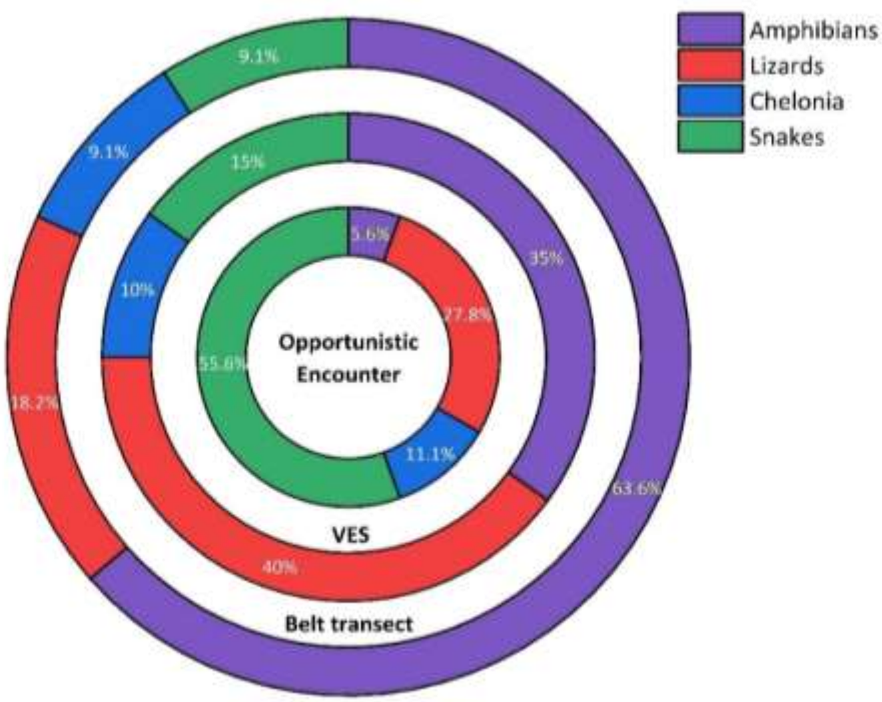


Figure 3.5: Donut-Chart representing the percentage of the number of species in each group of herpetofauna encountered during Opportunistic encounter (inner), Visual encounter survey (VES) (middle) and Belt transect (Outer).

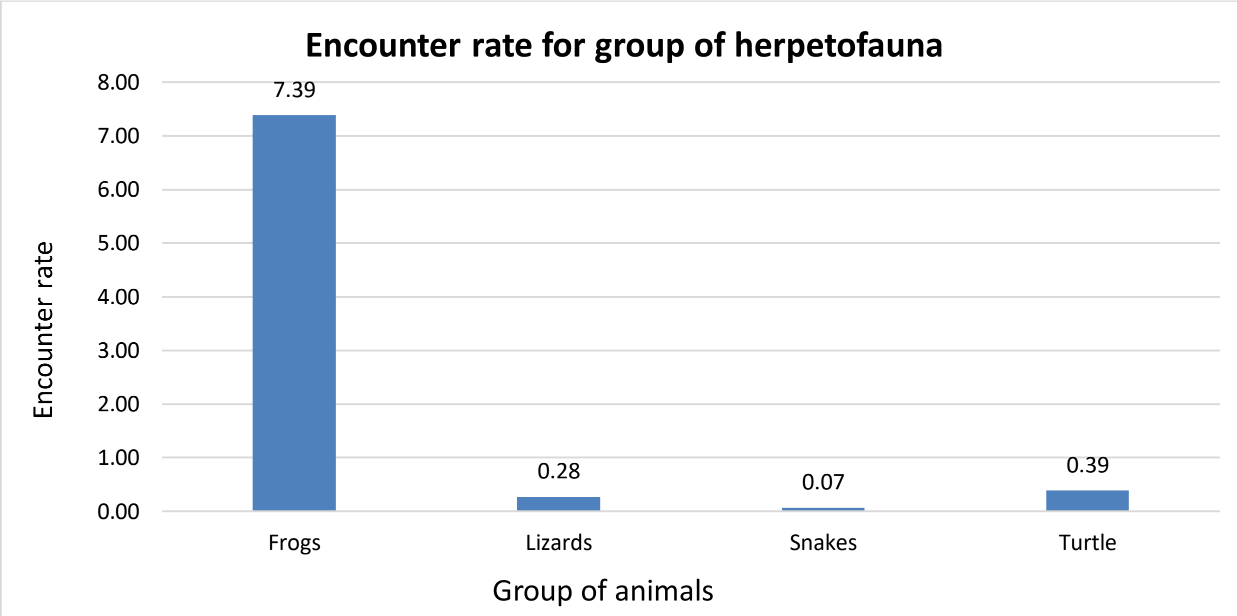


Figure 3.6: Encounter rate of different group of Herpetofauna from Col. Sher Jung National Park.

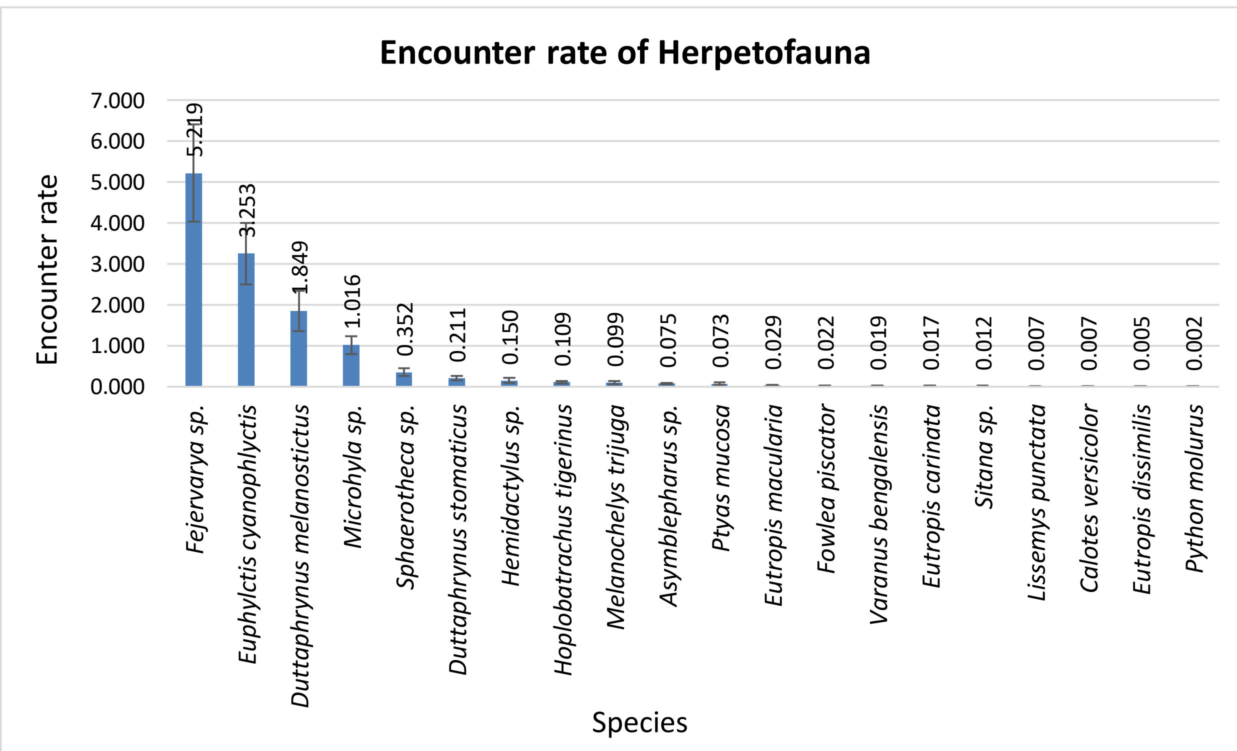


Figure 3.7: Encounter rate of all species of Herpetofauna from Col. Sher Jung National Park.

Table 3.5: Encounter rate per hour of herpetofauna species during Visual encounter survey (VES) (Manhour of 413 hours) and belt transect (Manhour of 218 hours) from Col. Sher Jung National Park along with Standard error (SE)

Species	**No. of Individuals in VES**	**Encounter rate in VES ± SE**	**No. of Individuals in Belt Transect**	**Encounter rate in Belt Transect ± SE**
Duttaphrynus melanostictus	762	1.85 ± 0.494	455	2.06 ± 0.702
Duttaphrynus stomaticus	87	0.21 ± 0.055	14	0.06 ± 0.040
Euphylctis cyanophlyctis	1344	3.25 ± 0.752	590	2.67 ± 0.921
Fejervarya sp.	2149	5.22 ± 1.191	1269	5.78 ± 1.373
Microhyla sp.	420	1.02 ± 0.221	103	0.47 ± 0.145
Sphaerotheca sp.	145	0.35 ± 0.091	36	0.16 ± 0.058
Hoplobatrachus tigerinus	45	0.11 ± 0.034	5	0.02 ± 0.015
Melanochelys trijuga	41	0.10 ± 0.037	1	0.004 ± 0.004
Lissemys punctata	3	0.01 ± 0.005	0	0
Fowlea piscator	9	0.02 ± 0.005	0	0
Ptyas mucosa	30	0.07 ± 0.025	3	0.01 ± 0.007
Python molurus	1	0.002 ± 0.002	0	0
Sitana sp.	5	0.01 ± 0.008	0	0
Hemidactylus sp.	62	0.15 ± 0.058	4	0.02 ± 0.012
Eutropis carinata	7	0.02 ± 0.007	0	0
Riopa punctata	2	0.004 ± 0.003	0	0
Ablepharus sp.	31	0.08 ± 0.019	2	0.01 ± 0.006
Eutropis macularia	12	0.03 ± 0.009	0	0
Calotes versicolor	3	0.01 ± 0.004	0	0
Varanus bengalensis	8	0.02 ± 0.008	0	0

The area of 15 VES sites was classified into major six habitat types. The number of individuals of each species was noted in different habitats (Figure 3.8). Rank abundance for different species in different habitats was noted. 19 species and 18 species were detected from the Riparian area with dense canopy habitat and Riparian areas with open canopy habitat showing it the most diverse habitat for herpetofauna distribution. Sal dominated mixed forest and Moist bed streams habitat was home to 16 and7 species respectively. Eucalyptus-dominated mixed forest and Dry riverbed with no canopy habitat showed the presence of only one species in each. *Hemidactylus* sp. was the only species encountered in the Eucalyptus-dominated mixed forest with 46 individuals as this habitat was completely void of water. Also, the individuals encountered dwelled on the tree bole under the bark of the trees showing the habitat importance for the species. *Sitana* sp. was the only species encountered in Dry riverbed with no canopy habitat. This habitat had dry and withered shrubs that were used by the species for hiding and resting making it a habitat-specific species and stating the importance of the habitat as the species was not found in any other habitats. *Fejervarya* sp. was the most dominant species found in the Riparian area with open canopy habitat with 1039 individuals. *Euphylctis cyanophlyctis* was the most dominant species of Sal-dominated mixed forest habitat with 263 individuals as the habitat consists of some small water pools. *Fejervarya* sp. was the most dominant species in the Riparian area with dense canopy habitat with 797 individuals. *Fejervarya* sp. was the most dominant species of Moist streams bed habitat with 173 individuals (Table 3.6).

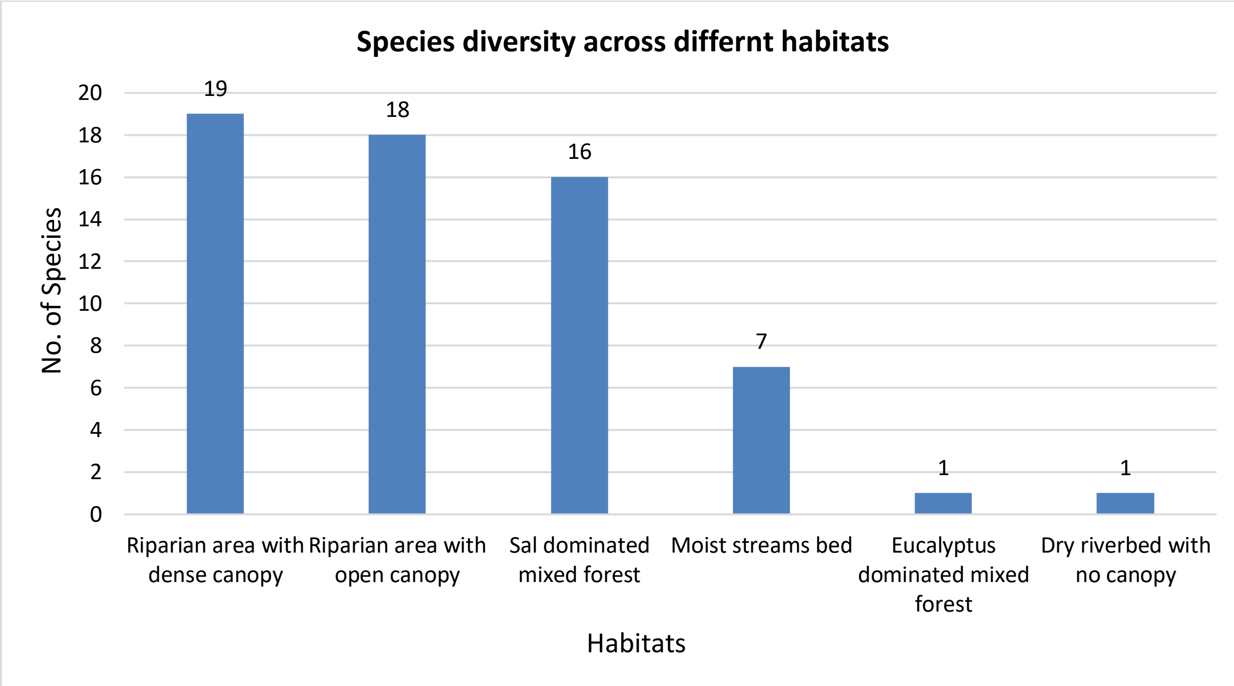


Figure 3.8: Number of herpetofauna species encountered during visual encounter survey and belt transect in six different habitats of Col. Sher Jung National Park.

Table 3.6: Number of individuals and species encountered in different habitat types in SNP

Species	Eucalyptus dominated mixed forest	Riparian area with dense canopy	Riparian area with open canopy	Sal dominated mixed forest	Moist streams bed	Dry riverbed with no canopy
Duttaphrynus melanostictus	0	265	425	65	24	0
Duttaphrynus stomaticus	0	39	31	29	0	0
Euphylctis cyanophlyctis	0	577	595	263	42	0
Fejervarya sp.	0	797	1039	225	173	0
Microhyla sp.	0	220	84	114	23	0
Sphaerotheca sp.	0	59	69	23	0	0

Hoplobatrachus tigerinus	0	22	14	17	0	0
Melanochelys trijuga	0	22	8	23	0	0
Lissemys punctata	0	2	3	3	0	0
Fowlea piscator	0	4	11	3	0	0
Ptyas mucosa	0	15	3	4	3	0
Sitana sp.	0	2	24	0	0	24
Hemidactylus sp.	46	24	2	30	0	0
Eutropis carinata	0	2	1	2	0	0
Eutropis dissimilis	0	1	13	0	0	0
Ablepharus sp.	0	14	4	8	2	0
Eutropis macularia	0	6	1	3	2	0
Calotes versicolor	0	2	3	0	0	0
Varanus bengalensis	0	4	0	2	0	0
Total no. of Individuals	46	2077	2330	814	269	24
Number of Species	1	19	18	16	7	1

Fejervarya sp. was the most abundant and widely distributed species of the park with 2234 individuals and observed in four different habitats followed by *Euphylctis cyanophlyctis* and *Duttaphrynus melanostictus* with 1477 and 779 individuals. The heat map for the distribution of different species in different habitats was prepared to know the distribution of all species in the Col. Sher Jung National Park (Figure 3.9).

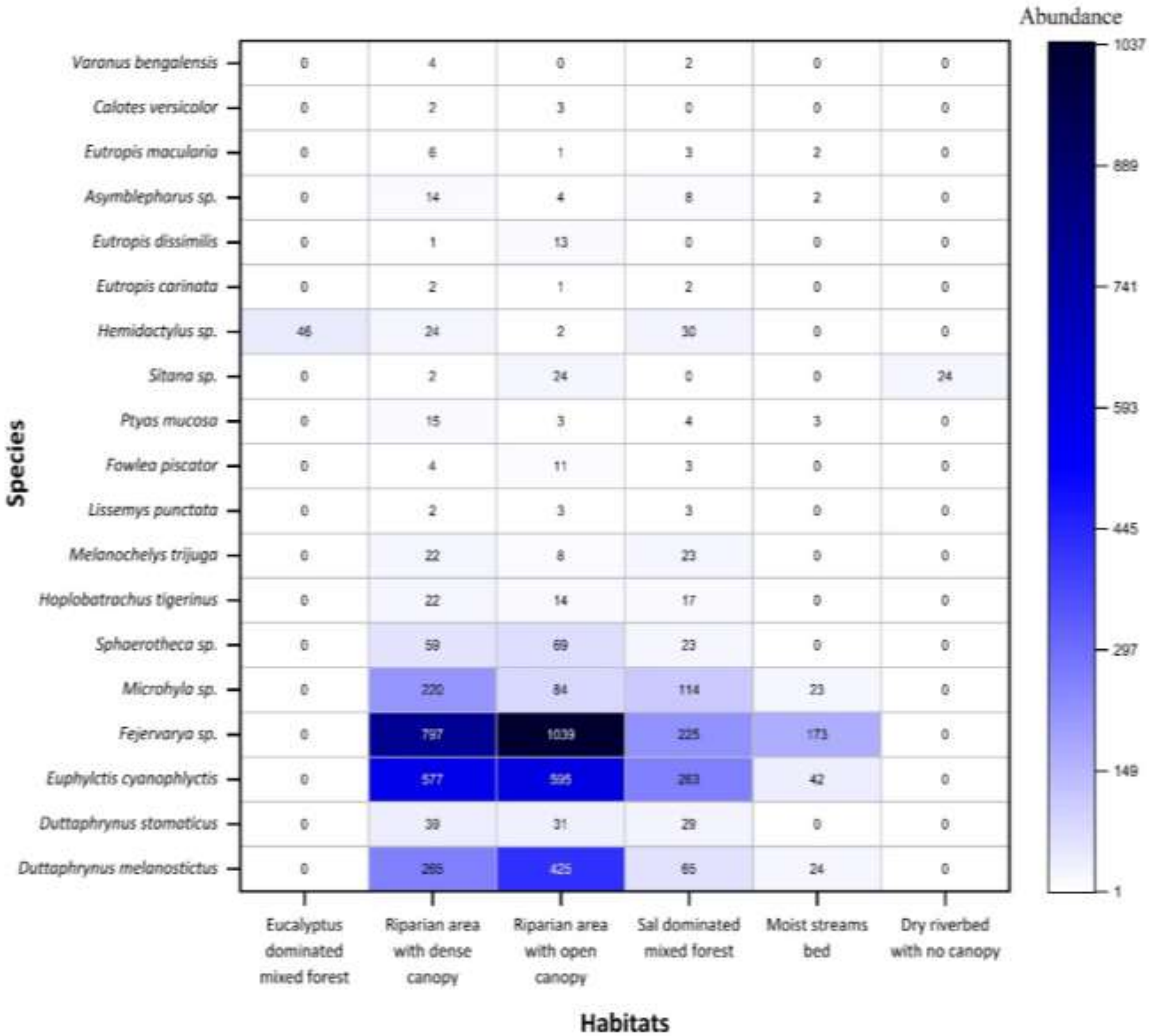


Figure 3.9: Abundance and Distribution of species of herpetofauna in different habitats in Visual encounter survey and belt transect (Darker blue areas indicate high abundance).

3.5.2. SPECIES ACCUMULATION

The species accumulation curve for the whole national park showed the efficacy of the sampling effort (Figure 3.10). Species accumulation curve in the six different habitat types showed our sampling effort adequacy (Figure 3.11). Riparian area with dense canopy and Riparian area with open canopy showed slightly lower adequacy of our sampling effort while Sal dominated mixed forest showed good sampling adequacy. More sampling efforts are needed in some as very few encounters are from these sites. This helped us in understanding the sampling effort put to survey the herpetofauna of Col. Sher Jung National Park.

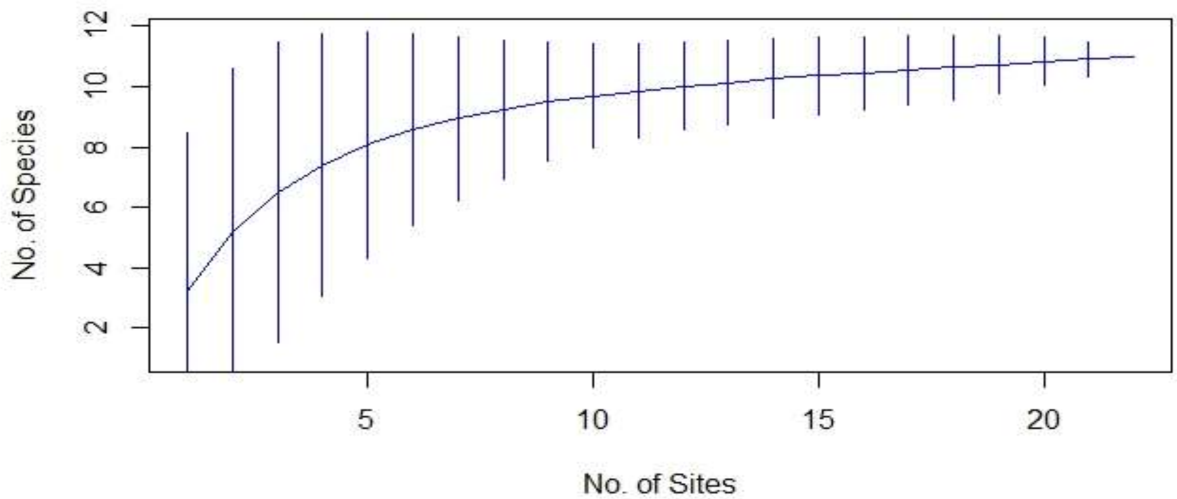


Figure 3.10: Species accumulation curve of Col. Sher Jung National Park.

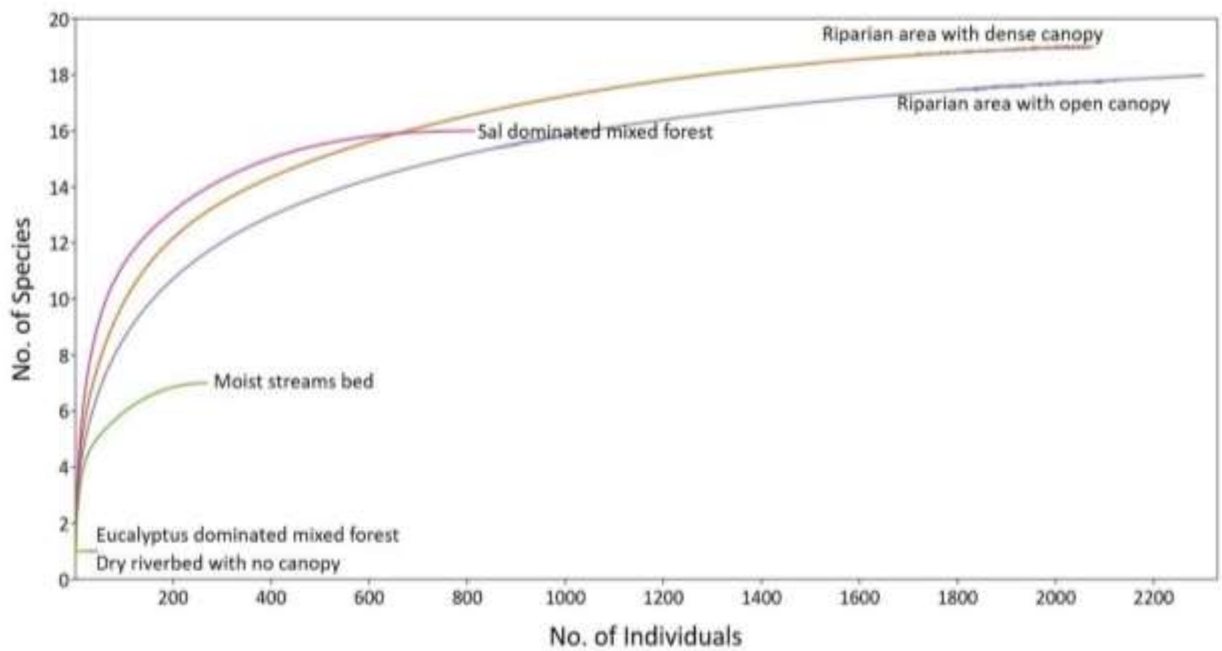


Figure 3.11: Species accumulation curve for herpetofauna in different habitats of Col. Sher Jung National Park.

3.5.3. ANURANS ABUNDANCE AND OCCUPANCY:

During the survey conducted in the park, seven species of amphibians belonged to six genera of three families. The seven species of amphibians were *Duttaphrynus melanostictus, Duttaphrynus stomaticus, Euphlyctis cyanophlyctis, Fejervarya* sp., *Hoplobatrachus tigerinus, Microhyla* sp., *and Sphaerotheca* sp. (Figure 3.12). Notably, the *Fejervarya* sp. species was found to be the most abundant with 1935 ± 16.31 individuals encountered across all locations. This was followed by *Euphlyctis cyanophlyctis* with 1212 ± 25.19 individuals and *Duttaphrynus melanostictus* with 649 ± 7.58 individuals. On the other hand, *Hoplobatrachus tigerinus* was the least encountered species with 45 ± 1.49 individuals. It was observed that the encounter of *Hoplobatrachus tigerinus*, *Microhyla* sp., and *Sphaerotheca* sp. was initially low and increased towards the end of the survey in Mid-May. During every replicate, all water parameters were recorded in each patch, and a range of different water parameters was recorded during the survey period. The recorded parameters included range of conductivity (107.2 to 410.8 µS), TDS (61.1 to 279.5 ppm), Salinity (39.7 to 184.5 ppm), pH (6.88 to 9.33), ORP (-132.5 to -58.8 mV), and temperature (23.3 to 33.50 C) in the study site. The prediction of abundance estimation of all species in the 78 surveyed locations using N-mixture top models was done to determine the diversity and distribution of different species in the Shivalik ranges (Supplementary Table 1). The top models with ΔAICc < 2 were used for model averaging and prediction of the abundance of the species and their correlation with abundance estimate (Supplementary Table 2). During analysis, the top model was used as the best model for all the species as other models just added a parameter to the top model which improves the fit but not enough to overcome the 2-unit ΔAICc penalty making them uninformative (Leroux 2019). The occupancy probability of *Duttaphrynus stomaticus, Euphlyctis cyanophlyctis, Hoplobatrachus tigerinus, Microhyla* sp., and *Sphaerotheca* sp. showed a correlation with several parameters, but the coefficients were not statistically significant for the number of cases (Table 3.7).

Duttaphrynus melanostictus. The average abundance of the species was using a Null model was estimated to be 18.1 ± 0.88 individuals per sight, with a detection probability of 0.41 ± 0.02. The global model showed higher fits as the AIC was lower than (ΔAIC = 3.61) the null model. The top model came out to be combination of salinity, conductivity and pH. Of all these covariates conductivity (0.79 ± 0.12) of the water showed a positive; and salinity (-1.05 ± 0.12) showed a negative statistically significant relationship with the abundance component of the species (Table 3.8). Despite attempts at occupancy estimation, no significant results were obtained as the species was present in all surveyed locations.

Duttaphrynus stomaticus. The detection probability of the species was estimated to be 0.05 ± 0.02 and the average abundance was estimated to be 6.60 ± 2.60 individuals per sight using the null model. The global model showed higher fits as the AIC was lower than (ΔAIC = 2.76) the null model. The top model came out to be combination of salinity, conductivity and temperature. Of all these covariates conductivity (1.94 ± 0.32) and temperature (0.46 ± 0.12) of the water showed a positive statistically significant relation whereas salinity showed a negative (-2.54 ± 0.36) statistically significant relation with the abundance estimate of the species (Table 3.8).
The naïve occupancy of *Duttaphrynus stomaticus* was estimated to be 0.42 ± 0.06, with a detection probability of 0.45 ± 0.04 according to the null model. To investigate the potential impact of covariates on the species' presence, an all-covariates model was executed. The results showed that the best model, which incorporated pH, TDS, and Temperature as covariates, had a statistically significant correlation with the species. Specifically, only temperature exhibited a positive statistically significant correlation ($z = 2.62$, $p < 0.05$) with the species.

Euphlyctis cyanophlyctis. The average abundance estimation using the Null model resulted to be 30.00 ± 0.82 individuals per sight with a detection probability of 0.44 ± 0.01. The global model showed higher fits as the AIC was lower than (ΔAIC = 2.30) the null model. The top model came out to be combination of salinity, temperature, conductivity and ORP. Of all these covariates conductivity (1.50 ± 0.09) and ORP (0.47 ± 0.09) of the water showed a positive statistically significant relation whereas salinity (-2.23 ± 0.09) showed a negative statistically significant relation with the abundance estimate of the species (Table 3.8).

The naïve occupancy of *Euphlyctis cyanophlyctis* was estimated to be 0.95 ± 0.03 with a detection probability of 0.76 ± 0.02 according to the null model. All covariates model was run to test the impact on the presence of the species. Of all covariates, the best model describing the occupancy contained ORP and conductivity. Of these ORP showed a positive statistically significant correlation ($z = 2.13$, $p < 0.05$) and conductivity showed a negative statistically significant correlation ($z = -2.11$, $p < 0.05$) with the species.

Fejervarya sp. The average abundance estimation using the Null model resulted to be 43.50 ± 1.39 individuals per sight with a detection probability of 0.54 ± 0.02. The global model showed higher fits as the AIC was lower than (ΔAIC = 2.92) the null model. The top model came out to be combination of salinity, conductivity, ORP and TDS. Of all these covariates conductivity (0.84 ± 0.07) and TDS (0.04 ± 0.01) of the water showed a positive statistically significant relation whereas salinity (-1.13 ± 0.07) showed a negative statistically significant relation with the abundance estimate of the species (Table 3.8).

Hoplobatrachus tigerinus. The average abundance estimation using the Null model resulted to be 7.60 ± 3.41 individuals per sight with a detection probability of 0.02 ± 0.01. The global model showed higher fits as the AIC was lower than (ΔAIC = 31.35) the null model. The top model came out to be combination of salinity, conductivity, temperature and pH. Of all these covariates conductivity (1.74 ± 0.41), pH (0.41 ± 0.16) and temperature (0.47 ± 0.19) of the water showed a positive statistically significant relation whereas salinity (-2.16 ± 0.50) showed a negative statistically significant relation with the abundance estimate of the species (Table 3.8).

The naïve occupancy of *Hoplobatrachus tigerinus* was estimated to be 0.56 ± 0. 10 with a detection probability of 0.22 ± 0.04 according to the null model. All covariates model was run to test the impact on the presence of the species. Of all covariates, the best model describing the occupancy contained Salinity and temperature. Of these none showed a statistically significant correlation with the species.

***Microhyla* sp.** The average abundance estimation using the Null model resulted to be 11.8 ± 0.97 individuals per sight with a detection probability of 0.13 ± 0.01. The global model showed higher fits as the AIC was lower than (ΔAIC = 6.07) the null model. The top model came out to be combination of all six models. Of all these covariates conductivity (0.60 ± 0.24), ORP (3.43 ± 0.30), pH (0.48 ± 0.07) and temperature (0.38 ± 0.07) of the water showed a positive statistically significant relation whereas salinity (-1.67 ± 0.26) showed a negative statistically significant relationship with the abundance estimate of the species (Table 3.8).

The naïve occupancy of *Microhyla* sp**.** was estimated to be 0.53 ± 0.06 with a detection probability of 0.50 ± 0.04 according to the null model. All covariates model was run to test the impact on the presence of the species. Of all covariates, the best model describing the occupancy contained Salinity and TDS. Of these none showed a statistically significant correlation with the species.

***Sphaerotheca* sp.** The average abundance estimation using the Null model resulted to be 15.80 ± 2.45 individuals per sight with a detection probability of 0.04 ± 0.01. The global model showed higher fits as the AIC was lower than (ΔAIC = 7.64) the null model. The top model came out to be combination of salinity and conductivity. Of all these covariates conductivity (0.73 ± 0.24) of the water showed a positive statistically significant relation whereas salinity (-0.89 ± 0.25) showed a negative statistically significant relationship with the abundance estimate of the species (Table 3.8).

The naïve occupancy of *Sphaerotheca* sp. was estimated to be 0.80 ± 0.07 with a detection probability of 0.33 ± 0.03 according to the null model. All covariates model was run to test the impact on the presence of the species. Of all covariates, the best model describing the occupancy contained Conductivity, ORP, pH, Temperature and TDS. Of these none showed a statistically significant correlation with the species.

Table 3.7: Parameter estimates of covariates retained in the top occupancy models of the study species

Species	**Covariates**	**β Estimate**	**SE**	**z**	**P value**
Duttaphrynus stomaticus	pH	1.10	0.66	1.63	0.10
	TDS	0.78	0.48	1.63	0.10
	Temperature	1.00	0.38	2.62	**0.01**
Euphlyctis cyanophlyctis	ORP	16.70	7.87	2.13	**0.03**
	Conductivity	-17.20	8.13	-2.11	**0.03**
Hoplobatrachus tigerinus	Salinity	-0.60	0.40	-1.51	0.13
	Temperature	0.78	0.41	1.89	0.06
Microhyla sp.	Salinity	-1.67	1.14	-1.47	0.14
	TDS	1.72	1.16	1.48	0.14
Sphaerotheca sp.	Conductivity	-111.46	105.08	-1.06	0.29
	ORP	34.28	31.86	1.08	0.28
	pH	7.04	6.36	1.11	0.27
	TDS	102.12	95.75	1.07	0.29
	Temperature	-6.28	5.91	-1.06	0.29

Table 3.8: Coefficient of abundance estimate with standard error (SE) and p-value after the model averaging the top models for each species

	Coefficient of Estimate	**SE**	**z**	**p-value**
Duttaphrynus melanostictus				
lam (Conductivity)	0.79	0.12	6.58	<2e-16
lam (pH)	-0.08	0.03	3.20	0.0014
lam (Salinity)	-1.05	0.12	8.62	<2e-16
Duttaphrynus stomaticus				
lam (Conductivity)	1.94	0.32	6.03	2.00E-16
lam (Salinity)	-2.54	0.36	7.11	2.00E-16
lam (Temperature)	0.46	0.12	3.86	0.000112
Euphlyctis cyanophlyctis				
lam (Conductivity)	1.50	0.09	17.17	2.00E-16
lam (ORP)	0.47	0.09	5.05	4.50E-07
lam (Salinity)	-2.23	0.09	24.19	2.00E-16
lam (Temperature)	0.22	0.03	6.83	2.00E-16
***Fejervarya* sp.**				
lam (Conductivity)	0.84	0.07	11.76	<2e-16
lam (ORP)	0.04	0.02	1.72	0.0852
lam (Salinity)	-1.13	0.07	15.67	<2e-16
lam (TDS)	0.04	0.02	2.60	0.0094
Hoplobatrachus tigerinus				
lam (Conductivity)	1.74	0.41	4.21	2.55E-05
lam (pH)	0.42	0.16	2.55	0.0109
lam (Salinity)	-2.16	0.50	4.35	1.35E-05

lam (Temperature)	0.47	0.19	2.49	0.0129
***Microhyla* sp.**				
lam (Conductivity)	0.60	0.24	2.48	0.013
lam (ORP)	3.43	0.30	11.53	<2e-16
lam (pH)	0.48	0.07	6.96	<2e-16
lam (Salinity)	-1.68	0.26	6.49	<2e-16
lam (Temperature)	0.38	0.07	5.43	6.00E-08
***Sphaerotheca* sp.**				
lam (Conductivity)	0.73	0.24	2.99	0.00275
lam (Salinity)	-0.89	0.25	3.62	0.00029

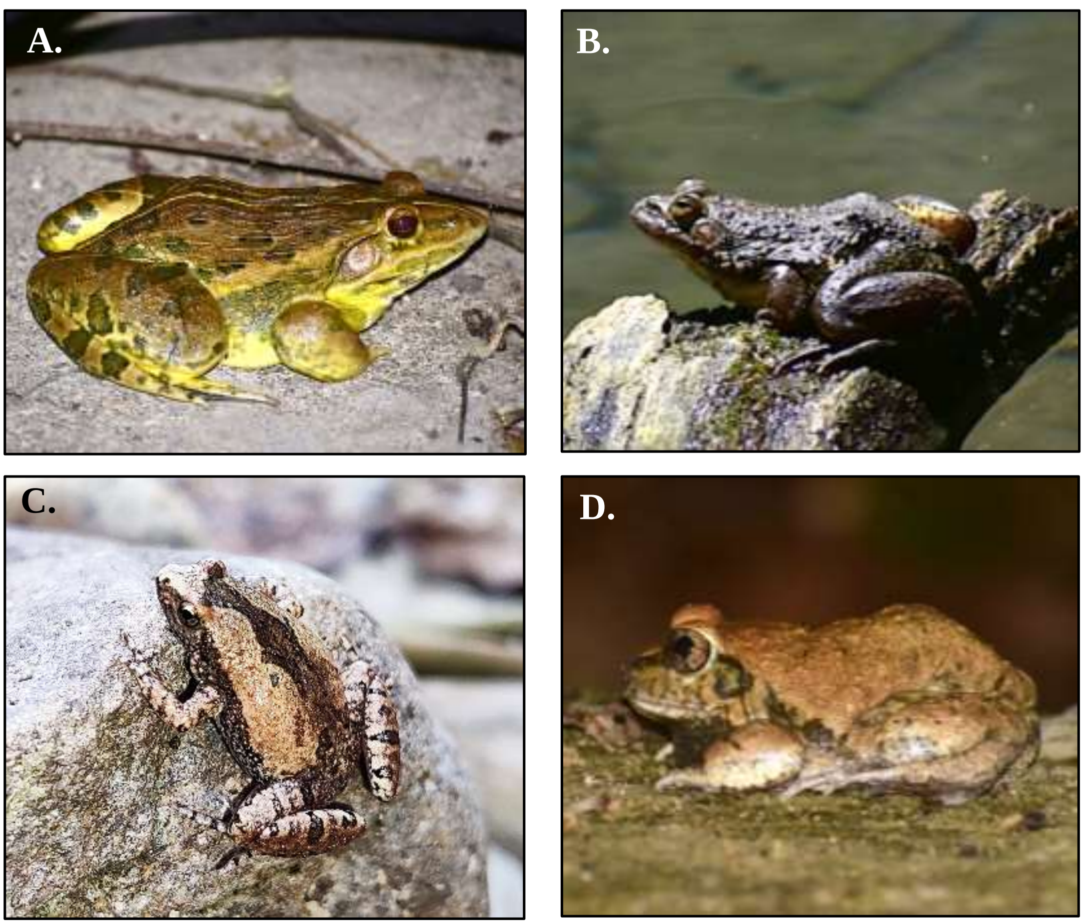
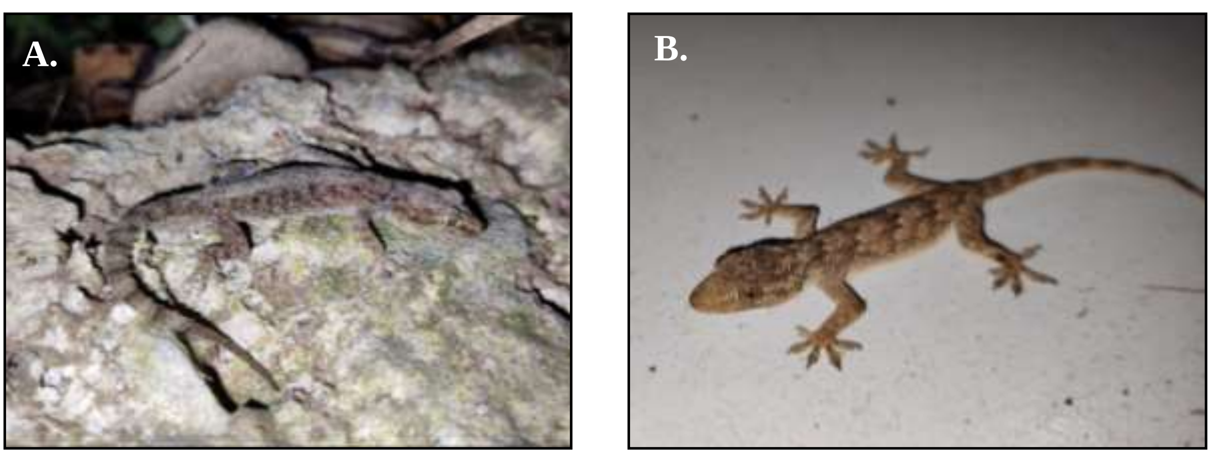


Figure 3.12: Anurans encountered from Col. Sher Jung National Park (A) *Hoplobatrachus tigerinus*, (B) *Euphlyctis cyanophlyctis*, (C) *Microhyla* sp., (D) *Sphaerotheca* sp., (E) *Fejervarya* sp., (F) *Duttaphrynus melanostictus* and (G) *Duttaphrynus stomaticus*




C.


D.


E.


F.

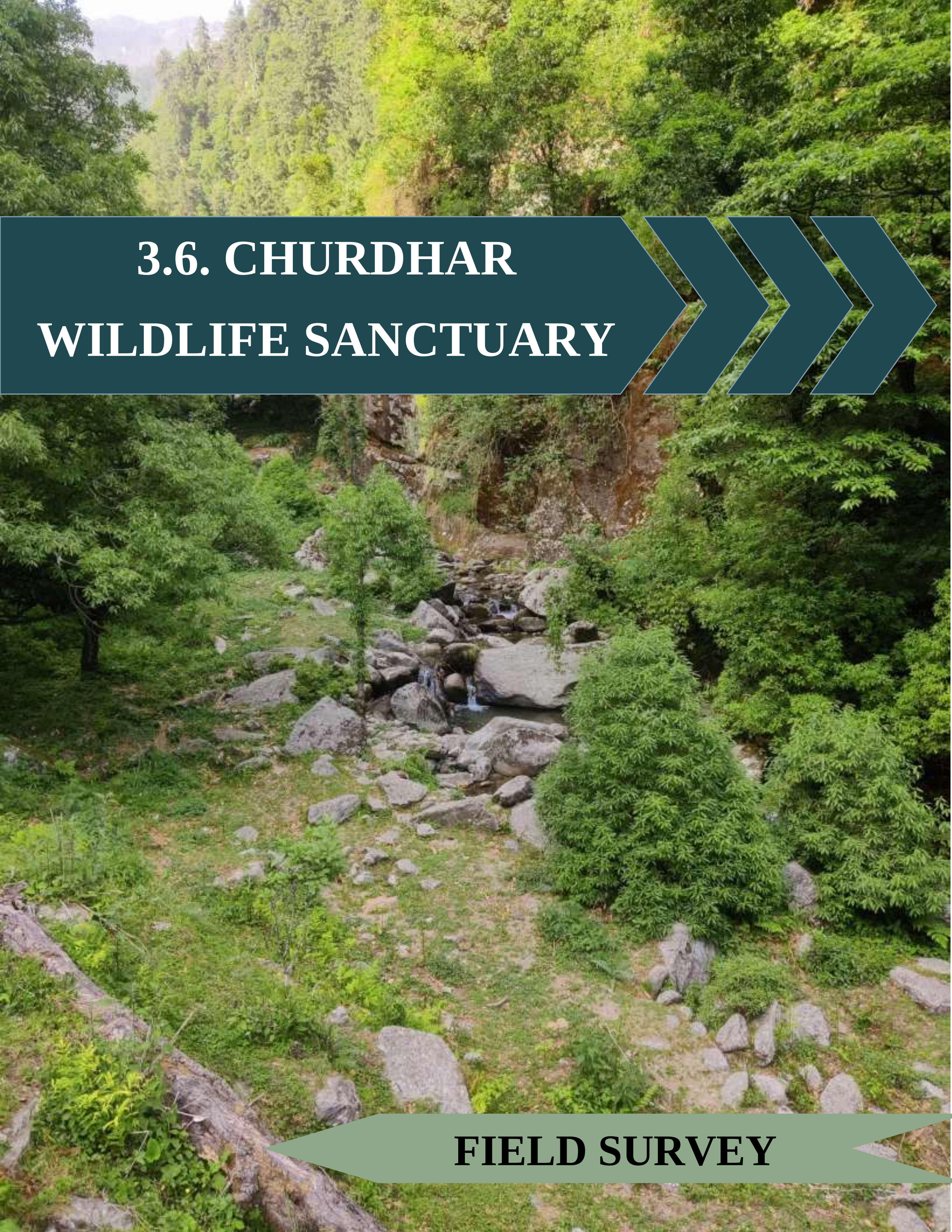

G.


H.

Figure 3.13: Some Reptiles encountered from Col. Sher Jung National Park (A) *Hemidactylus cf. Brokii*, (B) *Hemidactylus flaviviridis*, (C) *Calotes versicolor*, (D) *Eutropis macularia*, (E) *Sitana*

sp., (F) *Lissemys punctata* (G) *Melanochelys trijuga* (H) *Naja naja* (I) *Boiga trigonata* (J) *Indotyphlops braminus* (K) *Sibynophis Sagittarius* (L) *Python molurus* (M) *Ptyas mucosa* and (N) *Boiga forsteni*

3.6. CHURDHAR WILDLIFE SANCTUARY



FIELD SURVEY

3.5. CHURDHAR WILDLIFE SANCTUARY

We selected different habitats and stream in various areas as the key locations for the amphibians and reptiles survey. Some of the major suspected habitats present in the sanctuary were also used for the survey. After the selection of sites, we used a stratified random sampling approach using both nocturnal and diurnal Visual encounter survey (VES) (Time constrained) (Crump et al., 1994) to know the diversity and distribution of the herpetofauna in the study area. The survey was carried out in July of 2021 and 2022 in Churdhar wildlife sanctuary. The whole sanctuary was surveyed majorly based on 12 VES sites with a total manhour of 41 hours (Figure 3.14). The Frogs were detected by direct sighting or glitters of eyes using a waterproof flashlight. We also collected the samples for rare and hard to identify species on ground for further identification using genetic tools.

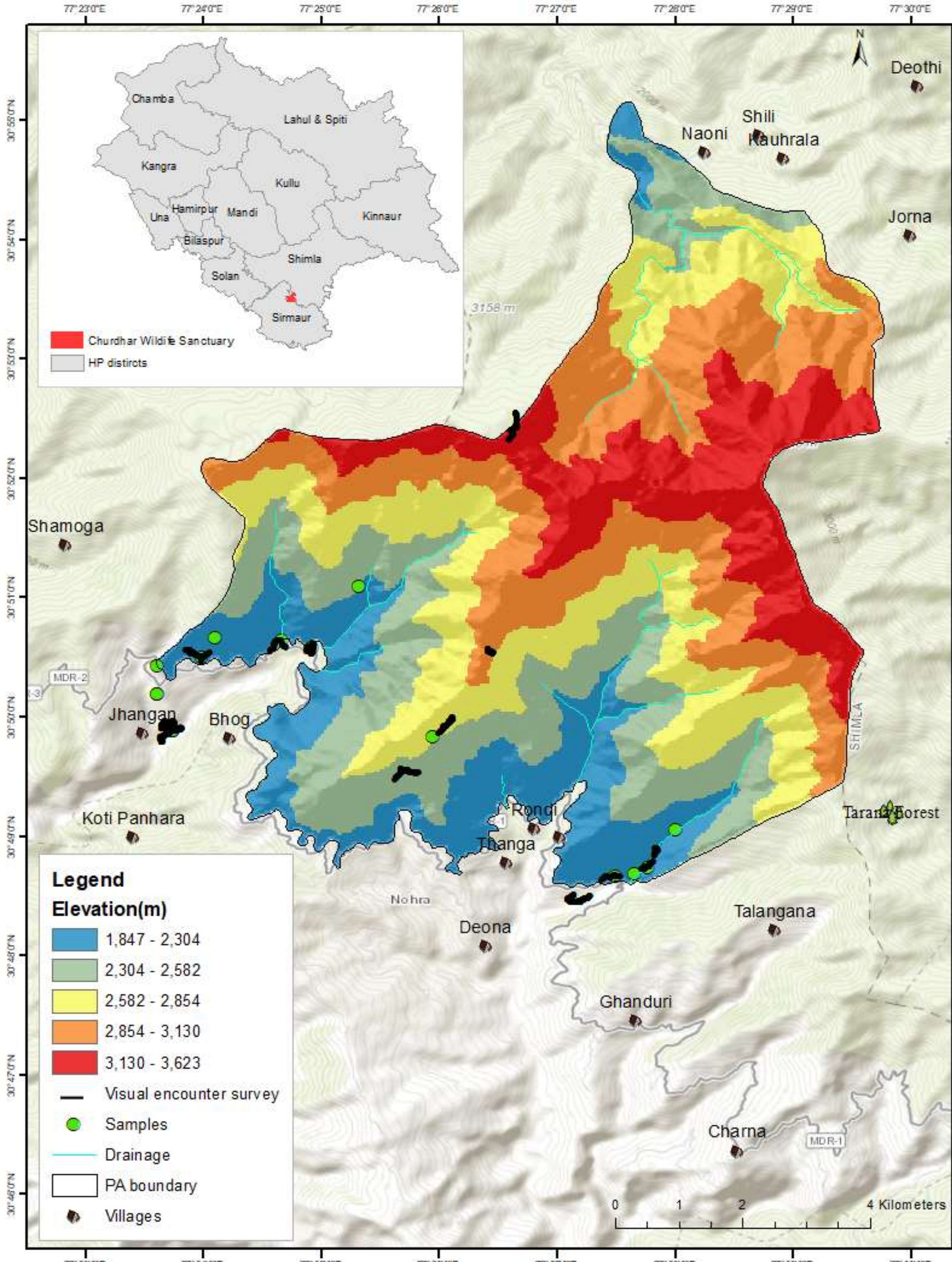


Figure 3.14: Churdhar wildlife sanctuary showing the VES locations and collected sample's location.

3.6.1. DATA ANALYSIS

We prepared a checklist for the species diversity in the study area. The number of species in each group of herpetofauna was noted for VES. Encounter rate for all the species in the park and for the group of herpetofauna was calculated for the park. Species accumulation curve was also prepared to show the adequacy of the sampling effort across the park.

3.6.2. RESULTS

During our survey, we encountered Four species of amphibians (Figure 3.18) and 15 species of reptiles (Figure 3.19) from the sanctuary. The four species of amphibians belonged to 3 genera of 3 families (Table 3.9). The 15 species of reptiles belonged to 14 genera of 5 families. Encounter rate for different groups of herpetofauna from Churdhar Wildlife Sanctuary was also calculated which showed the frogs being the most dominant group and snake being the least (Figure 3.15). The encounter rate for all species from the sanctuary was also calculated to know the most dominant species in the area. The most dominant species of the park was *Nanorana vicina* followed by *Nanorana minica* and the least encountered species was *Ptyas mucosa*, *Eurylepis* sp. and *Daboia russelii* (Figure 3.16). The species accumulation curve for the area was also plotted to show the efficacy of sampling effort in the area (Figure 3.17)

Table 3.9: Checklist of Herpetofauna diversity of Churdhar Wildlife Sanctuary

Reptiles			
S.No.	**Family**	**Genus**	**Species**
1	Viperidae	*Gloydius*	*Gloydius himalayanus*
2		*Trimeresurus*	*Trimeresurus septentrionalis*
3		*Daboia*	*Daboia russelii*
4	Colubridae	*Ptyas*	*Ptyas mucosa*
5		*Herpetoreas*	*Herpetoreas platyceps*
6		*Lycodon*	*Lycodon mackinonni*
7		*Coelognathus*	*Coelognathus radiata*
8		*Elaphe*	*Elaphe hodgsoni*
9	Agamidae	*Laudakia*	*Laudakia tuberculata*
10		*Calotes*	*Calotes versicolor*
11		*Japalura*	*Japalura sp.*
12	Scincidae	*Ablepharus*	*Ablepharus himalayanus*
13			*Ablepharus ladacensis*
14	Gekkonidae	*Eurylepis*	*Eurylepis sp.*
15		*Cyrtopodian*	*Cyrtopodian sp.*
Amphibians			
	Family	**Genera**	**Amphibians**
1	Dicroglossidae	*Nanorana*	*Nanorana (vicina) sp.*
2			*Nanorana (minica) sp.*
3	Ranidae	*Amolops*	*Amolops Formosus*
4	Bufonidae	*Duttaphrynus*	*Duttaphrynus himalayanus*

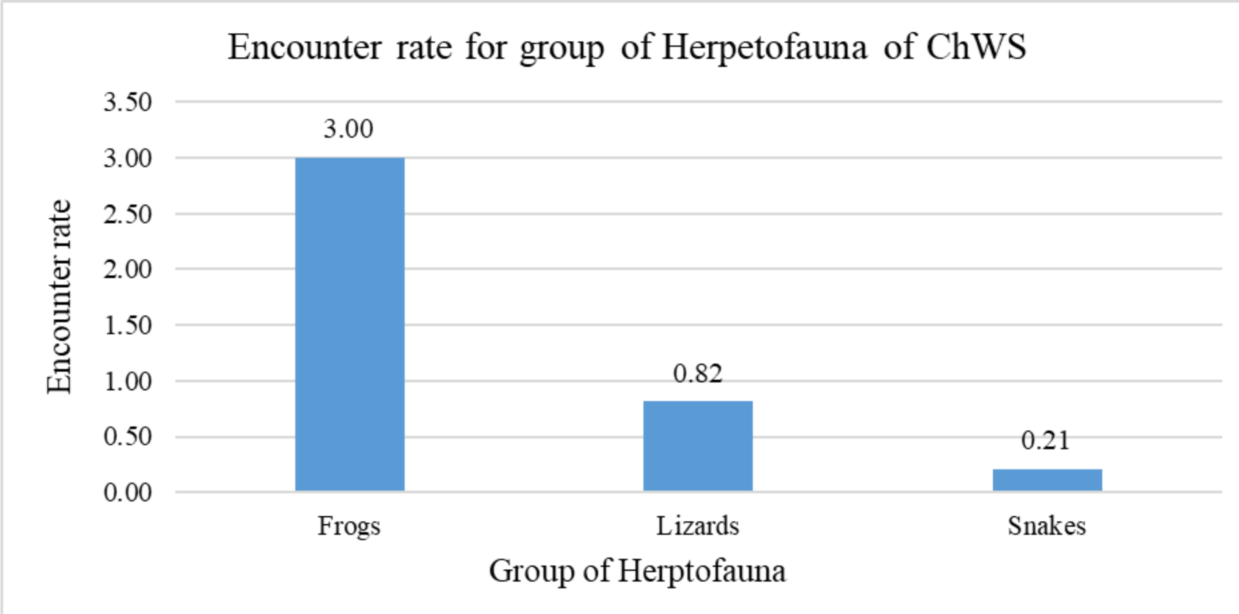


Figure 3.15: Encounter rate of different group of Herpetofauna from Churdhar Wildlife Sanctuary.

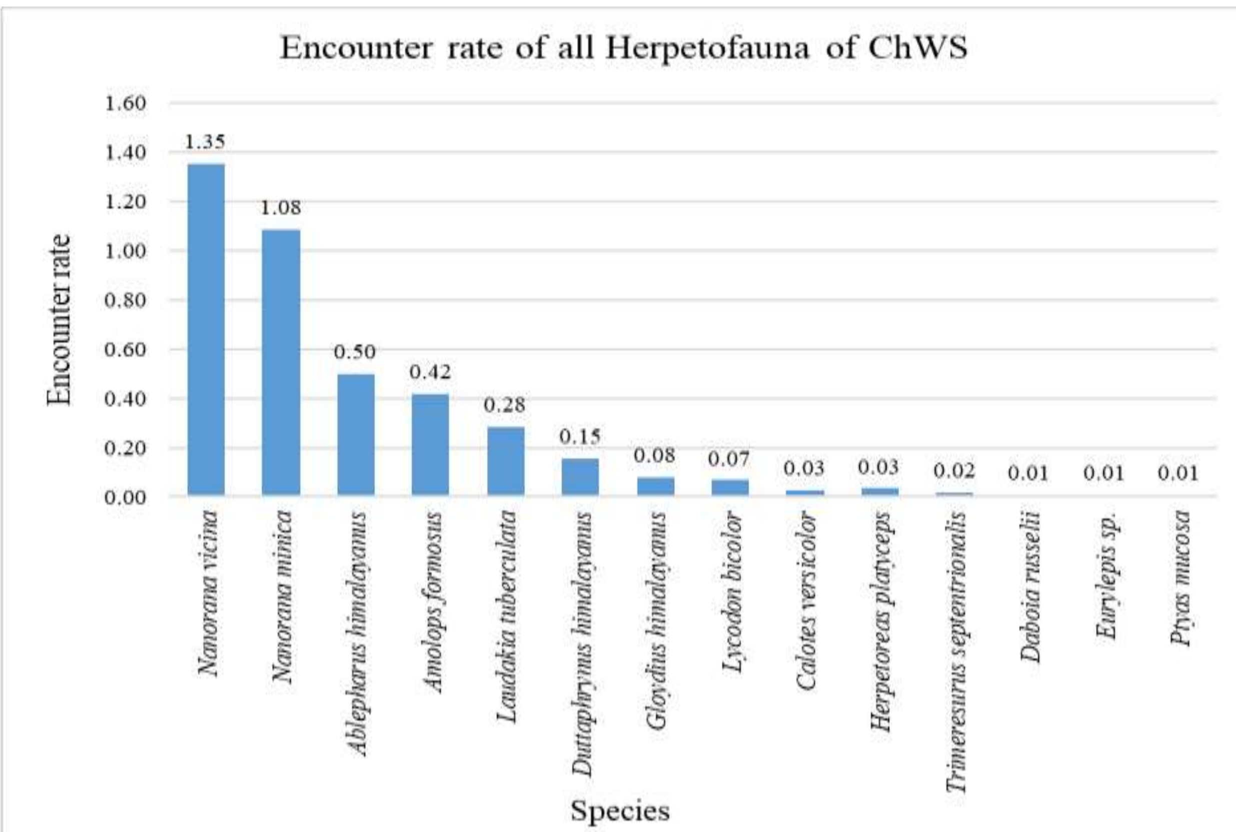


Figure 3.16: Encounter rate of all species of Herpetofauna from Churdhar Wildlife Sanctuary.

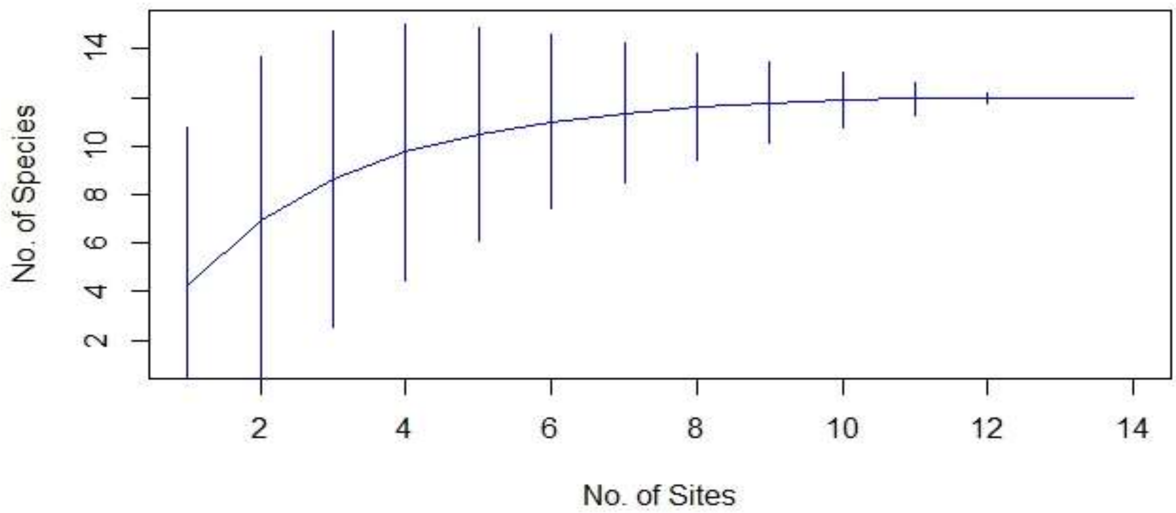


Figure 3.17: Species accumulation curve for sampling efficiency in Churdhar Wildlife Sanctuary.

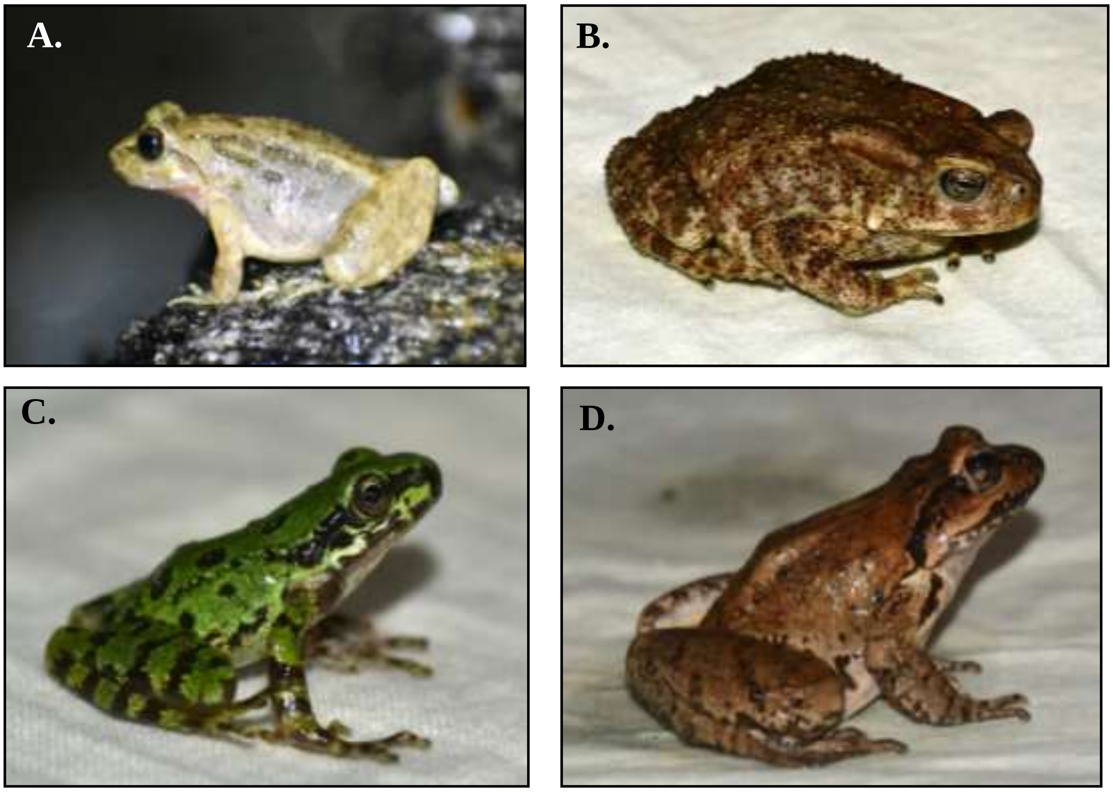
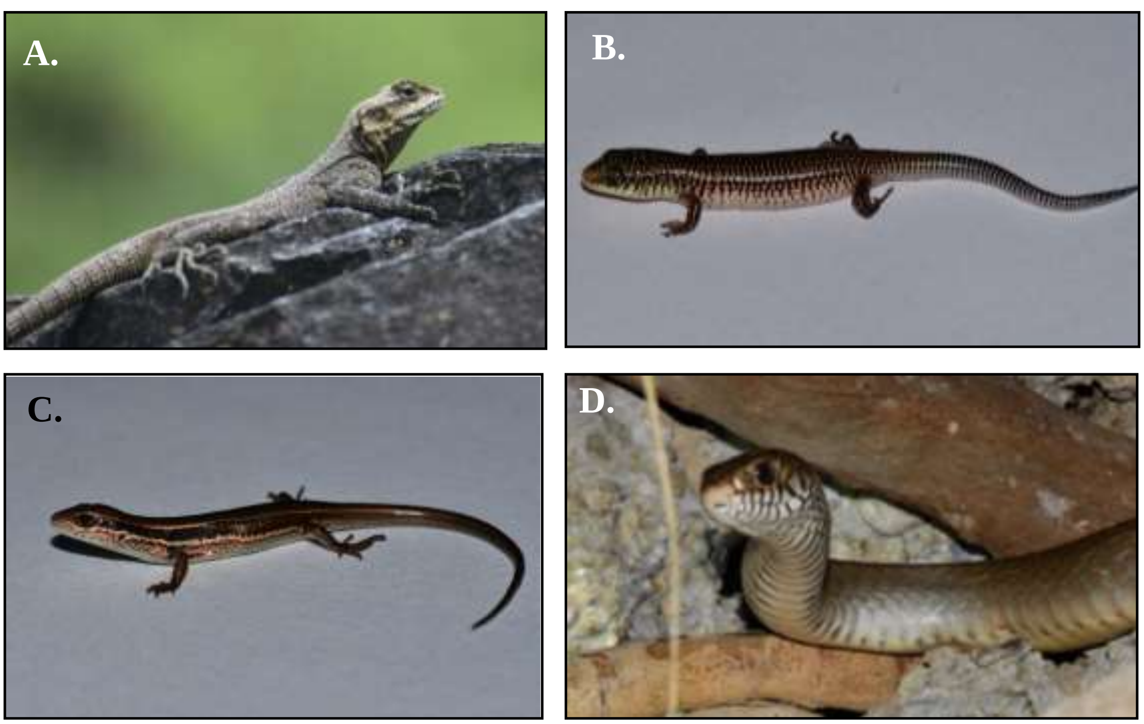


Figure 3.18: Anurans encountered from Churdhar Wildlife Sanctuary (A) *Nanorana minica*, (B) *Duttaphrynus himalayanus*, (C) *Amolops formosus*, and (D) *Nanorana vicina.*



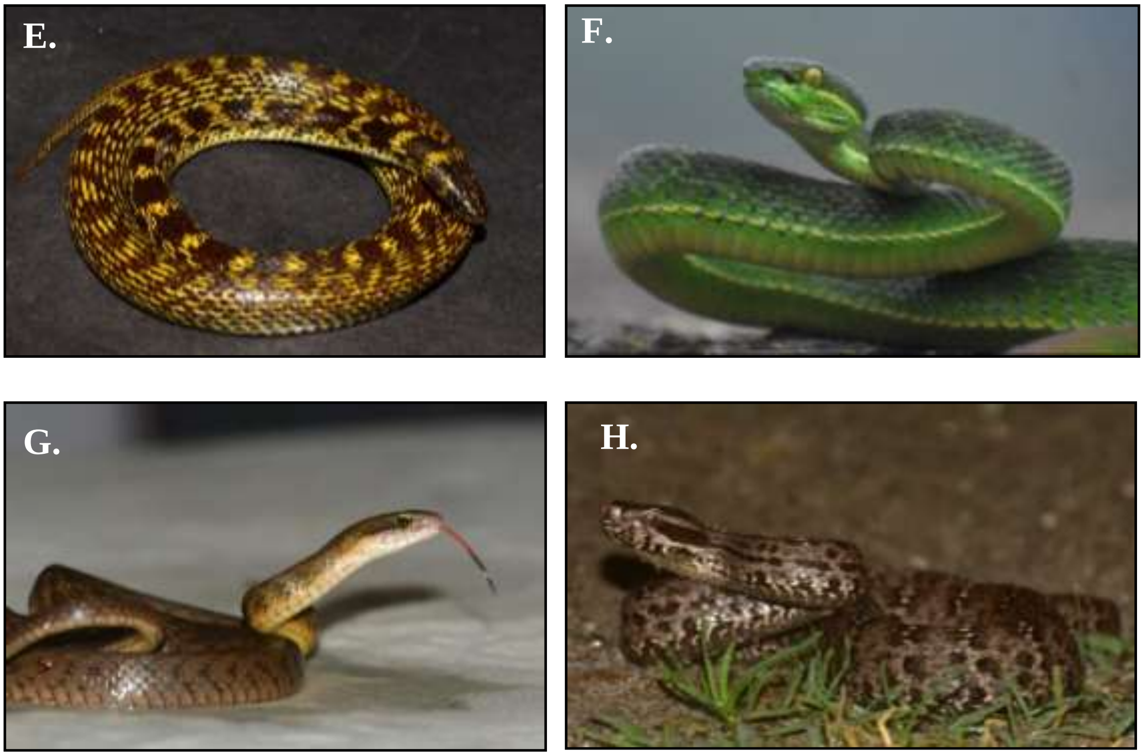
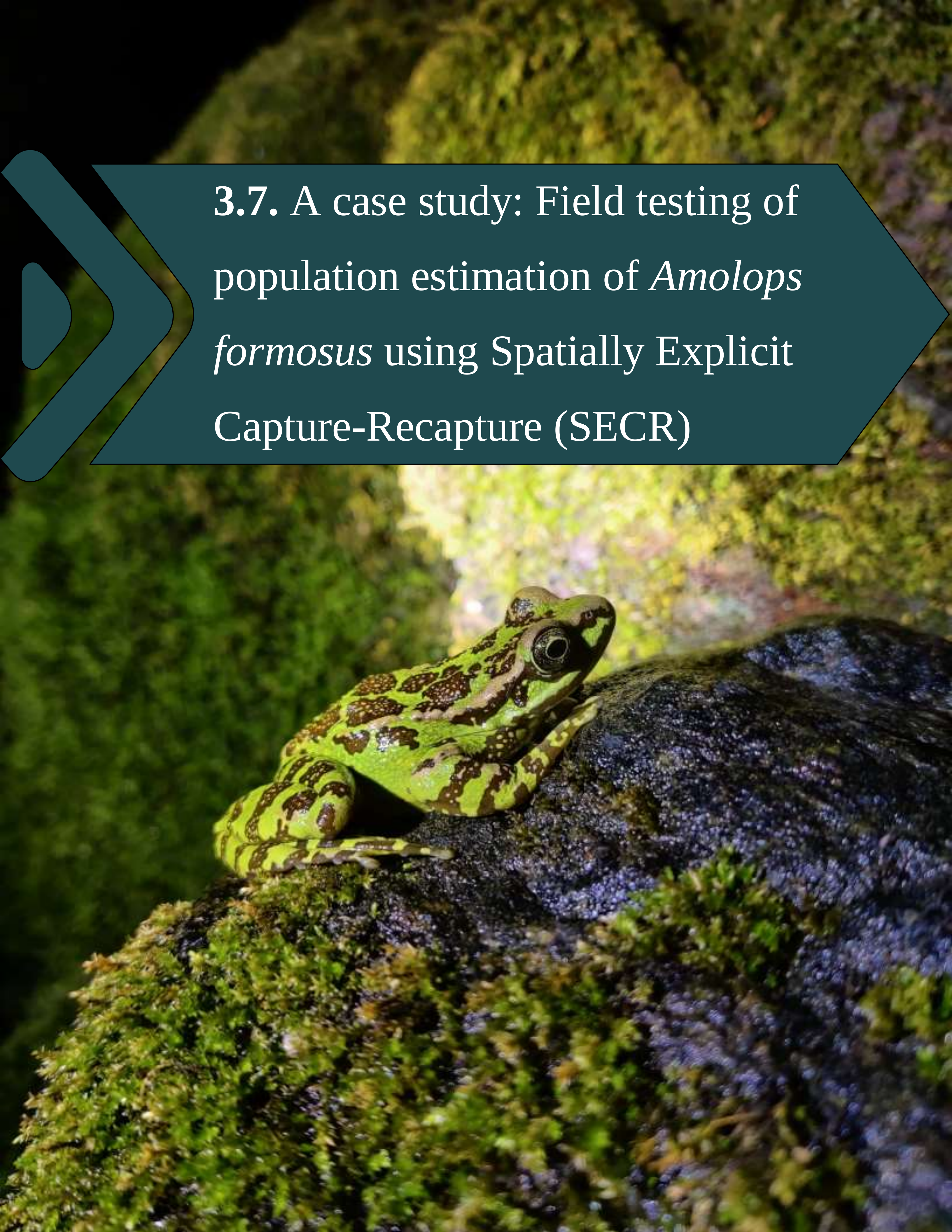


Figure 3.19: Some reptiles encountered from Churdhar Wildlife Sanctuary (A) *Laudakia tuberculate*, (B) *Eurylepis* sp., (C) *Ablepharus ladacensis*, (D) *Ptyas mucosa*, (E) *Lycodon mackinnoni*, (F) *Trimeresurus septentrionalis*, (G) *Herpetoreas platyceps* and (H) *Gloydius himalayanus.*

3.7. A case study: Field testing of population estimation of *Amolops formosus* using Spatially Explicit Capture-Recapture (SECR)



- ❖ A case study for population estimation of a rare endemic frog (*Amolops formosus*) based on spatially explicit capture recapture approach in Churdhar wildlife sanctuary.

3.7.1. FIELD SURVEY:

We used Nocturnal Visual Encounter Surveys (NVES) from 20:00 to 00:00 h to identify these streams initially (Heyer et al., 1993). We then selected four major streams for sampling, but due to the absence of the target species in some, only two streams CBS and KBS were surveyed for 12 days alternatively from 13 June 2022 to 25 June 2022. Belt transects of 30 x 400 m were laid in the sampling streams and replicated 6 times (Figure 3.20). Both locations were 20 km apart and had an elevation range of 1900m to 2000m for our sampling belt. Each belt was divided into 8 patches of 30 x 50m for spatially explicit capture-recapture and movement of the species. So, the two streams were sampled in a total of 16 patches to see the maximum movement of the individuals. The species was observed up to 5 m above the water level. The photographs were further used for abundance and density estimation. Frogs were detected using a flashlight. For all encountered frogs, we photographed the dorsal side of the individual using Nikon D3400 with 70-300mm lens without physically disturbing the individual. Each individual was photographed each time it was encountered during the six replicates to know the abundance and density estimation of the species. Individuals were manually identified based on these distinct dorsal patterns for further analysis (Figure 3.21). Six water parameters temperature, pH, salinity, TDS (Total dissolved solids), ORP (oxidation-reduction potential) and conductivity were collected using Aquasol AM-AL-01 Multiparameter Handheld Meter. The seventh parameter the flow of water was recorded using the Geopacks MFP126-S Advanced Stream Flowmeter. All seven water covariates were also recorded while photographing the individuals in each sampling patch. These parameters were further used for the abundance estimation of the species.

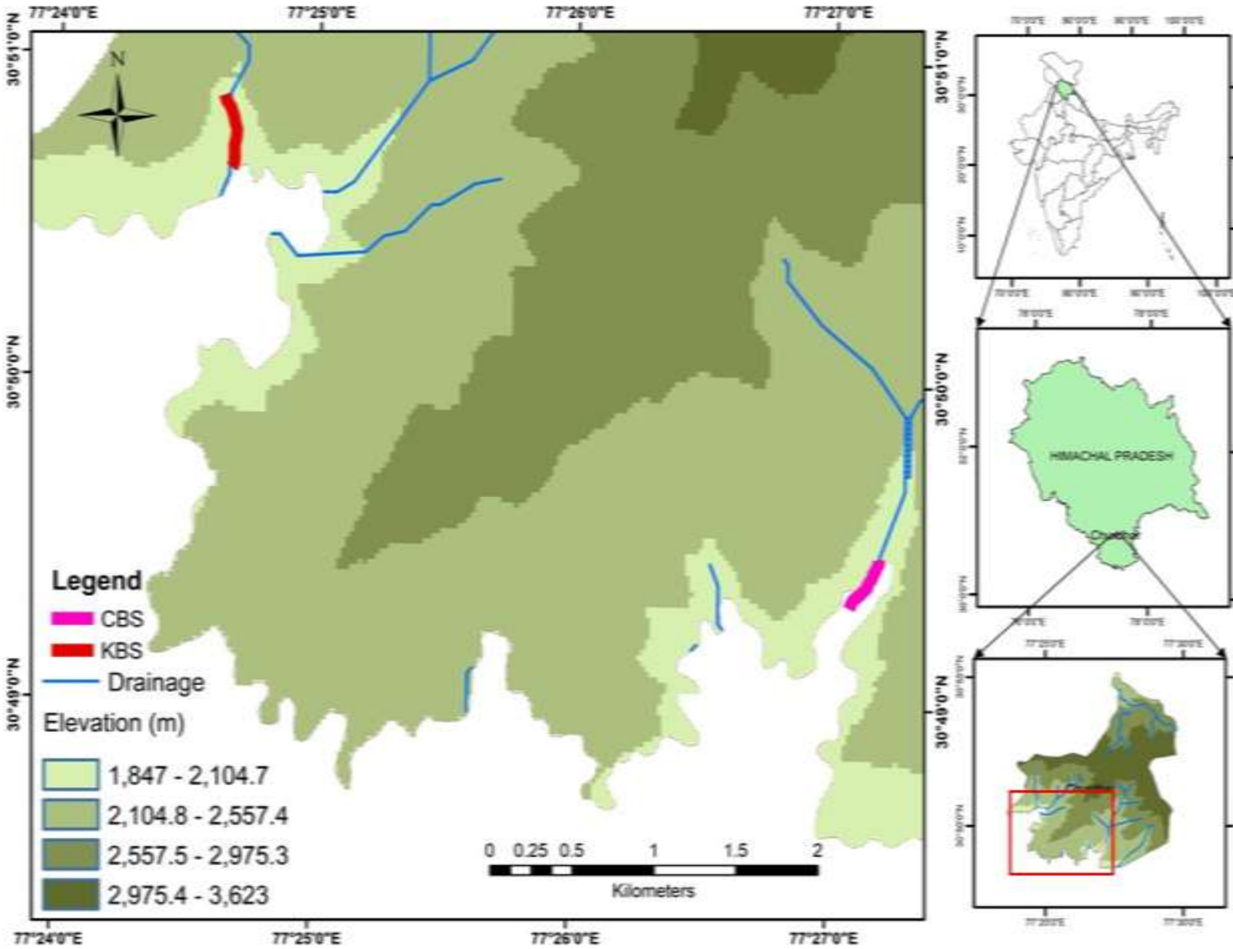


Figure 3.20: Churdhar Wildlife Sanctuary (ChWS) shows the major streams and two sampling location Chauras Beat Stream (CBS) and Kanda Beat Stream (KBS).

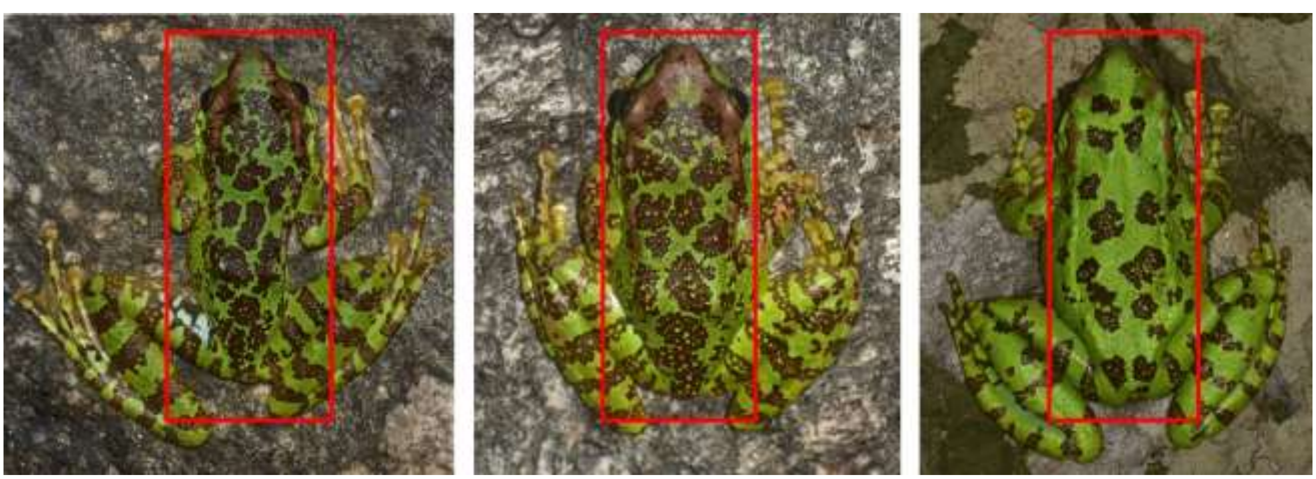


Figure 3.21: The distinct dorsal pattern in *Amolops formosus* used for individual identification.

3.7.2. ABUNDANCE

We used the N-mixture model (Royle, 2004) of the “unmarked” package (Fisk and Chandler, 2011) to estimate the abundance of the species and its association with the site-specific covariates. N-mixture works on the repeated count data and hierarchical model approach to estimate the abundance of the species in the sampling sites. The models were fitted using the maximum likelihood methods. From the count data of our NVES, a matrix containing the number of encounters per event on each site was generated to estimate abundance. The pcount function in the "unmarked" package was used to characterize N-mixture models by setting the mixture to Poisson distribution. As the mean and variance of the data had relatively little volatility, the Poisson distribution "P" was employed. We modelled abundance using seven water covariates viz: temperature, salinity, pH, conductivity, TDS, ORP and flow of water. All seven covariates were used as the abundance component for the N-mixture model and the flow of water was also used as a detection component for all supported models. An automated model selection in the MuMIn package (Barton, 2015) was used to generate sets of abundance models. We fitted 128 models using the predicted covariates and the best models were selected based on the AICc (Akaike information criterion) value. As our sample size was small, we used the model's AICc score, as the lower-case 'c' signifies that the value was computed from the AIC test corrected for small sample size. Models with the smallest AICc value and highest Akaike weight were considered to be the best models (Burnham and Anderson, 1998).

3.7.3. DENSITY

We estimated the density of *Amolops formosus* in two different streams CBS and KBS. In order to ensure that all individuals were adequately represented in the sampling process, a 200 m buffer was implemented around the sampling region. When a species is confined to a linear habitat, Secrlinear approach is employed. On the other hand, if the species exhibits a more widespread distribution across the study area, the SECR approach is recommended. By tailoring the choice of analytical approach to the ecological characteristics of the species under investigation, we can enhance the precision and reliability of their findings in the study. In our research, we employed both the SECR and Secrlinear methodologies to derive density estimates for the target species. This approach was chosen due to the lack of scientific consensus regarding the movement patterns of the species, as it has not been definitively established whether their distribution is exclusively limited to streams. By utilizing SECR, we were able to predict the species density in terms of area, whereas the secrlinear method allowed us to estimate density relative to the length of the habitat. The density estimation of the species was carried out using “SECR” (Efford, 2023) and “secrlinear” packages (Efford, 2023).

The spatial region in SECR was established using the values of σ obtained from preliminary analysis. In this regard, the buffer surrounding the sampling patch was determined based on a distance that was at least six times the initial σ parameter. The poisson distribution and half-normal detection function were used for fitting beta parameters and the variance-covariance matrix of beta parameters. The "SECR" function is utilized to estimate the density and spatial extent of animal populations that are distributed in a spatial manner. This estimation is based on data obtained from an array of passive detectors, which can be in the form of polygons or transects. In SECR, models are fitted by optimizing the estimation of parameters through the maximization of either the complete likelihood or the conditional likelihood on the observed number of individuals (n). Density estimates (D), detection functions (g0), and home range indices (σ) were derived for the target species within each sampling site. Three detection functions, namely half-normal (HN), negative exponential (EX), and hazard rate (HR), were employed for model selection in order to identify the most suitable initial model.

Other than SECR, another approach of Secrlinear (Efford, 2023) was employed to express the species' density as a quantity per unit length (animals per kilometer) rather than per unit area (animals per hectare). The spatially explicit model was used in Secrlinear for *A. formosus* in three ways (i) excluding the habitat linearity (fit2-DEuc), (ii) Using the default Euclidean distance model with a linear habitat map (fit1-DEuc), or 2 (iii) with the inclusion of both a linear habitat map and apposite non-Euclidean distance function. (fit1-DNet). The buffer area mask for the (fit2-DEuc) and linear mask for (fit1-DNet) were prepared to see the species movement and sampling patches (Figure 3.22).

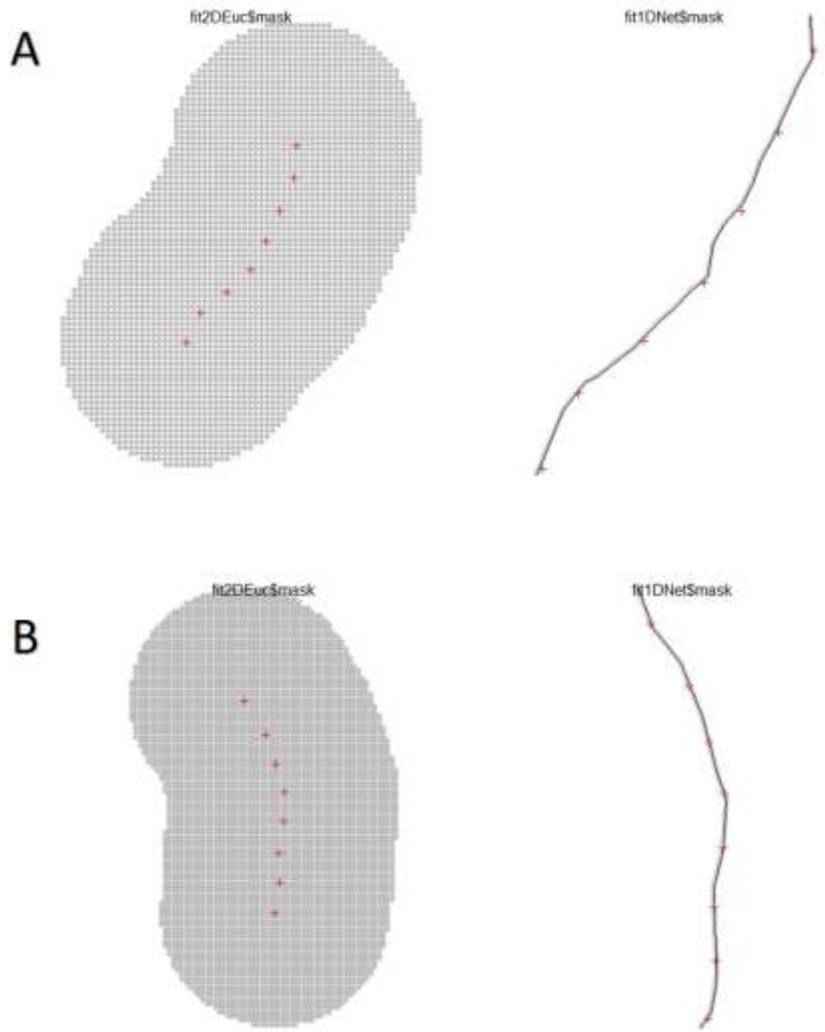


Figure 3.22: Fitted 200 m buffer mask and linear mask to the linear habitat with sampling location in Chauras beat stream (CBS); B) Fitted 200 m buffer mask and linear mask to the linear habitat with sampling location in Kanda beat stream (KBS).

3.7.4. RESULTS:

During our survey, we captured 161 photographs of *Amolops formosus* in six replicates of each site. We identified 51 different individuals of *Amolops formosus* in 48 manhours. Of these 23 were encountered in CBS and 28 were encountered in KBS. In CBS we recorded 2, 14, 9, 3, 1 and 8 individuals on the first, second, third, fourth, fifth and sixth occasions respectively. Of the 23 individuals; 14 individuals were captured only one time, five individuals were captured two times, three individuals were captured three times and one individual was captured four times. In KBS we recorded 3, 4, 4, 6, 6 and 23 individuals on the first, second, third, fourth, fifth and sixth occasions respectively. Of the 28 individuals; 20 individuals were captured only one time, two individuals were captured two times, three individuals were captured three times, two individuals were captured four times and one individual was captured five times. The minimum average movement of *Amolops formosus* was 57.14 ± 7.14m and 75 ± 11.18m in the CBS and KBS respectively. All water parameters are recorded in each patch during every replicate. The range of different water parameters is recorded during the survey time. The range of recorded parameters was conductivity (33.1 to 45.8 µS), TDS (22.3 to 30.4 ppm), Salinity (11.5 to 16.4 ppm), pH (8.27 to 8.76), ORP (-96.7 to -71.1 mV), temperature (12.1 to 16.5 ^{0}C) and flow (1.34 to 2.4 m/s) in our study site.

3.7.5. RELATIVE ABUNDANCE

The average abundance estimation was calculated using the null model with no detection covariate and flow as detection covariate. The AIC value of the null model without detection covariate was 252.92 and with the flow as detection covariate was 244.53 (ΔAIC 8.39) showing better fits with flow as detection covariate. Furthermore, when comparing the global model with and without flow as a detection covariate (AIC values 255.48 and 254.89 respectively), it was observed that the model fit was lower in both cases compared to the null model. In global model, flow as a detection covariate didn’t show any statistically significant relation. Therefore, several models were fitted using the seven covariates as abundance components only and top models were employed based on AICc values. The flow was found to be the top model as the other models all add a parameter to the top model, which improves the fit (logLik increases), but not enough to overcome the 2-unit ΔAICc penalty for having an additional parameter (Leroux 2019). Of all these covariates only the flow of water showed a statistically significant negative correlation (-0.39 ± 0.14) with the abundance of the species stating flow to be the main factor for the distribution of the species. The abundance estimation for 16 sample sites was predicted based on the top model (Figure 3.23).

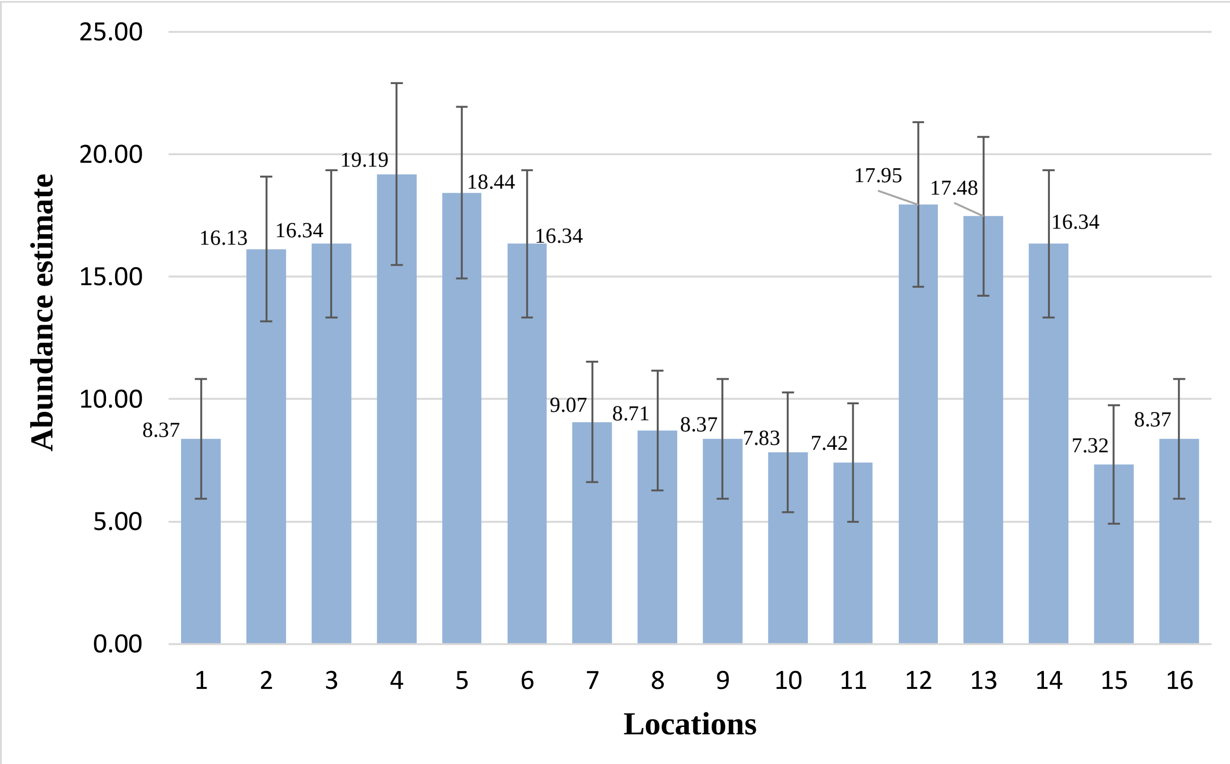


Figure 3.23: Predicted abundance estimate with standard error of *Amolops formosus* in 16 survey sites of Churdhar wildlife sanctuary (ChWS) using the top model.

3.7.6. DENSITY SECR:

The movement of the individuals in the stream can be shown using the detection probability of the species to the distance covered. We determine the maximum dispersal of any individual in the stream during our sampling time by looking at the movement of the majority of individuals in CBS (<110m) and KBS (<140m) (Figure 3.24).

The estimated density with fitted parameters evaluated at base levels of covariates was 5.68 ± 1.87 individuals per hectare, with 3.02 - 10.67 individuals per hectare (95% CI) in CBS and 5.33 ± 1.52 individuals per hectare, with 3.07 – 9.26 individuals per hectare (95% CI) in KBS. Subsequently, the data were subjected to analysis using three distinct models: the half-normal (HN), negative exponential (EX), and hazard rate (HR) models. Based on the AIC values, HN and EX model exhibited the superior fit for the density estimation of the species in CBS and KBS respectively (Table 3.10).

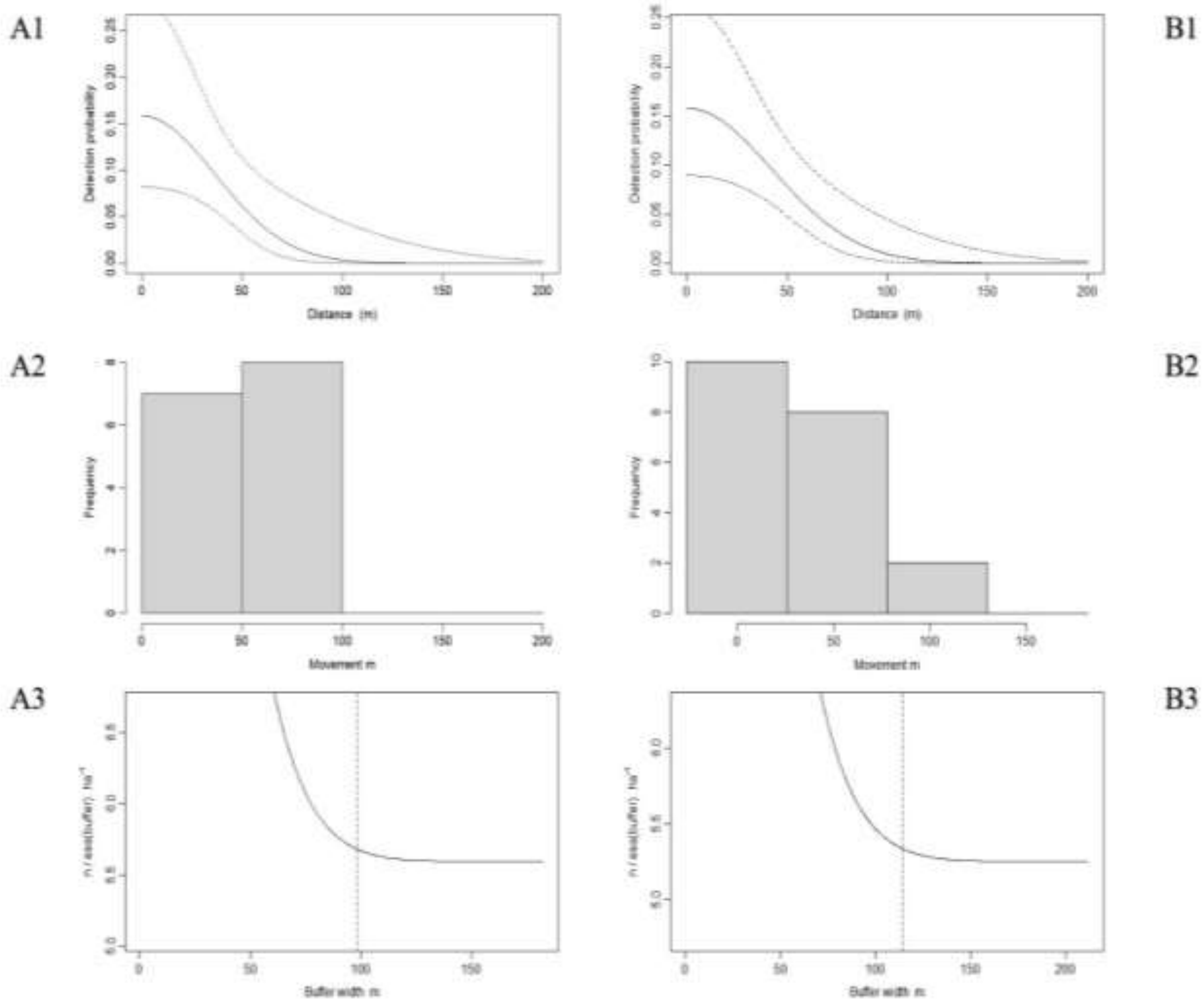


Figure 3.24: A1 & B1) Detection probability curves for *Amolops formosus* related to distance in Chauras beat stream (CBS) and Kanda beat stream (KBS) respectively; A2 & B2) *Amolops formosus* frequency of distance moved in metres in CBS and KBS respectively; A3 &B3) Effective sampling area as a function of increasing buffer width (m) (red line indicates buffer distance used) in CBS and KBS respectively.

We plotted the three models with the increase in the buffer. Density estimations derived from HN exhibit a relatively quick attainment of a plateau as the buffer width increases, whereas both HR and EX do not demonstrate such behaviour in both CBS and KBS (Fig 6). This indicates that density estimates remain susceptible to variations in buffer width even at considerable distances. So, we moved forward with HN in both CBS and KBS as the best model for density estimation. The estimated density of *A. formosus* using the HN was 5.58 ± 1.95 individuals per hectare, with 2.86 - 10.86 individuals per hectare (95% CI) in CBS and 5.11 ± 1.61 individuals per hectare, with 2.79 - 9.34 individuals per hectare (95% CI) in KBS (Table 3.11).

3.7.7. DENSITY SECRLINEAR:

The predicted linear density estimate of CBS was 90.5 ± 21.9 individuals per km and of KBS was 87.53 ± 19.02 individuals per km. The estimated density using the 2-dimensional mask Euclidean distances was 4.81 ± 1.70 and 5.04 ± 1.60 individuals per hectare for CBS and KBS respectively (Table 3.12). The 1-D Euclidean function was not utilized in this instance, as its impact was found to be minimal due to the unbranched and nearly straight nature of the stream. The derived function was used for 1-DNet and 2-DEuc model was used for further density estimation. The derived density estimates for *Amolops formosus* along the 2-DEuc was 4.82 ± 1.65 and 5.04 ± 1.57 individuals per hectare for CBS and KBS respectively. The derived density estimate for the 1-DNet was 90.51 ± 21.68 and 87.54 ± 18.81 individuals per km for CBS and KBS respectively. The CVa value was much lower for the 1-D model than the 2-D model for both sites which helps us in improving the precision of the density estimate. (Table 3.13).

Table 3.10: Model selection in Spatially explicit capture-recapture (SECR) based on three detection functions Half normal (HN), Negative exponential (EX) and hazard rate (HR) based on their AICc value in Chauras beat stream (CBS) and Kanda beat stream (KBS). HN was the best fit based on ΔAICc and weight for CBS. HN and EX were a close fit based on ΔAICc and weight for KBS but HN was selected as a better fit as HN only reach a plateau fairly promptly with increasing buffer width but not EX.

CBS						
Model	**Detection function**	**npar**	**logLik**	**AICc**	**ΔAICc**	**Weight**
D~1 g0~1 sigma~1	halfnormal	3	-39.41	86.09	0	0.59
D~1 g0~1 sigma~1	exponential	3	-40.51	88.28	2.18	0.20
D~1 g0~1 sigma~1 z~1	hazard rate	4	-39.04	88.30	2.21	0.19

KBS						
Model	**Detection function**	**npar**	**logLik**	**AICc**	**ΔAICc**	**Weight**
D~1 g0~1 sigma~1	exponential	3	-52.76	112.53	0	0.43
D~1 g0~1 sigma~1	halfnormal	3	-52.76	112.53	0.008	0.42
D~1 g0~1 sigma~1 z~1	hazard rate	4	-52.48	114.69	2.16	0.14

Table 3.11: Density estimate (D) per hectare, detectability (g0) and home range (sigma) with standard error (SE) of *Amolops formosus* using halfnormal detection function in Spatially explicit capture-recapture (SECR) for the Chauras beat stream (CBS) and Kanda beat stream (KBS)

CBS					
	link	**estimate**	**SE**	**LCL**	**UCL**
D	log	5.58	1.95	2.86	10.87
g0	logit	0.16	0.05	0.08	0.28
sigma	log	36.33	7.01	24.98	52.83
KBS					
	link	**estimate**	**SE**	**LCL**	**UCL**
D	log	5.11	1.61	2.80	9.34
g0	logit	0.16	0.04	0.09	0.26
sigma	log	42.99	7.47	30.66	60.29

Table 3.12: Predicted density estimate (D) in secrlinear with detectability (g) and home ranges (sigma) with standard error (SE) of *Amolops formosus* in CBS (Chauras beat stream) and KBS (Kanda beat stream) based on ignoring the linearity of the habitat (fit2-DEuc), with a linear habitat map and the default Euclidean distance model (fit1-DEuc), with both linear habitat and an appropriate non-Euclidean distance function (fit1-DNet).

For CBS					
	link	**estimate**	**SE**	**LCL**	**UCL**
predict(fit2-DEuc)					
D/ha	log	4.81	1.70	2.46	9.43
g0	logit	0.19	0.06	0.09	0.34
sigma	log	37.26	7.44	25.29	54.89
predict(fit1-DEuc)					
D/km	log	90.67	22.07	56.66	145.09
g0	logit	0.11	0.03	0.06	0.19
sigma	log	39.88	8.18	26.79	59.36
predict(fit1-DNet)					
D/km	log	90.51	21.99	56.60	144.71
g0	logit	0.11	0.03	0.06	0.19
sigma	log	38.99	7.93	26.28	57.85
For KBS					
	link	**estimate**	**SE**	**LCL**	**UCL**
predict(fit2-DEuc)					
D/ha	log	5.04	1.60032	2.7481	9.25
g0	logit	0.21	0.06	0.12	0.36
sigma	log	38.96	6.99	27.48	55.24
predict(fit1-DEuc)					
D/km	log	87.55	19.03	57.46	133.38
g0	logit	0.13	0.03	0.08	0.21
sigma	log	38.73	6.80	27.52	54.51
predict(fit1-DNet)					

D/km	log	87.54	19.02	57.46	133.35
g0	logit	0.13	0.03	0.076	0.20
sigma	log	39.25	6.92	27.86	55.30

Table 3.13: Derived density estimates of *Amolops* formosus in secrlinear with standard error (SE) along the fit2-DEuc (ignoring the linearity of the habitat) and fit1-DNet (both linear habitat and an appropriate non-Euclidean distance function) in both Chauras beat stream (CBS) and Kanda beat stream (KBS).

CBS					
	Estimate	**SE**	**LCL**	**UCL**	**CVa**
derived(fit2-DEuc)					
Effective sampling area	4.78	NA	NA	NA	NA
D/ha	4.81	1.65	2.51	9.25	0.27
derived(fit1-DNet)					
Effective linear extent	0.25	NA	NA	NA	NA
D/km	90.51	21.68	56.97	143.8	0.12
KBS					
	Estimate	**SE.**	**LCL**	**UCL**	**CVa**
derived(fit2-DEuc)					
Effective sampling area	5.55	NA	NA	NA	NA
D/ha	5.04	1.56	2.79	9.13	0.24
derived(fit1-DNet)					
Effective linear extent	0.32	NA	NA	NA	NA
D/km	87.53	18.81	57.73	132.7	0.10

3.8. PIN VALLEY NATIONAL PARK (SPITI REGION)

3.8.1. FIELD SURVEY

We selected different habitats and stream in various areas as the key locations for the amphibians and reptiles survey. We selected various shrub communities and different habitat types to know about the diversity and distribution of Herpetofauna in Spiti region. After the selection of sites, we used a stratified random sampling approach using both nocturnal and diurnal Visual encounter survey (VES) (Time constrained) (Crump et al., 1994) to know the diversity and distribution of the herpetofauna in the study area. We also moved forward with the opportunistic encounter for the reptile survey. The survey was carried out in Pin Valley National Park, Chandratal Wildlife Sanctuary and most of the Spiti region key locations during August-September 2021 and November-December 2022 (Figure 3.25) using the major VES sampling sites.

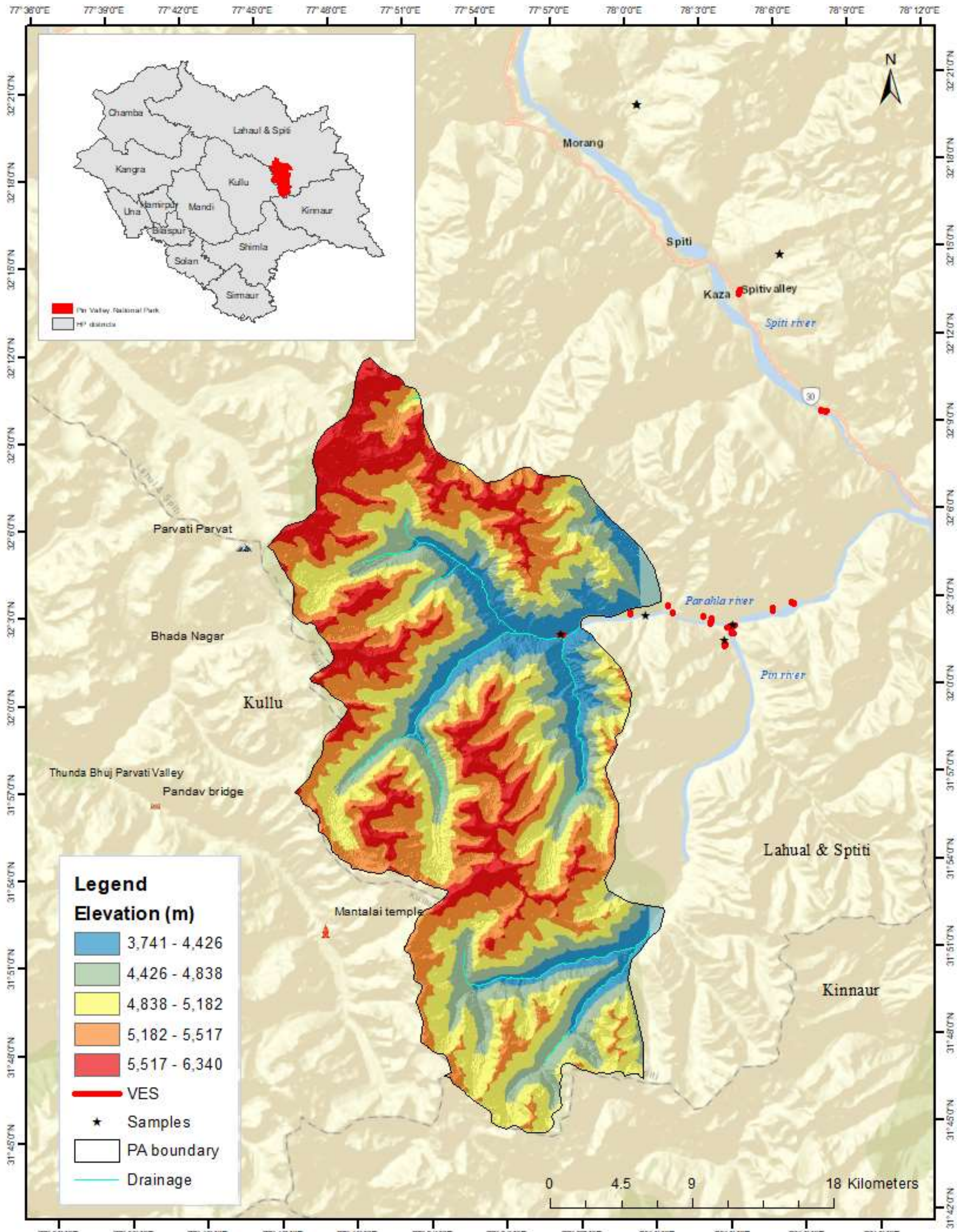


Figure 3.25: Spiti valley region showing the VES sites and the sample collection sites.

3.8.2. RESULTS

During our survey we only encountered two species of Herpetofauna from the region. One amphibian namely *Bufotes latastii* and one reptile namely *Ablepharus ladacensis* (Figure 3.26). Encounter rate for all species from sanctuary was also calculated to know the most dominant species of the area (Figure 3.27). There was no herpetofauna encountered from the Chandratal Wildlife Sanctuary. The interaction with the locals facilitated the presence of three additional herpetofauna species within the region. These species include the racer snake (*Coluber* sp.), the Himalayan pit viper (*Gloydius himalayanus*), and the Kashmir rock agama (*Laudakia tuberculata*).

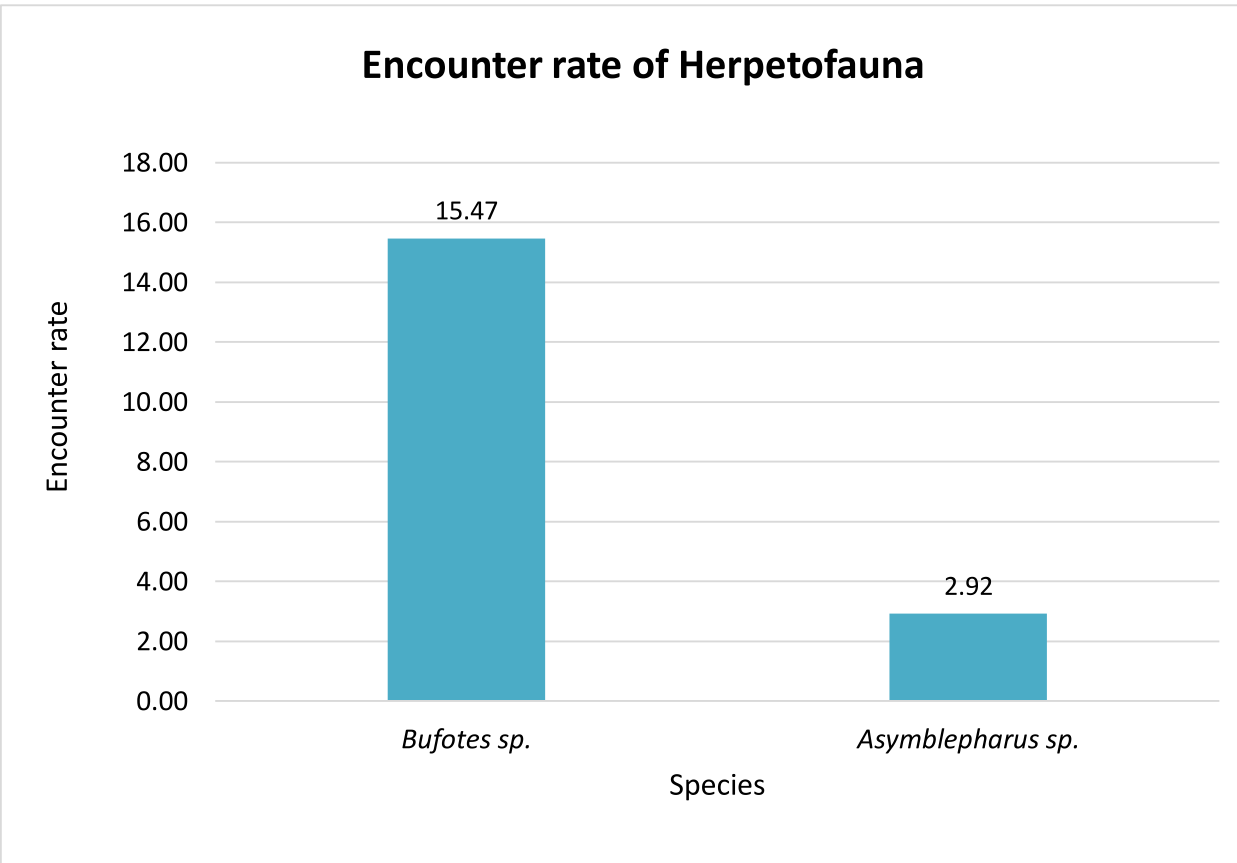


Figure 3.26: Encounter rate of Herpetofauna from Spiti region.

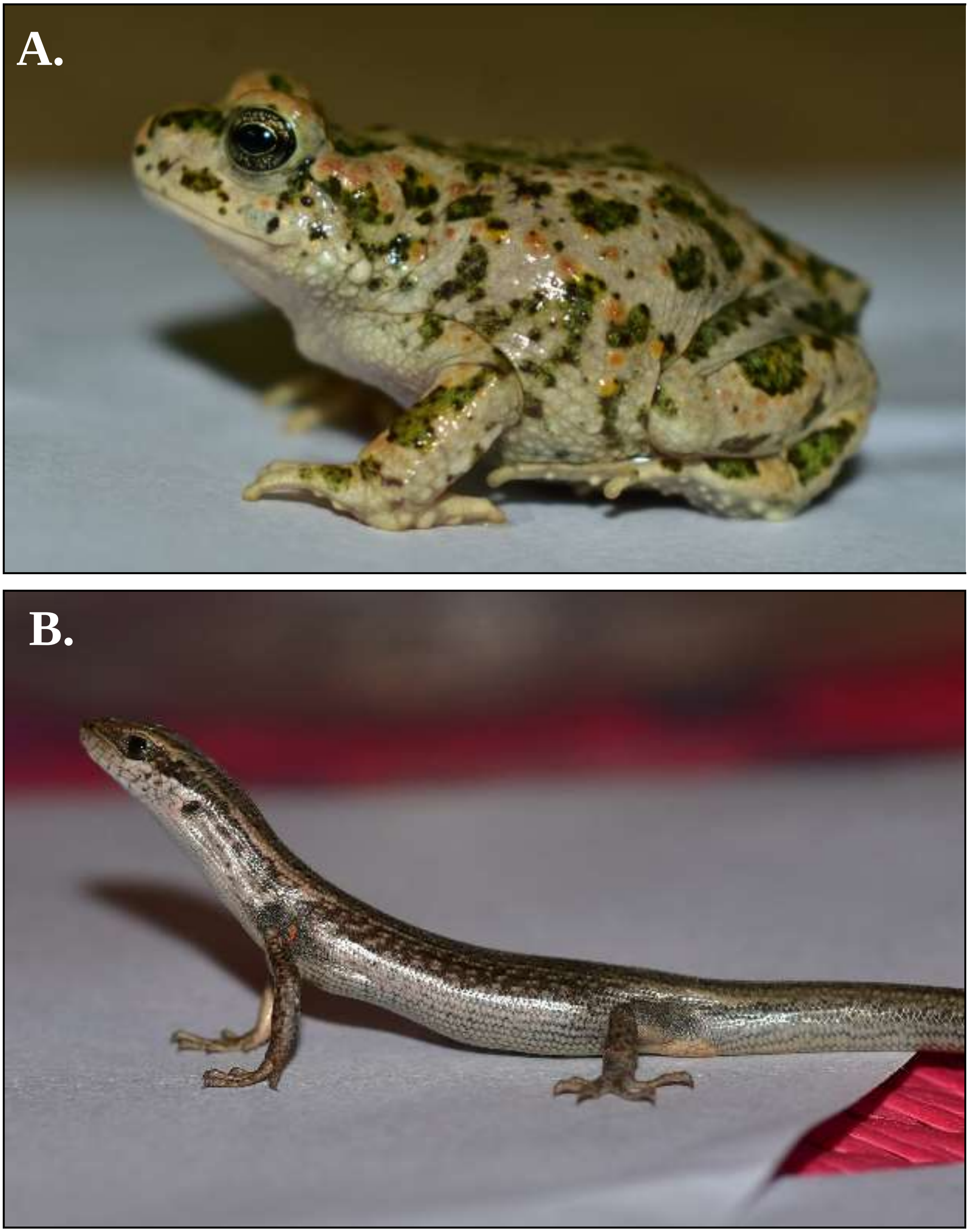


Figure 3.27: Herpetofauna of Spiti valley (A) *Bufotes Latastii* and (B) *Ablepharus ladacensis*

3.9. ALTITUDINAL VARIATIONS

3.9.1. RESULTS

In our study, we examined the diversity of herpetofauna across distinct altitudinal gradients in Himachal Pradesh. At lower elevations, we documented a total of 29 herpetofauna species, belonging to 25 genera and 13 families. Moving to middle elevations, we encountered 15 species from 13 genera and seven families (Figure 3.27). As we ascended to higher elevations, our observations yielded only two species, representing two genera and two families. The results consistently revealed a gradual decline in herpetofauna species encounters with increasing elevation gradient across the state. In the lower elevation regions, we encountered 29 species, with 11 species being unique to this habitat. In the mid-elevation range, we recorded 15 herpetofauna species, of which nine were unique to this particular landscape. At higher elevations, both encountered species were unique to the distinct climate and landscape characteristics found in that zone (Figure 3.28). Additionally, our comprehensive assessment of species composition throughout the entire state indicated that 25.58% of the total encountered species were endemic to the western Himalayas. To visually depict our findings, we generated a bar graph illustrating the distribution of different amphibians and reptiles along the various elevation gradients based on our observations (Figure 3.29 and 3.30). In conclusion, our study contributes valuable insights into the altitudinal patterns of herpetofauna diversity in Himachal Pradesh and emphasizes the importance of preserving the distinct and regionally adapted species within the western Himalayas.

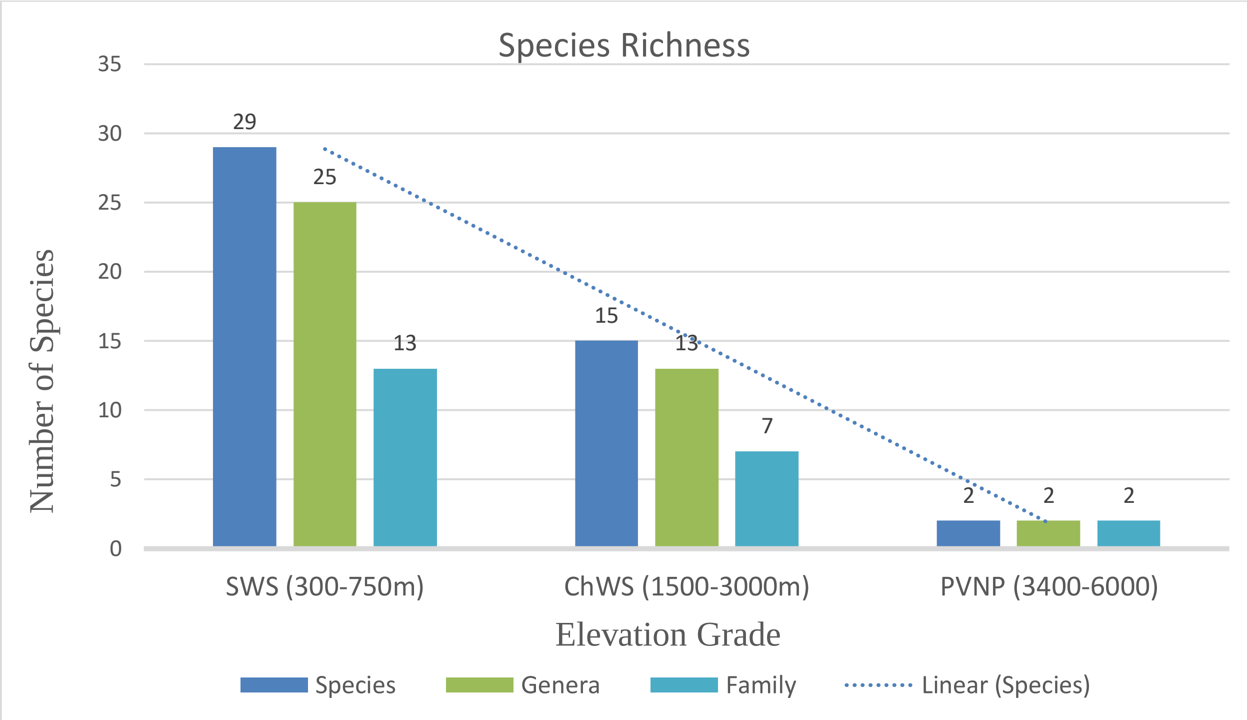


Figure 3.28: Showing the monotonous decrease in the species richness as the altitude increases

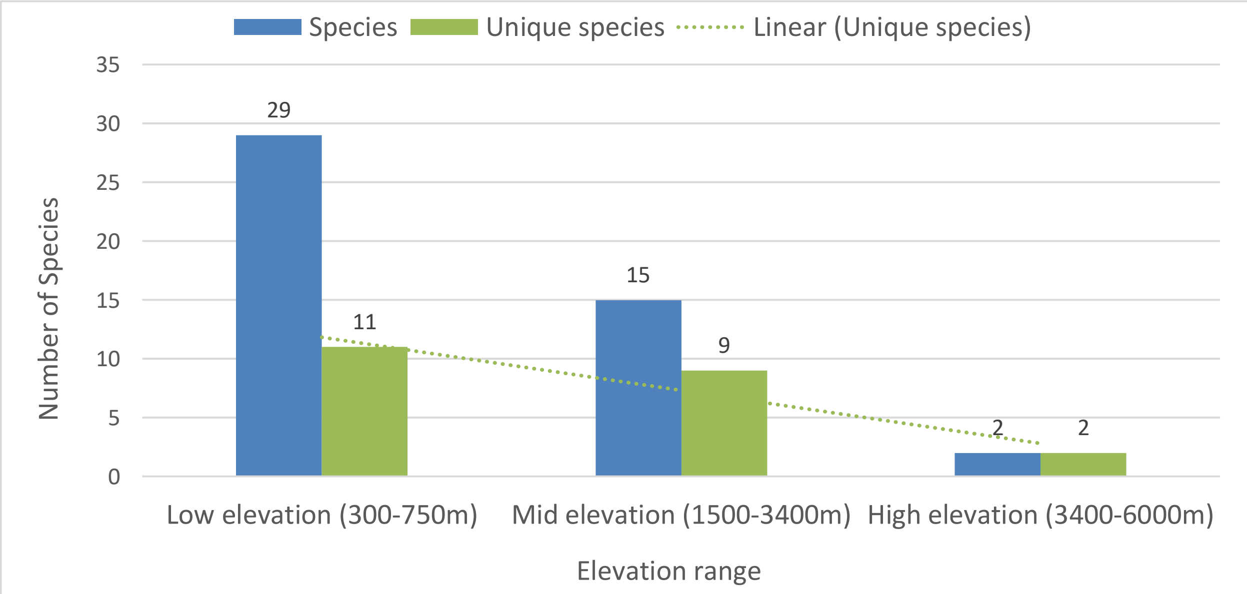


Figure 3.29: Species encountered from each elevation and unique species from the elevation

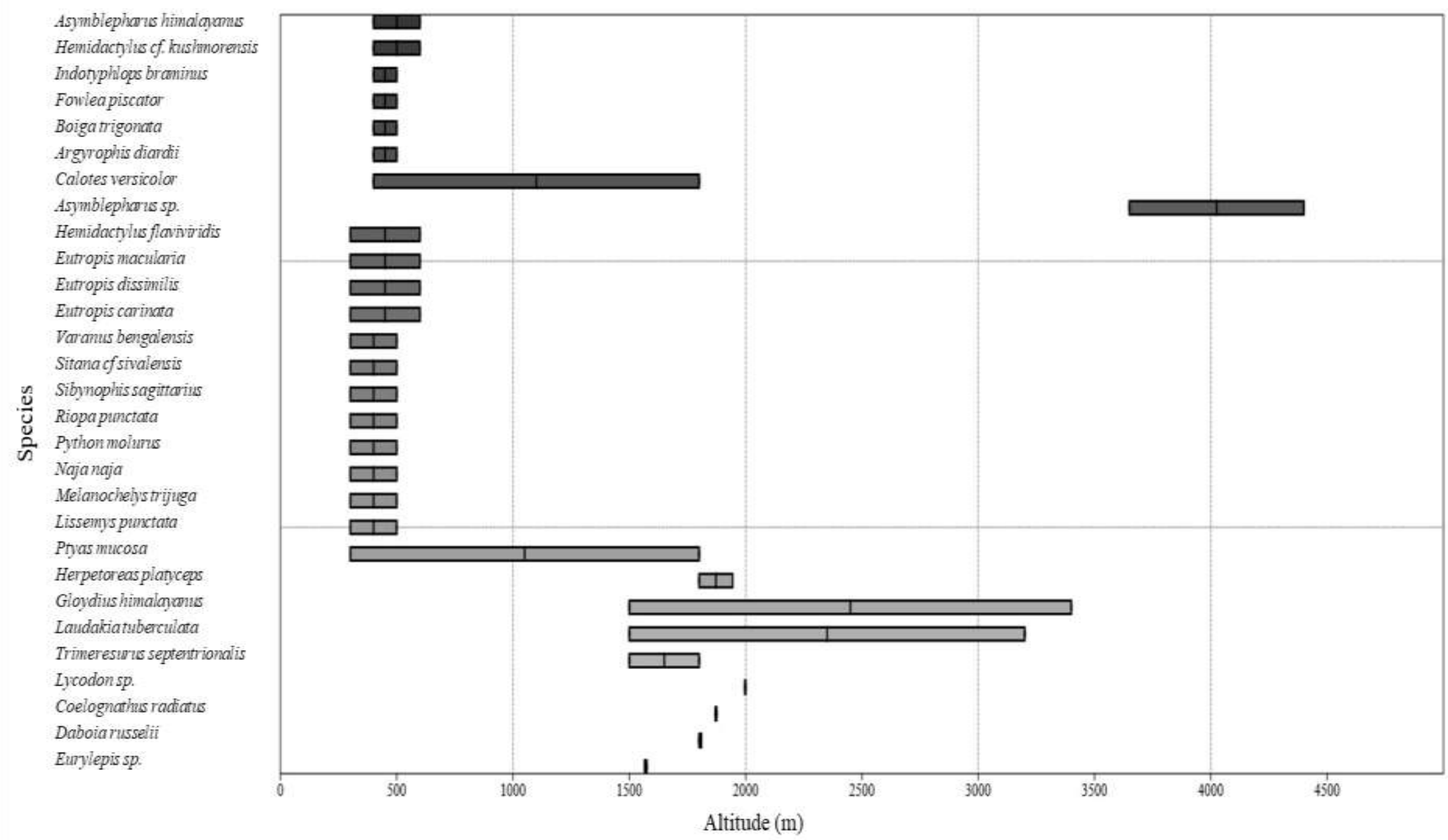


Figure 3.30: Elevation Range profile of reptiles of Himachal Pradesh encountered during our study period

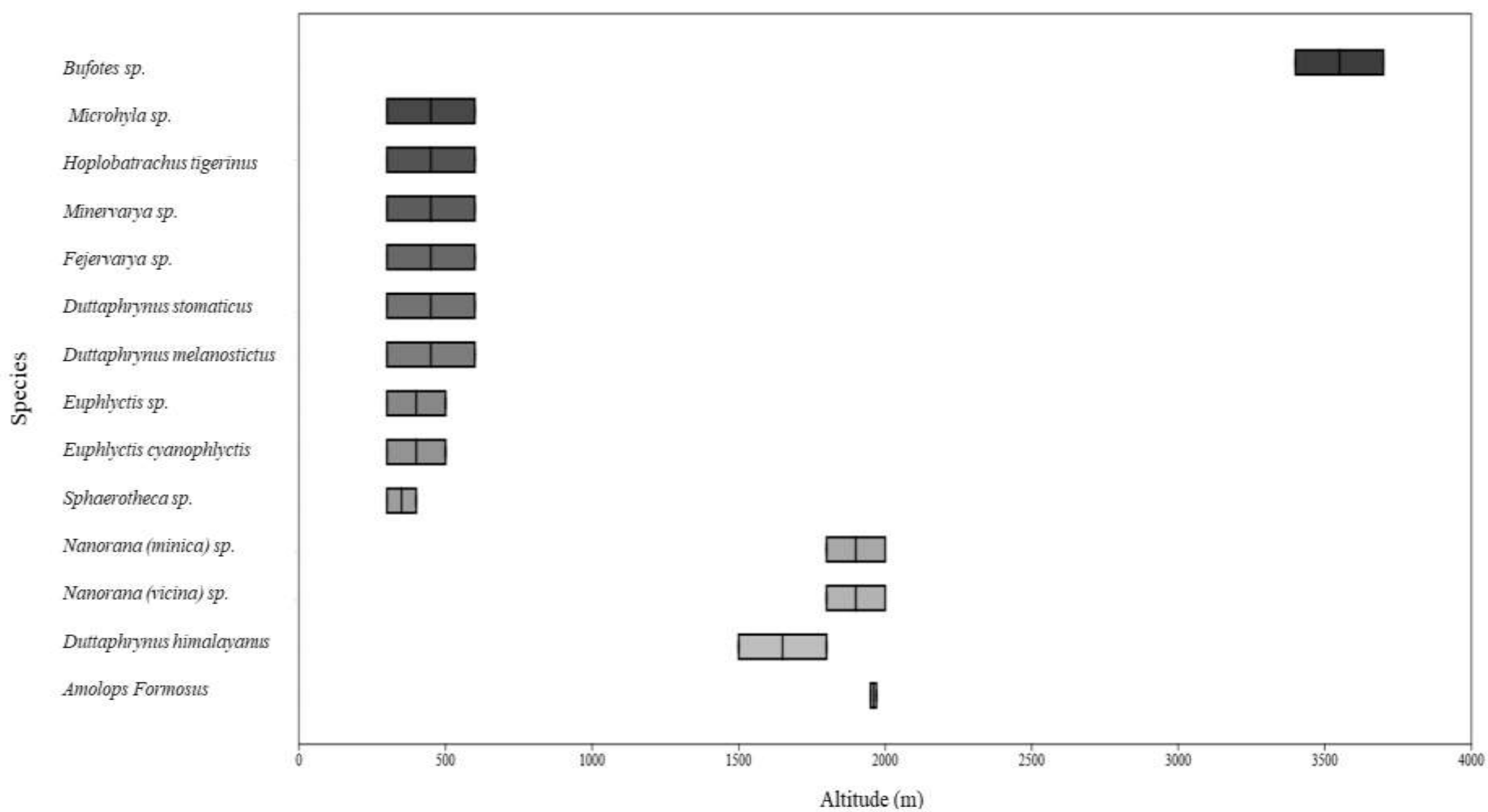


Figure 3.31: Elevation Range profile of amphibians of Himachal Pradesh encountered during our study period

3.10. DISCUSSION

3.10.1. COL SHER JUNG NATIONAL PARK

During our study we found *Fejervarya* sp. to be the most dominant amphibian of the park. We also encountered *Duttaphrynus melanostictus* in quite great numbers as our study was conducted during the breeding season of the species. The national park also has several small pools and water bodies which resulted in a higher abundance of *Euphylctis cyanophlyctis*. The most abundant snake and Chelonia of the park were *Ptyas mucosa* and *Melanochelys trijuga* respectively. During our study, we also observed how VES was a better technique for surveying amphibians and lizards. In belt transects, we found the effectiveness of the sampling design for amphibians and opportunistic encounters for the snakes. So, these three approaches helped us document the diversity of herpetofauna in Col. Sher Jung National Park on a finer scale and covering all groups of herpetofauna.

Conducting a comprehensive investigation of Col. Sher Jung National Park involved categorizing the area into six distinct habitats, which significantly contributed to our understanding of species distribution patterns within the park. Notably, this approach shed light on the crucial role of Riparian habitats in supporting herpetofauna diversity, harbouring approximately 70% of the herpetofauna species present in the entire national park. Of particular significance was the prominent occurrence of *Sitana* sp. exclusively within the Dry riverbed with no canopy cover habitat, emphasizing the species' strong habitat specificity. This habitat was characterized by desiccated shrubs, providing ideal hiding and resting spots for *Sitana* sp., thereby reinforcing the significance of these habitat conditions for this species. Additionally, *Hemidactylus cf. brokii* was frequently encountered on the forest floor during numerous observations, but notably, a considerable number of individuals were found seeking shelter on the bole beneath the bark of Sal and Eucalyptus trees, underscoring the pivotal role of such tree boles as essential habitats for this species. These critical observations have the potential to inform more effective conservation strategies for these site-specific species.

The previous study from SNP showed the presence of 8 amphibian species and 17 reptile species (Mehta and Sharma 2009). The present study showed the presence of 7 amphibian species and 21 reptile species. The previous study also included *Uperodon systoma* which we didn’t encounter during the survey. For reptiles, we encountered eight new species from the area which were not stated in the previous study namely *Argyrophis diardii, Boiga forsteni,* *Boiga trigonata, Bungarus sp., Eutropis carinata, Eutropis dissimilis, Lissemys punctata* and *Sibynophis Sagittarius*. The previous study showed the presence of four more species that we did not encounter namely *Amphiesma stolatum, Eurylepis taeniolata, Laudakia tuberculata* and *Ophisops jerdonii*. Further investigation is warranted to address the limited representation of certain species in our survey, which highlights the necessity for a more comprehensive and intensive sampling approach within the study area. Our research provides a comprehensive account of the distribution and abundance of herpetofauna species within Col. Sher Jung National Park, offering valuable insights into their ecological presence. Moreover, our findings indicate the importance of employing diverse sampling designs tailored to the specific characteristics of different herpetofauna groups. Nevertheless, it is crucial to acknowledge that the study faced limitations, particularly the requirement for sampling across multiple months and an extended temporal scale to enhance the robustness of our results. These results in the near future can help us monitor and take proper conservation steps for these lesser-known taxa. Amphibians play a significant role in wetland ecosystems, as evidenced by their substantial biomass proportion (Gibbons et al., 2006; McCoy et al., 2009; Albecker and McCoy, 2017). Moreover, they are categorized as "climate change susceptible" by the International Union for Conservation of Nature (IUCN) (Foden et al., 2009; Albecker and McCoy, 2017). Due to their life cycle, which relies on water at various stages, amphibians are considered exemplary species for studying wetland habitat health (Neill, 1958; Vitt et al., 1990; Carignan and Villard, 2002; Hopkins and Brodie, 2015). Their interdependence on both aquatic (e.g., eggs and tadpoles) and terrestrial environments makes them particularly suitable for investigating chemical changes, temperature fluctuations, water quality, and other related factors. The availability of freshwater is crucial for amphibians due to their unique life history traits (Alcaide and Ríos, 2011). Additionally, their limited dispersal ability prevents them from escaping unfavourable environmental conditions on a large scale, resulting in a strong localized habitat selection (Wells, 2007). Salinity plays a significant role in the distribution of amphibians, as they exhibit sensitivity to water salinity owing to their highly vascularized and porous skin (Hillyard, 1999; Venturino et al., 2003; Wake and Koo, 2018). Observations have shown that amphibians select water bodies based on the salinity levels present (Soligon et al., 2022). High salinity negatively impacts different life stages of amphibians (Albecker and McCoy, 2017), while low salinity is vital for the healthy development of embryos and larvae (Haramura, 2007; Albecker and McCoy, 2017). Reproductive females also choose oviposition sites based on salinity (Viertel, 1999; Haramura, 2008; Albecker and McCoy, 2017). Elevated salinity retards the growth of adult amphibians and larvae, leading to delayed metamorphosis and increased mortality rates (Tyler, 1972; Beebee, 1985; Quincey, 1991; Voigt, 1991; Viertel, 1999).

Numerous studies have highlighted the significant impact of salinity on amphibian populations across different life stages. In particular, the mortality of Australian frog populations has been attributed to salt toxicity, in addition to habitat loss (Ferraro and Burgin, 1993; Roberts et al., 1999). Adult frog species, eggs, and tadpoles exhibit varying responses to increased salt concentration in aquatic environments (Chinathamby et al., 2006). Chuang et al. (2022) conducted experiments on three amphibian species, namely *Fejervarya limnocharis, Duttaphrynus melanostictus, and Microhyla fissipes*, to investigate the impact of salinity on their survival and development. They found no mortality in freshwater and low salinity treatments, while a high salinity setup resulted in a mortality rate of up to 40% (Chuang et al., 2022). Additionally, they observed that increased salinity reduced the thermal tolerance of amphibians (Chuang et al., 2022). It is noteworthy that *Duttaphrynus melanostictus* and species belonging to the *Microhyla* and *Fejervarya* genera were also present in our study area, allowing for meaningful comparisons with the findings of Chuang et al. (2022). In our study, salinity emerged as a major covariate affecting the abundance of all amphibian species in the park. We found that all seven encountered species exhibited a statistically significant negative correlation with water salinity, indicating that an increase in salinity led to a decrease in the abundance of these species.

Temperature plays a crucial role in the regulation of ions and osmolality in amphibians. Mature amphibians exhibit the ability to adjust their osmoregulatory "set point" in response to temperature fluctuations (Brown et al., 1986; Jørgensen, 1991; Vegso et al., 2022). For instance, when frogs and tadpoles adapted to warmer climates experience colder conditions during hibernation or overwintering, their body water content increases, resulting in a gain in mass (Bradford, 1984; Jørgensen, 1991; Vegso et al., 2022). In our study, we found a significant positive relationship between temperature and the abundance of four species. Furthermore, when considering the impact of various environmental factors on species abundance, oxidation-reduction potential (ORP) exhibited the strongest positive effect, followed by conductivity, pH, and temperature. ORP affected the abundance of six species, conductivity influenced five species, while both pH and temperature had an impact on four species each. Total dissolved solids (TDS), on the other hand, did not demonstrate any significant relationship or influence on species abundance, except for *Sphaerotheca* sp., where it positively affected the species' abundance. Notably, both the occupancy and abundance of *Duttaphrynus stomaticus* and *Euphlyctis cyanophlyctis* were positively influenced by temperature and ORP. These findings highlight the importance of temperature as a key factor shaping the distribution and abundance of amphibian species, alongside other environmental variables (ORP, conductivity, pH, and TDS).

The scientific literature regarding amphibians in the western Himalayas, particularly Himachal Pradesh, remains scarce, thus highlighting the need for further research and publications in this area. In light of this, our study aimed to establish a fundamental understanding of amphibian diversity within Col. Sher Jung National Park, documenting the presence of seven distinct amphibian species alongside 21 reptile species. Specifically, our research focused on elucidating the distribution patterns of these species throughout the park in relation to various water parameters. By investigating key factors such as salinity, temperature, and conductivity, we sought to identify the primary influences shaping the distribution patterns of amphibians within the park. This comprehensive investigation provides critical baseline information regarding the ecological requirements and habitat preferences of amphibians in this specific region. Moreover, it serves as a crucial foundation for future studies, encouraging the collection of long-term data and fostering a closer engagement with amphibian species to facilitate effective conservation practices. Amphibians are recognized as valuable indicator species, possessing the capacity to serve as sensitive indicators of even minute environmental changes. Thus, our study not only enhances our understanding of the distribution patterns of amphibians within the park but also contributes to the broader comprehension of the intricate relationships between these species and their environment. The acquisition of more detailed knowledge about amphibians through ongoing research will allow for more comprehensive investigations into their ecology. Consequently, this will enable us to work closely with amphibians and implement conservation strategies that effectively address their specific needs and mitigate the potential impacts of environmental changes.

3.10.2. CHURDHAR WILDLIFE SANCTUARY

Previous information pertaining to the herpetofauna diversity from and around the Churdhar Wildlife Sanctuary were non-existent. Thus, our current investigation stands as the inaugural repository of knowledge concerning the herpetofauna inhabiting the sanctuary in question. The assemblage of species documented within Churdhar Wildlife Sanctuary predominantly comprises taxa commonly observed within habitats across similar zones of Himachal Pradesh.

Among the notable findings are instances of an endemic and rare amphibian *Amolops formosus* (Assam cascade frog), a species confined to the elevated watercourses of the Himalayan ecosystem. Additionally, the identification of less common snake species, such as Mackinnon's wolf snake (*Lycodon bicolor*) and Hodgson's rat snake (*Elaphe hodgsoni*), along with the sighting of rare lizard like *Japalura* sp. and *Eurylepis* sp., contributes to an enhanced comprehension of the ecological significance attributed to the sanctuary and its habitat within the western Himalayan context.

As for the case study of *Amolops Formosus*, our study provides the first baseline information about the population dynamics of the species from western Himalayas. The anuran population dynamics often deals with capturing, anesthetizing, and putting PIT tags but we used a non-physical, less stress approach for the species. We looked into detailed information about the correlation of different water parameters with the species abundance and density. Amphibians are highly dependent on the availability of freshwater due to their dual life cycle depending on both aquatic and terrestrial environments (Alcaide and Ríos, 2011). They are particularly sensitive to the salinity (Hillyard, 1999; Venturino et al., 2003; Wake and Koo, 2018) and temperature (Brown et al., 1986; Jørgensen, 1991; Vegso et al., 2022) of water due to their porous skin. There are numerous other studies showing the effect of rainfall (Eterovick and Sazima 2000; Prado et al. 2005; Moreira et al. 2007), landscape configurational heterogeneity (Li et al., 2018) on relative abundance of anurans. Eskew et al. (2011) stated how occupancy and abundance of anurans were affected by distance from nearest dam, mentioning flow regulation as an important amphibian population stressor. Our study focused on the importance of water covariate for population and distribution of anurans in any landscape. We used seven water covariates: TDS, salinity, temperature, conductivity, pH, ORP and flow to understand their influence on the abundance and density of *Amolops formosus*. Only the flow of water had a negative significant correlation with the abundance and detection component of the species. Despite being the sensitive covariates, TDS, salinity, temperature, conductivity, pH and ORP did not show a statistically signification relation with the abundance of *Amolops formosus*. None of the covariate had a major influence on the density, detection and home range of the species in our study area.

Amolops formosus is a species associated with high-flowing and gradient hilly streams (Frost, 2021). Despite that, in our study the species is negatively related to the flow of the stream. The high-water flow tends to carry more sediments that contributes to an increase of water turbidity

(Harahap et al., 2021) which might be the major cause of negative correlation with the abundance and detection of the species. We observed that the species was present when the flow of the stream was about 1.2 to 1.4 m/s. As the water flow increased more than 1.7 m/s the encounters of the species decreased. So, it seems the optimal flow of water for species ranges from 1.2 to 1.5 m/s. This result may be further used in future studies with different locations to get a better insight into the ecology of the species.

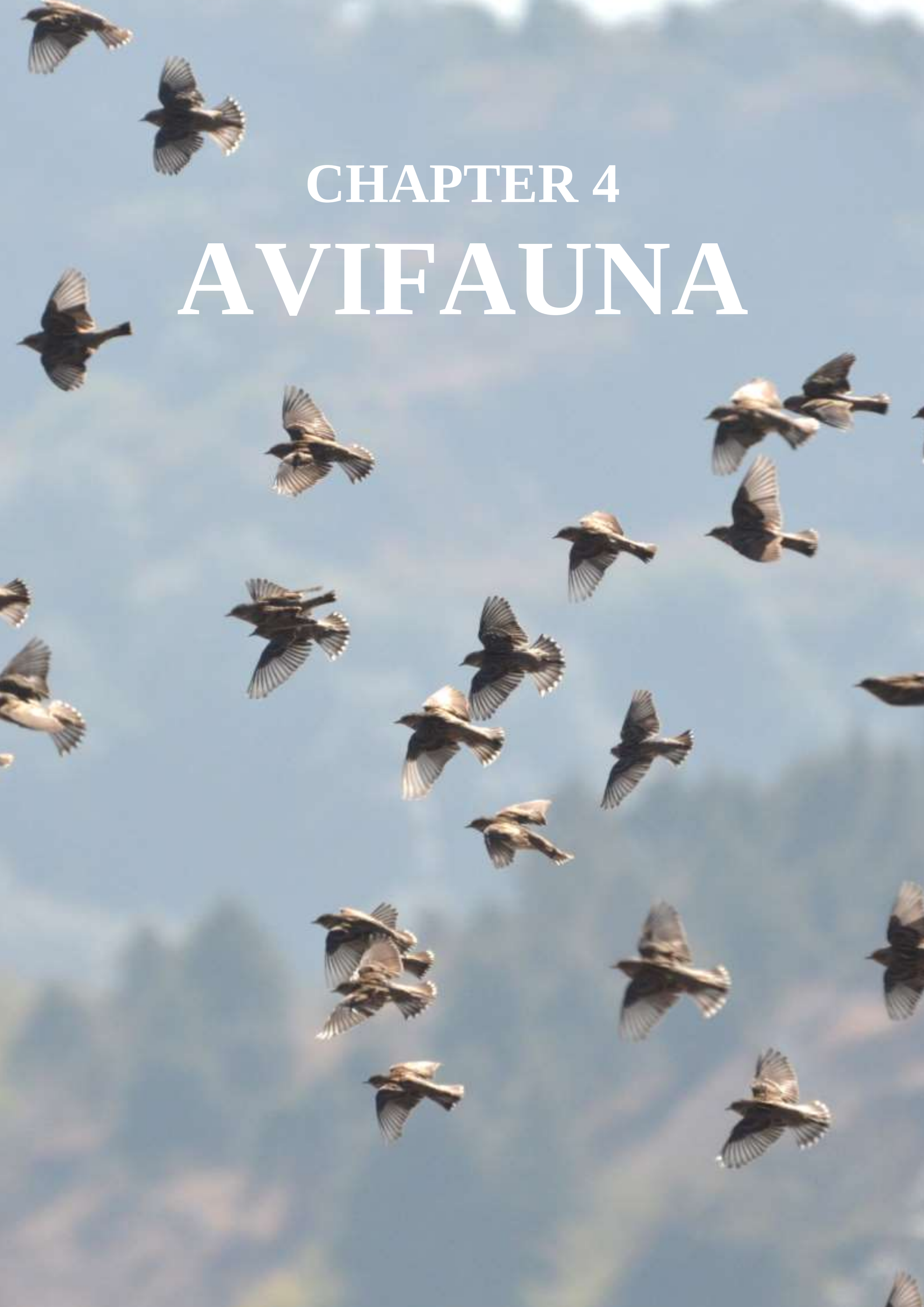
Understanding the size and trend of any wildlife population is critical to its long-term conservation (Hellawell, 1991; Fasham and Mustoe, 2005; Tucker et al., 2005; Measey et al., 2017). Changes and effects in different ecosystems in the regions with high biodiversity are important in scientific research (Venter et al., 2016). To understand these effects, it has become increasingly crucial to provide baseline information on species distribution and population sizes, particularly for rare and elusive species which play particularly crucial roles in regulating ecosystems (Beschta and Ripple, 2009; Laundre et al., 2010; Ripple et al., 2014; Green et al., 2020). Density estimation is frequently regarded as the gold standard in biodiversity studies for any taxa (O'Connell et al., 2011; Tobler and Powell, 2013; Royle et al., 2014). The density estimates of the species in this study helped us understand the distribution of the endemic *Amolops formosus* in an unexplored landscape of western Himalayas.

One of the limitations of our study was confined to a small area and sample size. Although we focused on the major water parameters, it is important to acknowledge that the measurement of turbidity, a significant parameter, was hampered by the unavailability of suitable equipment. Despite these constraints, our results provide major insights to the population dynamics of a rare and endemic anuran. Although the results of prior studies show the impact of temperature and salinity on anurans, our species is quite tolerant to the same. However, it is majorly influenced by the water flow. Furthermore, changes in the flow of water because of dams, water blockage, stream diversion to the villages may lead to the local extinction of the species. The low and high rainfall may also impact the ecology of the species. Although the species is listed as Least Concern according to IUCN red list, continuous population decline of such endemic species is of utmost concern. Understanding the effect of water parameters on anuran distribution should be a priority for future research to improve the knowledge of anuran ecology in different landscapes.

Accurately estimating animal abundance within a defined area is crucial for effective ecosystem management (Skalski and Robson, 1992). However, conventional methods involving the capture, marking, and recapture of individual animals or the use of tagging techniques are often characterized by their time-consuming nature, labor-intensive requirements, and high costs. Radio telemetry represents a highly precise approach for investigating the movement, habitat utilization, and ecological aspects of anuran amphibians. Nevertheless, the implementation of radio telemetry is limited by its significant financial investments. Acoustic sampling, although reliable, is constrained to populations with vocal-male individuals, leading to potentially biased estimations. In contrast, photographic identification based on natural colour patterns has emerged as a robust and cost-effective means of individual identification in amphibians such as *Leiopelma archeyi, Melanophryniscus cambaraensis, Anaxyrus baxteri, Salamandrina perspicillata, Triturus dobrogicus,* and *Amolops formosus.* By leveraging these distinctive natural colour patterns, researchers can accurately identify individuals and gain valuable insights into population dynamics and species ecology.

The utilization of natural colour patterns for photographic identification enables the reliable distinction of individual amphibians, thereby facilitating population monitoring and ecological research. This cost-effective method offers numerous advantages over conventional techniques, as it eliminates the need for capture or physical handling of animals, reducing potential stress and disturbance. By capturing images of amphibians displaying unique colour patterns, researchers can establish long-term monitoring programs and track individual movements, growth, and survival over time. These data can provide valuable information on population demographics, individual behaviour, and habitat preferences. Furthermore, photographic identification can be utilized to investigate the impact of environmental factors, such as habitat loss or climate change, on population dynamics and species distribution. By continuously expanding the photographic database, researchers can gain insights into population trends, connectivity, and genetic diversity.

CHAPTER 4
AVIFAUNA



4.1 INTRODUCTION

Studying avifaunal diversity is a crucial ecological tool that serves as a key indicator to assess different ecosystems and also accomplishes a number of ecological tasks, such as disease control, biomass recycling, seed dissemination of succulent fruits, and pollination ((Rai Babbar et al. 2017). Similarly, to conduct community-level conservation and proper management it is important to understand habitat grade ecology (Scalet et al. 1996, Morrison et al.1998) and ecological community complexity and size (Gratto-Trevor et al., 2012). However, only those trends and public awareness-raising campaigns that focus on a certain population or aspect of a system, like forest ecosystem, are taken into account. For an understanding of how the ecosystem functions, it is required to take a variety of components and their interactions under consideration. (Mavrommati and Richardson, 2012; Mendez et al., 2012). Understanding the factors controlling the distribution of biodiversity is a key goal of ecology (Lubchenco et al. 1991). An independent area of research in community ecology has traditionally focused on the dispersal of birds across various habitat types. (Wiens, 1985). In areas consisting of habitat mosaics, assessment of the effect of gradients and their composition on biodiversity is well achieved when studying groups that respond to different spatial scales, such as birds (Mac Nally et al., 2004; Bossenbroek et al., 2005). A distinct area of inquiry in community ecology has traditionally been the examination of bird distributions across various habitat types (Mac Nally et al., 2004; Bossenbroek et al., 2005). Patterns of diurnal and seasonal migratory movements are frequently strongly correlated with fluctuations in the availability of food across and within habitats (reviewed by Moore as al. 1995), and migrants use stopover habitats selectively (Bairlein 1983; Moore et al. 1990). Food availability is a crucial fundamental habitat component and it is believed to be ultimately to be responsible for fine-scale patterns of habitat usage (Hutto 1985).In this scenarios biotic processes like food availability, land use patterns, and disturbance interact significantly with abiotic variables including terrain and microclimate (Barbaro et al., 2007).The abundance of species can be explained by the structural complexity of the given ecosystem and its associated disturbance mechanisms (Jose and Jose, 2001). Understanding other aspects, such as the bioclimatic process, is also crucial. Regional bioclimatic processes frequently result in gradients or a patchy topography (Allen & Starr, 2017). Locally, it is anticipated that these structural characteristics may influence assemblages of species subsets, perhaps as a result of microclimatic circumstances, structural elements, and resource needs (Meynard and Quinn, 2008). Reporting habitat differences in species richness has taken the role of latitudinal trends as a basis for large-scale gradient research. (2008) Nogues-Bravo et al). Habitat variability also results from variations in biological, meteorological, and geographic variables, which have a negative impact on patterns of species richness (Rahbek 1995; Lomolino 2001). Understanding natural communities has been aided greatly by studies of species dispersion along various habitats (Whittaker, 1967).

Although comprehensive avifaunal lists have been compiled for many National Parks across India, Simbalbara National Park (SNP), Churdhar Wildlife Sanctuary (ChWLS), Pin Valley National Park (PVNP), and Chandratal Wildlife Sanctuary (CWLS) remain unexplored and limited reports from here focus on avian diversity. Perhaps, quantitative data on seasonal bird distributions with proper avifaunal assessments were overlooked here for a long time.

LITERATURE REVIEW

Many broad primary Oriental biogeographic ridges make up global oriental biogeography, which includes the Indian subcontinent is abundant in biodiversity. More than 1300 species, or more than 13% of the 9000 bird species in the world, can be observed on the Indian subcontinent (Grimmett et al. 1998). Out of the 75 bird families in the globe, 48 are found in this avifauna-rich subcontinent. However, two families—the Irenidae family of leaf-birds and the Megalaimidae family of Asiatic barbets occur in the Oriental area. Other biogeographical areas are home to other bird families as well. Many bird species, including parrot bills, barbets, laughing thrushes, parakeets, flower-peckers drongos, leaf-birds, pittas, and pheasants have their radiation centers in the oriental region.

For the protection of several pheasant and woodland bird species, Himachal Pradesh is a stronghold. The six primary forest types in the western Himalayas contain species, some of which have sizable populations, the state currently harbours 390 different bird species (Grimmett & Inskipp 2003). Seven globally threatened species are found in the State. Two vultures and two eagle species are widely found but two pheasant species, i.e., cheer pheasant and Western tragopan, have restricted range, both in altitude and habitat. The wood snipe classified as vulnerable (BirdLife International 2001) also had a wide distribution in the Himalayas based on old shooting records (Ali & Ripley 1987). Only a few recent records are available after the sports-hunting prohibition in India. It is reported only from Dhauladhar WLS but is likely to be found in many more areas. Himachal Pradesh lies in the Western Himalayas Endemic Bird Area (EBA 128). Eleven species are confined to this EBA (Stattersfield et al. 1998), out of which ten are known to occur in this State with confirmed records. They are Western tragopan, cheer pheasant, Brook's leaf warbler, Tytler's leaf warbler, Kashmir flycatcher, white-cheeked tit, white-throated tit, Kashmir nuthatch, spectacled finch and orange bullfinch. These restricted-range species are confined to the Western Himalayas of Himachal Pradesh on an elevation between 1,500 to 3,600 m in the Temperate Coniferous or Broadleaf Forest, Sub-alpine forest, and Montane Grassland (Stattersfield et al. 1998).

4.2 METHODS

We established point count stations laid along transects (2000 m each), each separated by at least 150 m across four different transects in summer and winter seasons. Our observation focused on point counted and accidental sightings of all bird species which encompasses resident, passage migrants and long-distance migrants. At each station, all birds were observed visually within a 50 m radius; most of the species were photographed and counted.

Recorded data were analyzed to obtain species dominance, diversity and evenness across both habitat types. Shannon Index (H') (Magurran 1988), $H' = -\sum pi \ln pi$. Where pi = the proportion of the i th species in the total sample, Simpson Dominance Index (D)=sum((ni/n)2), where ni is the number of individuals of taxon i. Buzas and Gibson's evenness = eH/S, where H is the Shannon diversity index and S is the number of species.

Density estimation was done on the software Distance version 7.0. The best-fit model was selected based on Akaike Information Criteria (AIC). AIC value provides an objective and quantitative method for model selection.

4.3 RESULTS

Col. Sher Jung National Park (CSJNP)

4.4.1 Avian family composition

A total of 163 species belonging to 52 families were reported from SNP during (Table 4.3). Within the Stream-line habitats, the most dominant families were Muscicapidae (10.43%), Accipitridae (9.20%), Phylloscopidae (6.13%) and Columbidae (4.29%), while the most recessive were species from family Sittidae, Laniidae, Falconidae and Coraciidae (0.04% each). Species belonging to Family Vangidae, Upupidae and Fringillidae found in Dry Deciduous habitats were absent in Stream-line habitats. Within the Dry deciduous habitat, the most dominant family was found to be Sylviinae (10.26%), followed by Nectarinidae (9.83%), Turdinae (9.01), and Pycnonotidae (7.71%). The most recessive families found were Upupidae and Alcedinidae (0.05% each). Species from the family Falconidae, Coraciidae, Captionidae and Scolopacidae, were absent in this habitat type and were also observed in low numbers in stream-line habitat.

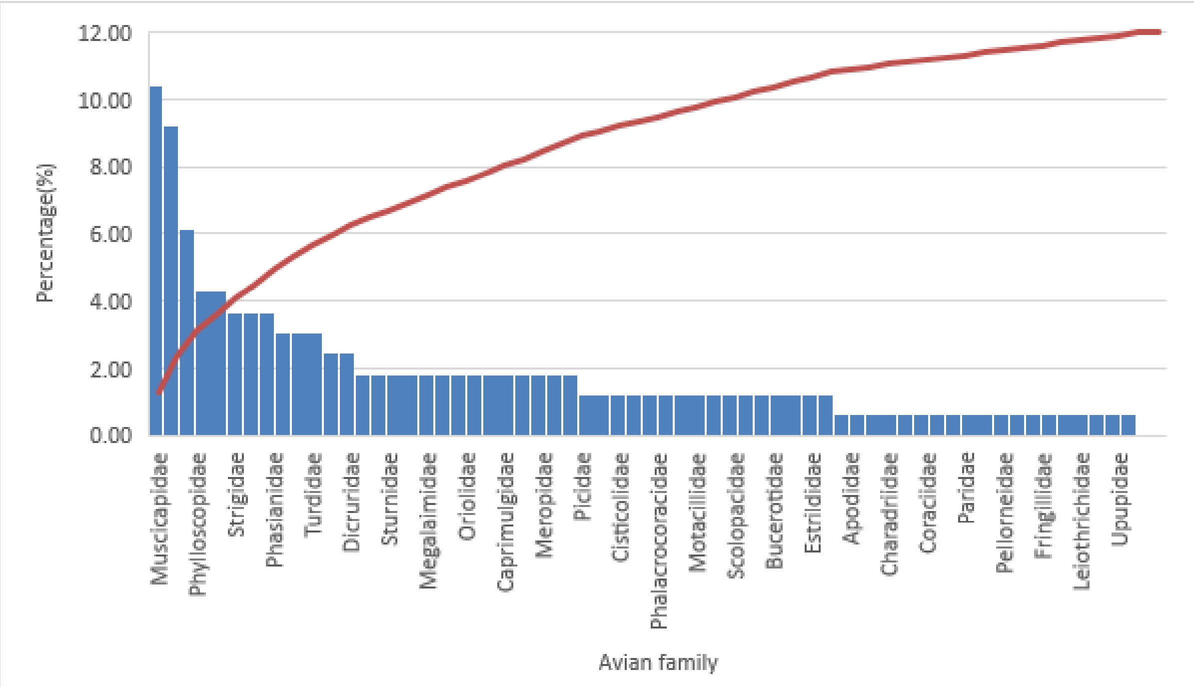


Figure 4.1 Percentile representation of familywise avian composition in CSJNP, Himachal Pradesh.

4.4.2 Density estimation using the point count method

The birds in different habitat types have shown different densities. During winter and summer recorded a total of 660 observations were from 48-point count stations, of which 315 (128 in summer, 187 in winter) & 345 (166 in summer, 179 in winter) observations were recorded respectively from Dry Deciduous Forest (DDF) and Stream Line Forest (SLF). The best-fit model was selected based on Akaike Information Criteria (AIC). AIC value provides an objective and quantitative method for model selection. The selected models along with the key functions and other estimates have been mentioned in table 4.1 and 4.2. In the case of DDF, the estimated average density was 73.4 birds per sq. km. during summer and 85.8 during winter. While for SLF the estimated average density was 115.5 birds per sq. km. in summer and 117.4 in winter. SLF showed an overall higher avian density in both summer and winter.

Table 4.1 Result of bird density estimation for CSJNP in summer; DS - estimate of density of clusters; E(S) - estimate of expected value of cluster size; D - estimate of density of animals, DDF- Dry deciduous forest, SLF – Stream line forest.

Transect	Model	Key function	DS	E(S)	D	CV	Minimum AIC	Detection probability	Encounter rate	Cluster size
DDF1	Hazard rate	Simple polynomial	44.11	1.65	72.8	24.55	128	59	31	9.9
DDF2	Half normal	Cosine	41.86	1.77	74.09	27	91.9	50.1	33.7	16.3
SLF1	Half normal	Simple polynomial	76.4	1.62	124.05	18.97	163.43	57.6	28.2	14.2
SLF2	Half normal	Simple polynomial	40.62	2.63	107.07	24.94	129.12	49.5	33	17.5

Table 4.2 Result of bird density estimation for CSJNP in winter; DS - estimate of density of clusters; E(S) - estimate of expected value of cluster size; D - estimate of density of animals, DDF- Dry deciduous forest, SLF – Stream line forest.

Transect	Model	Key function	DS	E(S)	D	CV	Minimum AIC	Detection probability	Encounter rate	Cluster size
DDF1	Half normal	Cosine	53.53	2.36	126.5	20.13	131.01	67.2	11.1	21.8
DDF2	Half normal	Simple polynomial	21.77	2.07	45.15	19.68	138.06	62	6.9	31.1
SLF1	Half normal	Simple polynomial	56.4	2.87	162	19.45	175.81	62.1	14.6	23.3
SLF2	Half normal	Cosine	28.1	2.59	72.92	24.28	128.57	49.8	32.7	17.4

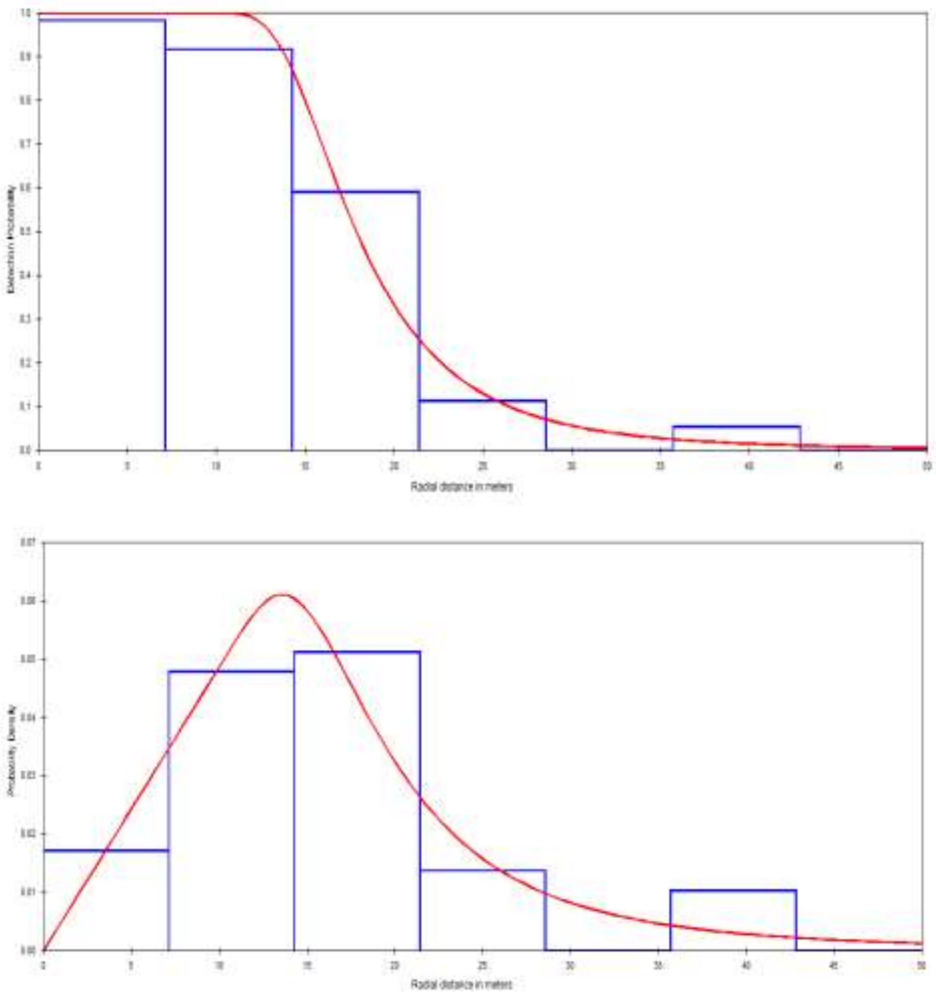


Figure 4.2 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for DDF1 in CSJNP during summer respectively.

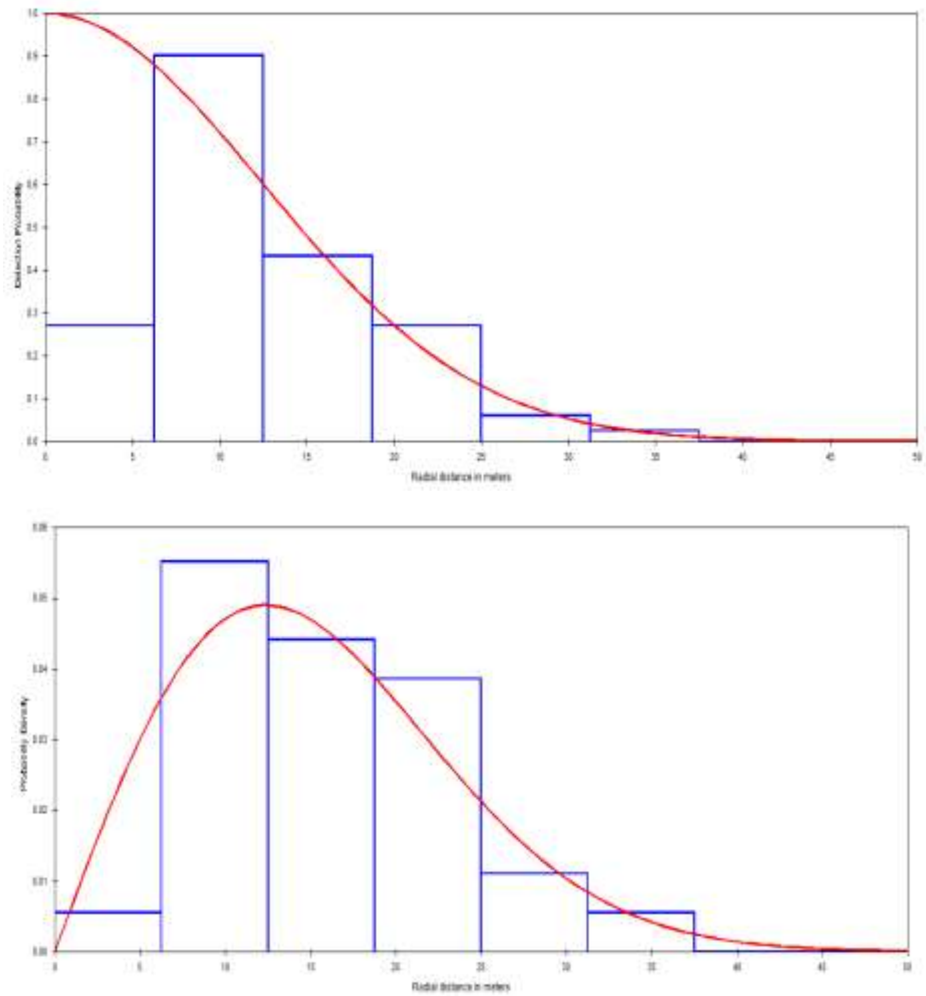
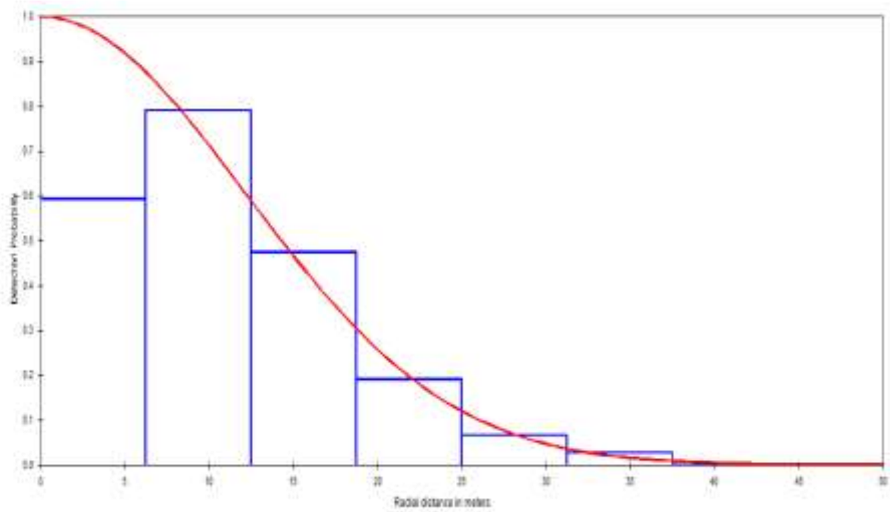


Figure 4.3 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for DDF2 in CSJNP during summer respectively.



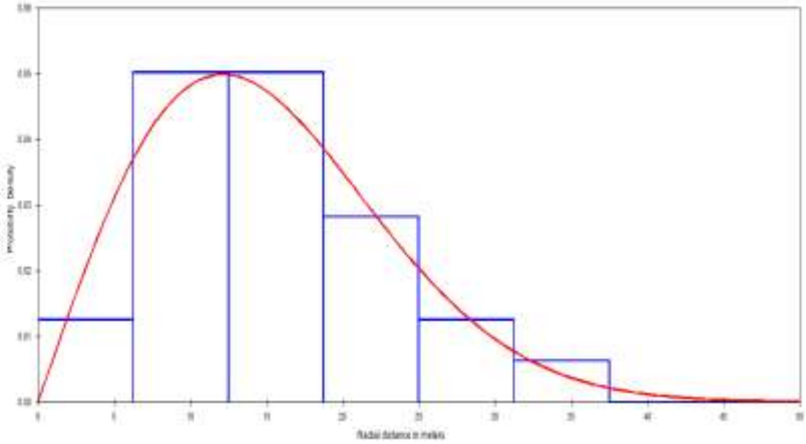


Figure 4.4 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for SLF1 in CSJNP during summer respectively.

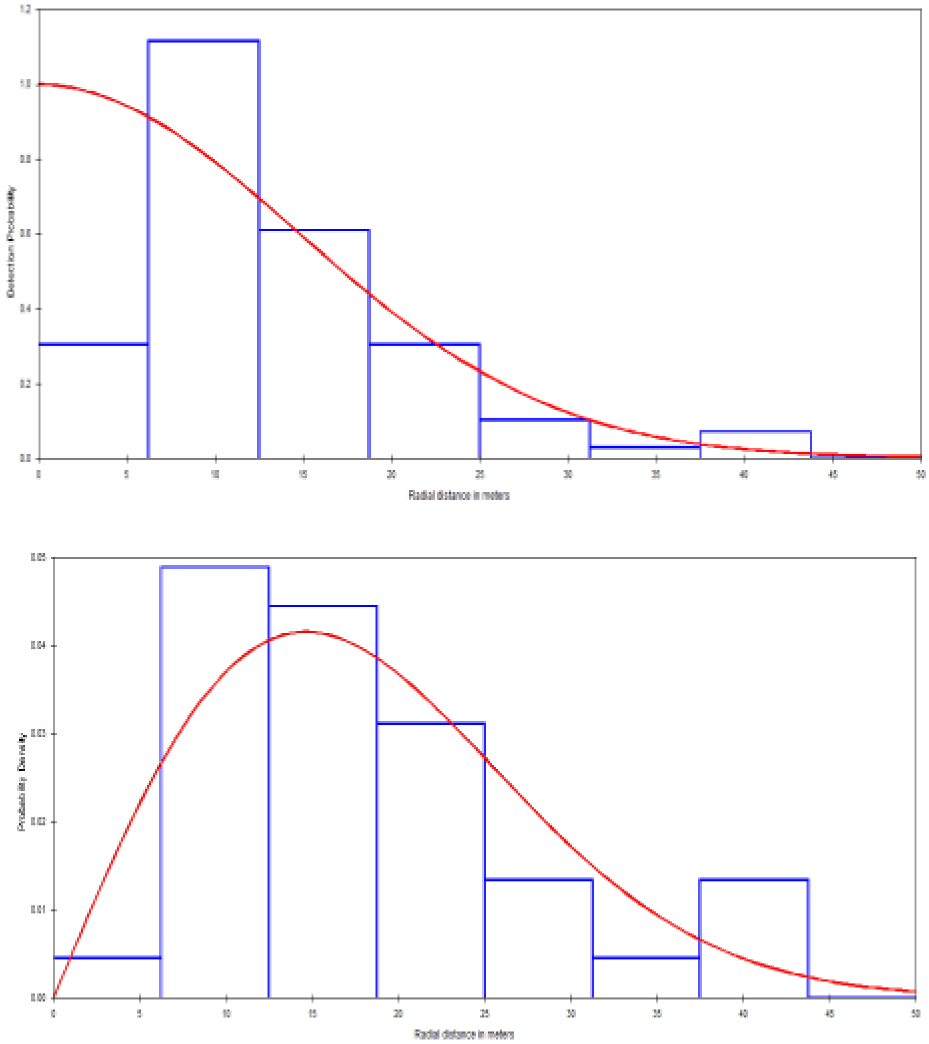


Figure 4.5 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for SLF2 in CSJNP during summer respectively.

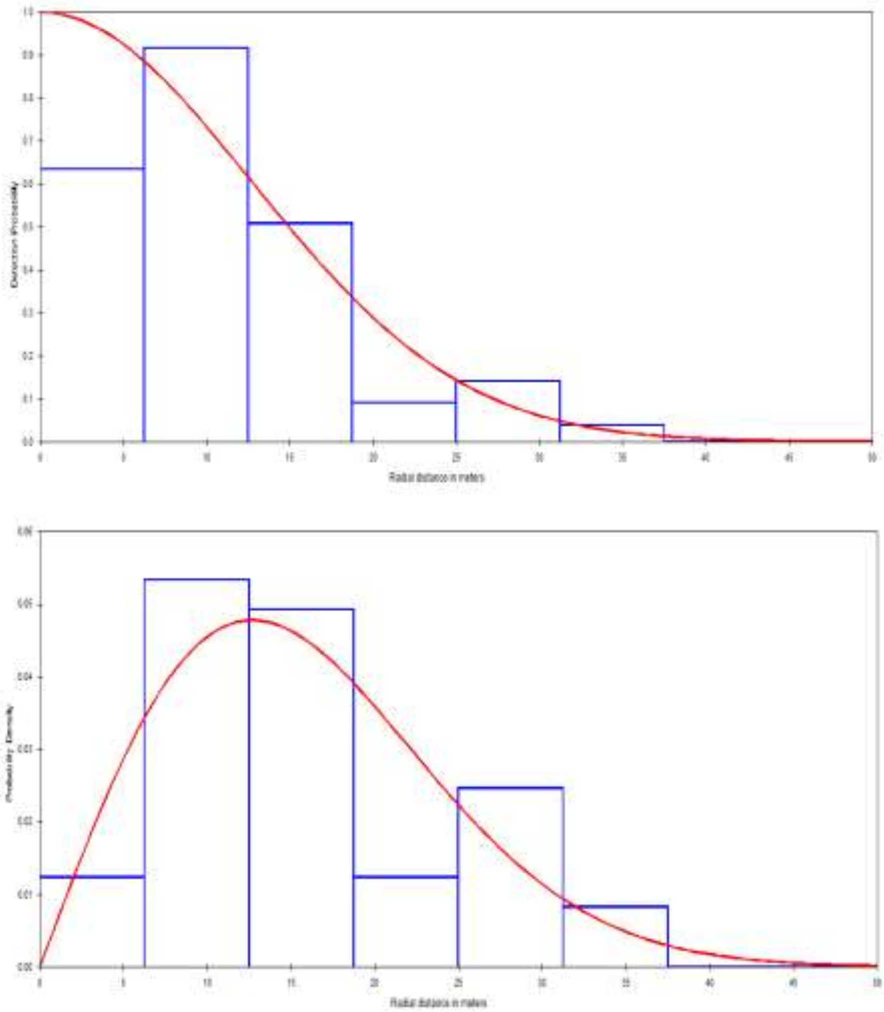
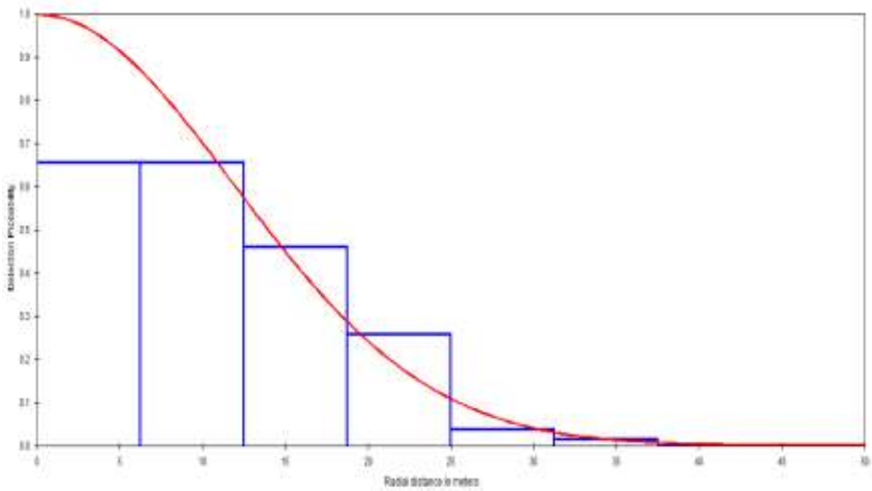


Figure 4.6 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for DDF1 in CSJNP during winter respectively.



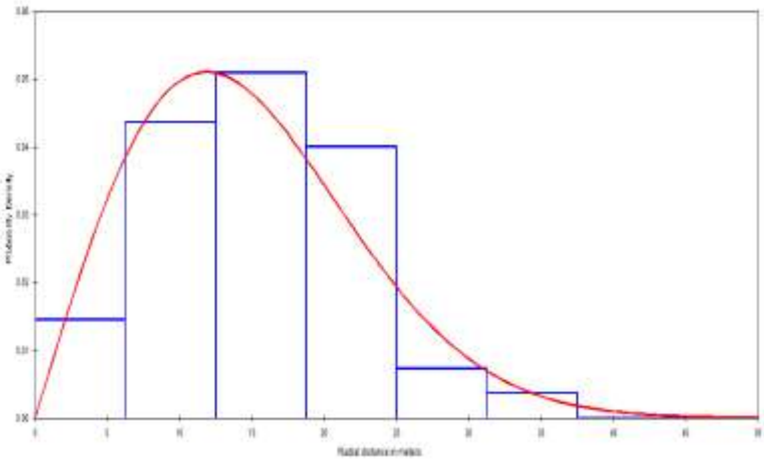
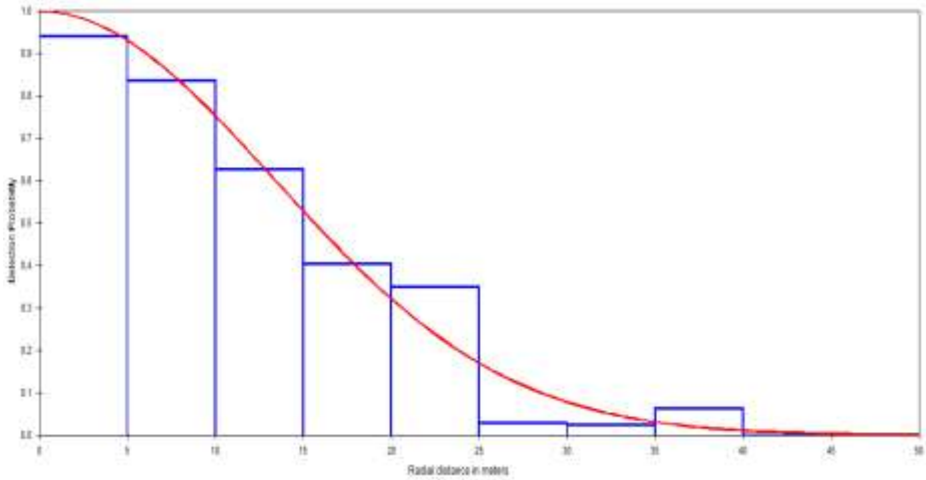


Figure 4.7 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for DDF2 in CSJNP during winter respectively.



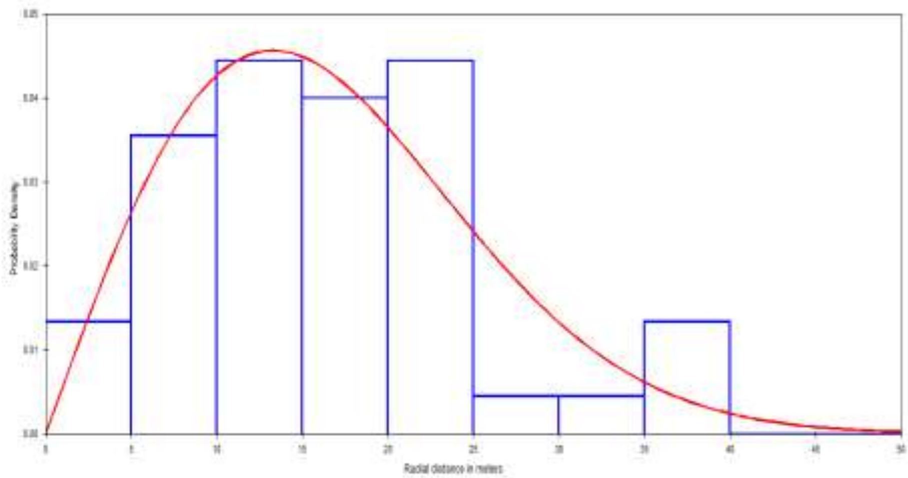


Figure 4.8 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for SLF1 in CSJNP during winter respectively.

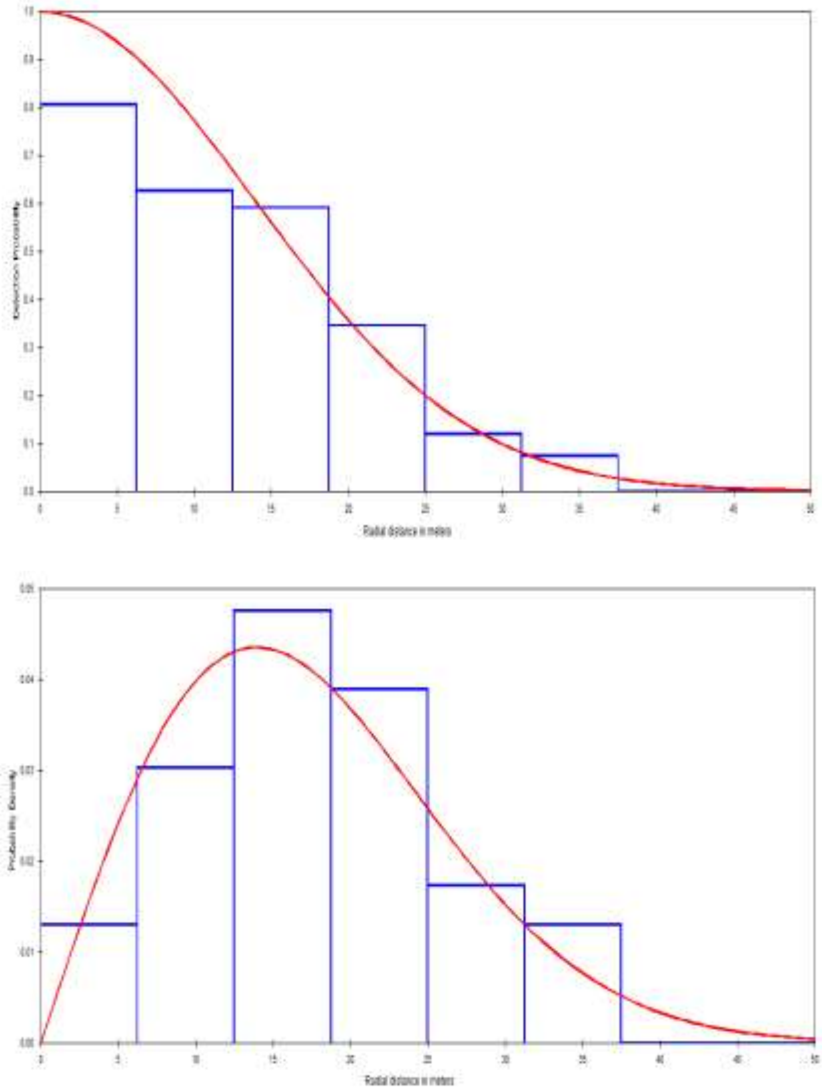


Figure 4.9 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for SLF2 in CSJNP during winter respectively.

4.4.3 Feeding guild structure

The feeding guild data were mainly collected from two majorly available habitat types i.e. streamline (SL) and dry deciduous forest (DDF). Two transects were laid on each of the habitat types.

During summer, insectivore (41.18% for SL1 & SL2, 28.13% for DDF1 and 21.05% for DDF2) were found to be most abundant followed by omnivore (20.59% for SL1, 22.58% for SL2, 21.88% for DDF1, 31.58% for DDF2). Nectarivore (2.94% for SL1, 3.13% for DDF1 and absent for SL1 and DDF2) were the least found guild across all the transects followed by frugivore and piscivore. Piscivore percentage (5.88 for SL1, 6.45 for SL2, 3.13 for DDF1 and absent from DDF 2) in SL and Frugivore percentage in DDF (3.13 for DDF1, 5.26 for DDF2 and absent from both SL1 and SL2) depicts the specificity of representative species from the specific guilds.

During winter, the total number of representative species from insectivore (36.36% for SL1, 50% for SL2, 44% for DDF1 and 21.05% for DDF2) and omnivore (36.36% for SL1, 30.56% for SL2, 20% for DDF1, 31.58% for DDF2) have shown to increased significantly in comparison to summer. For insectivore the total percentage of representative species changed from 132.2 in summer to 151.41, while in case of omnivore it changed from 96.63 to 118.5. Nectarivore (2.78, found only in SL2) and Piscivore (4, found only in DDF1)

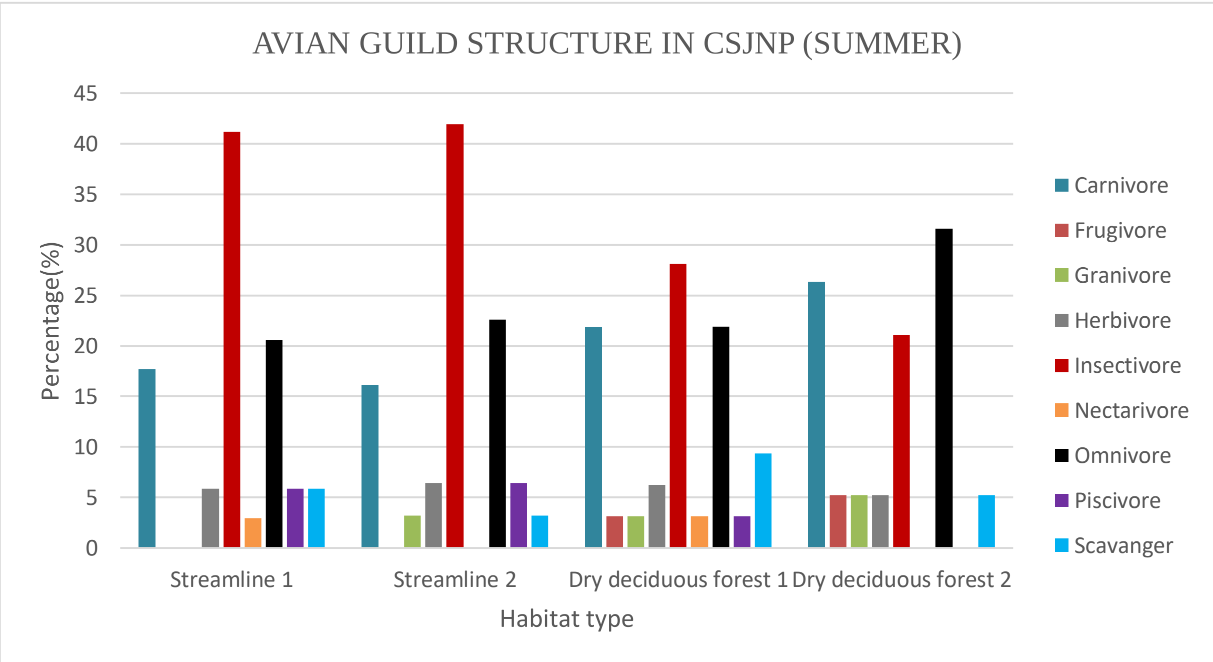


Figure 4.10 Percentages of avian feeding guild composition in different available habitat types in CSJNP during summer.

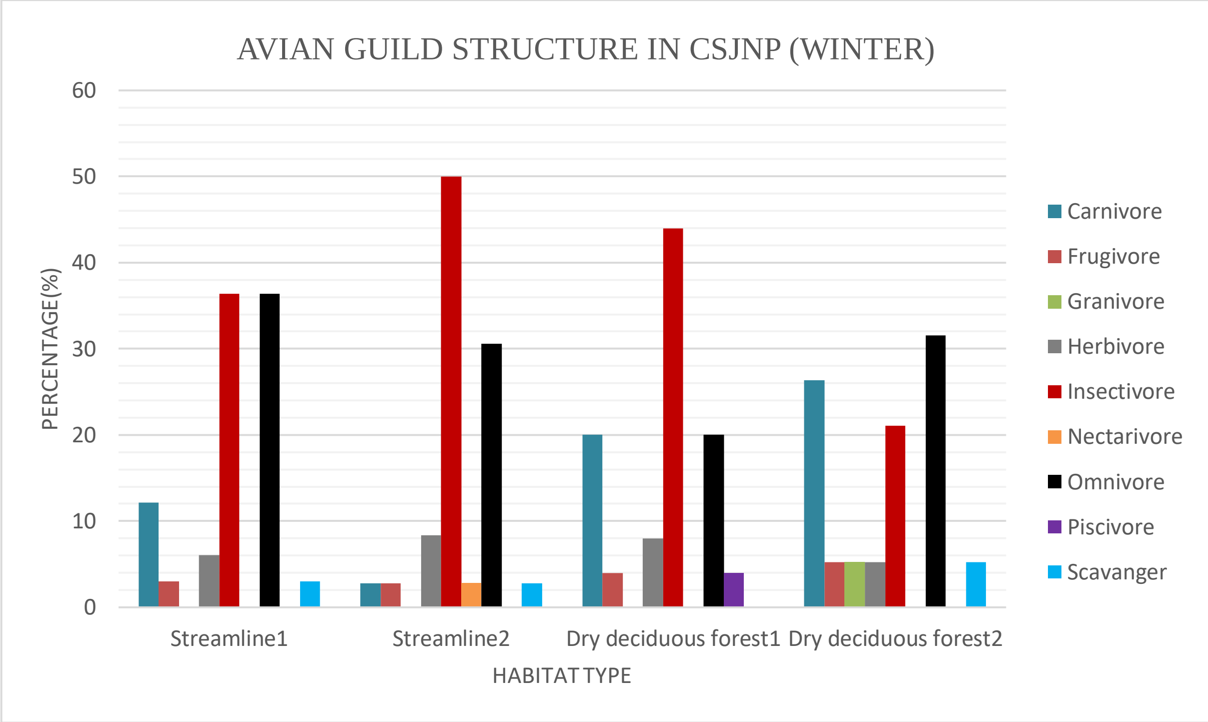


Figure 4.11 Percentages of avian feeding guild composition in different available habitat types in CSJNP during winter.

Table 4.3. Checklist of Birds found in CSJNP.

Sl.No.	Family	Order	*Scientific name*	Common name
1	Accipitridae	Accipitriformes	*Elanus caeruleus*	Black-winged Kite
2		Accipitriformes	*Milvus migrans*	Black Kite
3		Accipitriformes	*Milvus (migrans) lineatus*	Black-eared Kite
4		Accipitriformes	*Neophron percnopterus*	Egyptian Vulture
5		Accipitriformes	*Gyps himalayensis*	Himalayan Griffon
6		Accipitriformes	*Gyps fulvus*	Eurasian Griffon
7		Accipitriformes	*Butastur teesa*	White-eyed Buzzard
8		Accipitriformes	*Pernis ptilorhynchus*	Oriental Honey-buzzard
9		Accipitriformes	*Aquila fasciata*	Bonelli's Eagle
10		Accipitriformes	*Aquila clanga*	Greater Spotted Eagle
11		Accipitriformes	*Spilornis cheela*	Crested Serpent-Eagle.
12		Accipitriformes	*Accipiter nisus*	Eurasian sparrow-hawk
13		Accipitriformes	*Accipiter badius*	Shikra
14		Accipitriformes	*Nisaetus nipalensis*	Mountain Hawk Eagle
15		Accipitriformes	*Nisaetus cirrhatus*	Changeable Hawk-Eagle
16	Alcedinidae	Coraciiformes	*Alcedo atthis*	Common Kingfisher
17		Coraciiformes	*Pelargopsis capensis*	Stork-billed Kingfisher
18		Coraciiformes	*Halcyon smyrnensis*	White-breasted Kingfisher
19	Apodidae	Apodiformes	*Apus affinis*	House Swift
20	Ardeidae	Pelecaniformes	*Egretta garzetta*	Little Egret
21		Pelecaniformes	*Bubulcus ibis*	Cattle Egret
22		Pelecaniformes	*Ardeola grayii*	Indian Pond-Heron

23	Bucerotidae	Bucerotiformes	*Ocyceros birostris*	Indian Grey Hornbill
24		Bucerotiformes	*Anthracoceros albirostris*	Oriental Pied Hornbill
25	Campephagidae	Passeriformes	*Pericrocotus cinnamomeus*	Small Minivet
26		Passeriformes	*Pericrocotus ethologus*	Long-tailed Minivet
27		Passeriformes	*Pericrocotus flammeus*	Scarlet Minivet
28		Passeriformes	*Tephrodornis pondicerianus*	Common Wood-shrike
29	Capitonidae	Piciformes	*Psilopogon zeylanicus*	Brown-headed Barbet
30		Piciformes	*Psilopogon haemacephalus*	Coppersmith barbet
31	Caprimulgidae	Caprimulgiformes	*Caprimulgus indicus*	Jungle Nightjar
32		Caprimulgiformes	*Caprimulgus macrurus*	Large-tailed Nightjar
33		Caprimulgiformes	*Caprimulgus asiaticus*	Indian Nightjar
34	Charadriidae	Charadriiformes	*Vanellus indicus*	Red-wattled Lapwing
35	Ciconiidae	Ciconiiformes	*Ciconia nigra*	Black Stork
36	Columbidae	Columbiformes	*Columba livia*	Blue Rock Pigeon
37		Columbiformes	*Streptopelia orientalis*	Oriental Turtle-Dove
38		Columbiformes	*Streptopelia tranquebarica*	Red Collared Dove
39		Columbiformes	*Streptopelia decaocto*	Eurasian Collared Dove
40		Columbiformes	*Streptopelia chinensis*	Spotted Dove
41		Columbiformes	*Chalcophaps indica*	Emerald Dove
42		Columbiformes	*Treron phoenicoptera*	Yellow-footed Green-Pigeon
43	Coraciidae	Coraciiformes	*Coracias benghalensis*	Indian Roller
44	Corvidae	Passeriformes	*Urocissa erythrorhyncha*	Red-billed Blue Magpie

45		Passeriformes	*Dendrocitta vagabunda*	Rufous treepie
46		Passeriformes	*Dendrocitta formosae*	Grey treepie
47		Passeriformes	*Corvus culminatus*	Jungle Crow
48		Passeriformes	*Corvus macrorhynchos*	Large billed crow
49		Passeriformes	*Corvus splendens*	House crow
50	Cuculidae	Cuculiformes	*Hierococcyx varius*	Common hawk cuckoo
51		Cuculiformes	*Cuculus micropterus*	Indian Cuckoo
52		Cuculiformes	*Eudynamys scolopacea*	Asian Koel
53		Cuculiformes	*Centropus sinensis*	Greater Coucal
54	Dicaeidae	Passeriformes	*Dicaeum agile*	Thick-billed Flowerpecker
55		Passeriformes	*Dicaeum erythrorhynchos*	Pale-billed flowerpecker
56	Dicruridae	Passeriformes	*Dicrurus macrocercus*	Black Drongo
57		Passeriformes	*Dicrurus leucophaeus*	Ashy Drongo
58		Passeriformes	*Dicrurus caerulescens*	White-bellied Drongo
59		Passeriformes	*Dicrurus hottentottus*	Spangled Drongo
60	Estrildidae	Passeriformes	*Lonchura punctulata*	Scaly breasted munia
61		Passeriformes	*Lonchura malacca*	Black headed munia
62	Falconidae	Falconiformes	*Falco tinnunculus*	Common Kestrel
63	Fringillidae	Passeriformes	*Carpodacus erythrinus*	Common Rosefinch
64	Hirundinidae	Passeriformes	*Hirundo rustica*	Common Swallow
65		Passeriformes	*Hirundo smithii*	Wire-tailed Swallow
66	Irenidae	Passeriformes	*Aegithina tiphia*	Common lora
67		Passeriformes	*Chloropsis aurifrons*	Golden-fronted leafbird
68	Laniidae	Passeriformes	*Lanius vittatus*	Bay-backed Shrike
69	Meropidae	Coraciiformes	*Merops orientalis*	Green Bee-eater

70		Coraciiformes	*Merops leschenaulti*	Chestnut-headed Bee-eater
71	Motacillidae	Passeriformes	*Motacilla cinerea*	Grey Wagtail
72		Passeriformes	*Motacilla alba*	White Wagtail
73	Nectariniidae	Passeriformes	*Cinnyris asiaticus*	Purple Sunbird
74		Passeriformes	*Aethopyga siparaja*	Crimson Sunbird
75	Oriolidae	Passeriformes	*Oriolus oriolus*	Golden Oriole
76		Passeriformes	*Oriolus xanthornus*	Black-hooded Oriole
77		Passeriformes	*Oriolus traillii*	Maroon Oriole
78	Passeridae	Passeriformes	*Passer domesticus*	House Sparrow
79		Passeriformes	*Emberiza stewarti*	White capped bunting
80		Passeriformes	*Gymnoris xanthocollis*	Chestnut shouldered petronia
81	Phalacrocoracidae	Suliformes	*Phalacrocorax fuscicollis*	Indian Cormorant
82		Suliformes	*Microcarbo niger*	Little Cormorant
83	Phasianidae	Galliformes	*Ortygornis pondicerianus*	Grey Francolin
84		Galliformes	*Coturnix coromandelica*	Rain Quail
85		Galliformes	*Arborophila torqueola*	Hill Partridge
86		Galliformes	*Gallls gallus*	Red Junglefowl
87		Galliformes	*Lophura leucomelanos*	Kaleej Pheasant
88		Galliformes	*Pavo cristatus*	Indian Peafowl
89	Picidae	Piciformes	*Yungipicus nanus*	Brown-capped Pygmy Woodpecker
90		Piciformes	*Micropternus brachyurus*	Rufous Woodpecker
91		Piciformes	*Chrysocolaptes lucidus*	Greater Golden-backed Woodpecker

92	Psiitacidae	Psittaciformes	*Psittacula eupatria*	Alexandrine Parakeet
93		Psittaciformes	*Psittacula krameri*	Rose-ringed Parakeet
94		Psittaciformes	*Psittacula cyanocephala*	Plum-headed Parakeet
95	Pycnonotidae	Passeriformes	*Rubigula flaviventris*	Black-crested Bulbul
96		Passeriformes	*Pycnonotus jocosus*	Red whiskered Bulbul
97		Passeriformes	*Pycnonotus leucogenys*	Himalayan Bulbul
98		Passeriformes	*Pycnonotus cafer*	Red-vented Bulbul
99		Passeriformes	*Hypsipetes leucocephalus*	Black Bulbul
100	Scolopacidae	Charadriiformes	*Scolopax rusticola*	Eurasian Woodcock
101		Charadriiformes	*Tringa ochropus*	Green Sandpiper
102	Sittidae	Passeriformes	*Sitta frontalis*	Velvet-fronted Nuthatch
103		Passeriformes	*Certhia himalayana*	Bar-tailed Tree-Creeper
104	Strigidae	Strigiformes	*Tyto alba*	Barn Owl
105		Strigiformes	*Strix leptogrammica*	Brown Wood-Owl
106		Strigiformes	*Glaucidium cuculoides*	Asian Barred Owlet
107		Strigiformes	*Ninox scutulata*	Brown Hawk-Owl
108		Strigiformes	*Ketupa zeylonensis*	Brown fish owl
109		Strigiformes	*Athene brama*	Spotted Owlet
110	Sturnidae	Passeriformes	*Sturnus contra*	Asian Pied Starling
111		Passeriformes	*Acridotheres fuscus*	Jungle Myna
112		Passeriformes	*Acridotheres tristis*	Common Myna
113	Sylviinae	Passeriformes	*Prinia socialis*	Ashy Prinia
114		Passeriformes	*Acrocephalus dumetorum*	Blyth's Reed-Warbler
115		Passeriformes	*Orthotomus Sutorius*	Common Tailorbird
116		Passeriformes	*Phylloscopus neglectus*	Plain Leaf-Warbler

117		Passeriformes	*Phylloscopus humei*	Hume's Warbler
118		Passeriformes	*Phylloscopus trochiloides*	Greenish Leaf-Warbler
119		Passeriformes	*Phylloscopus tytleri*	Tytler's Leaf-Warbler
120		Passeriformes	*Phylloscopus occipitalis*	Western Crowned Warbler
121		Passeriformes	*Horornis fortipes*	Brown flanked bush warbler
122		Passeriformes	*Phylloscopus griseolus*	Sulphur bellied warbler
123		Passeriformes	*Phylloscopus affinis*	Tickells leaf warbler
124		Passeriformes	*Phylloscopus trochiloides nitidus*	Green warbler
125		Passeriformes	*Acrocephalus concinens*	Blunt winged warbler
126		Passeriformes	*Phylloscopus inornatus*	Yellow browed warbler
127		Passeriformes	*Phylloscopus whistleri*	Whistler's Flycatcher-Warbler
128		Passeriformes	*Curruca curruca*	Lesser Whitethroat
129		Passeriformes	*Ficedula parva*	Red-throated Flycatcher
130		Passeriformes	*Ficedula strophiata*	Orange-gorgeted Flycatcher
131		Passeriformes	*Ficedula superciliaris*	Ultralnmarine Flycatcher
132		Passeriformes	*Eumyias thalassina*	Verditer Flycatcher
133		Passeriformes	*Niltava macgrigoriae*	Small NiItava
134		Passeriformes	*Cyornis tickelliae*	Tickell's Blue-Flycatcher
135		Passeriformes	*Culicicapa ceylonensis*	Grey-headed Flycatcher
136		Passeriformes	*Terpsiphone paradisi*	Asian Paradise-Flycatcher
137		Passeriformes	*Muscicapa dauurica*	Asian Brown Flycatcher

138		Passeriformes	*Ficedula hyperythra*	Snowy browed flycatcher
139		Passeriformes	*Rhipidura albicollis*	Yellow-bellied Fantail
140		Passeriformes	*Rhipidura aureola*	White-browed Fantail
141		Passeriformes	*Parus major*	Great Tit
142	Timaliinae	Passeriformes	*Argya striata*	Jungle Babbler
143		Passeriformes	*Pellorneum ruficeps*	Puff-Throated Babbler
144	Turdinae	Passeriformes	*Myophonus caeruleus*	Blue Whistling-Thrush
145		Passeriformes	*Turdus ruficollis*	Black-throated Thrush
146		Passeriformes	*Zoothera citrina*	Orange-headed Thrush
147		Passeriformes	*Zoothera dauma*	Scaly Thrush
148		Passeriformes	*Turdus unicolor*	Tickell's Thrush
149		Passeriformes	*Turdus boulboul*	Grey-winged Blackbird
150		Passeriformes	*Luscinia pectoralis*	Hiamalayan Rubythroat
151		Passeriformes	*Copsychus saularis*	Oriental Magpie-Robin
152		Passeriformes	*Copsychus malabaricus*	White-rumped Shama
153		Passeriformes	*Phoenicurus ochruros*	Black Redstart
154		Passeriformes	*Chaimarrornis leucocephalus*	White-capped Redstart
155		Passeriformes	*Saxicola torquata*	Common Stonechat
156		Passeriformes	*Saxicola caprata*	Pied Bushchat
157		Passeriformes	*Saxicola ferreus*	Grey Bushchat
158	Upupidae	Bucerotiformes	*Upupa epops*	Common Hoopoe
159	Vangidae	Passeriformes	*Hemipus picatus*	Bar-winged Flycatcher Shrike
160	Zosteropidae	Passeriformes	*Zosterops palpebrosus*	Oriental White-eye

Churdhar Wildlife Sanctuary (CWS)

4.4.4 Avian family composition

160 species belonging to 43 families from 12 orders were reported from ChWLS during July and November (Table 32). Within the study area, the most dominant families were Muscicapidae (11.88%), Picidae (6.88%), Corvidae (5.62%) and Phylloscopidae (5.62%). At the same time, the most recessive were species from family Apodidae, Caprimulgidae, Certhiidae, Cinclidae, Estrildidae, Falconidae, Paradoxornithidae, Pellorneidae, Rhipiduridae, Stenostiridae, Troglodytidae, Turdidae, Upupidae, Vireonidae and Zosteropidae (0.62% each) (Figure 52). We also encountered three Near Threatened (NT) species from the area: *Gyps himalayensis*, *Gypaetus barbatus*, and *Nisaetus nipalensis.*

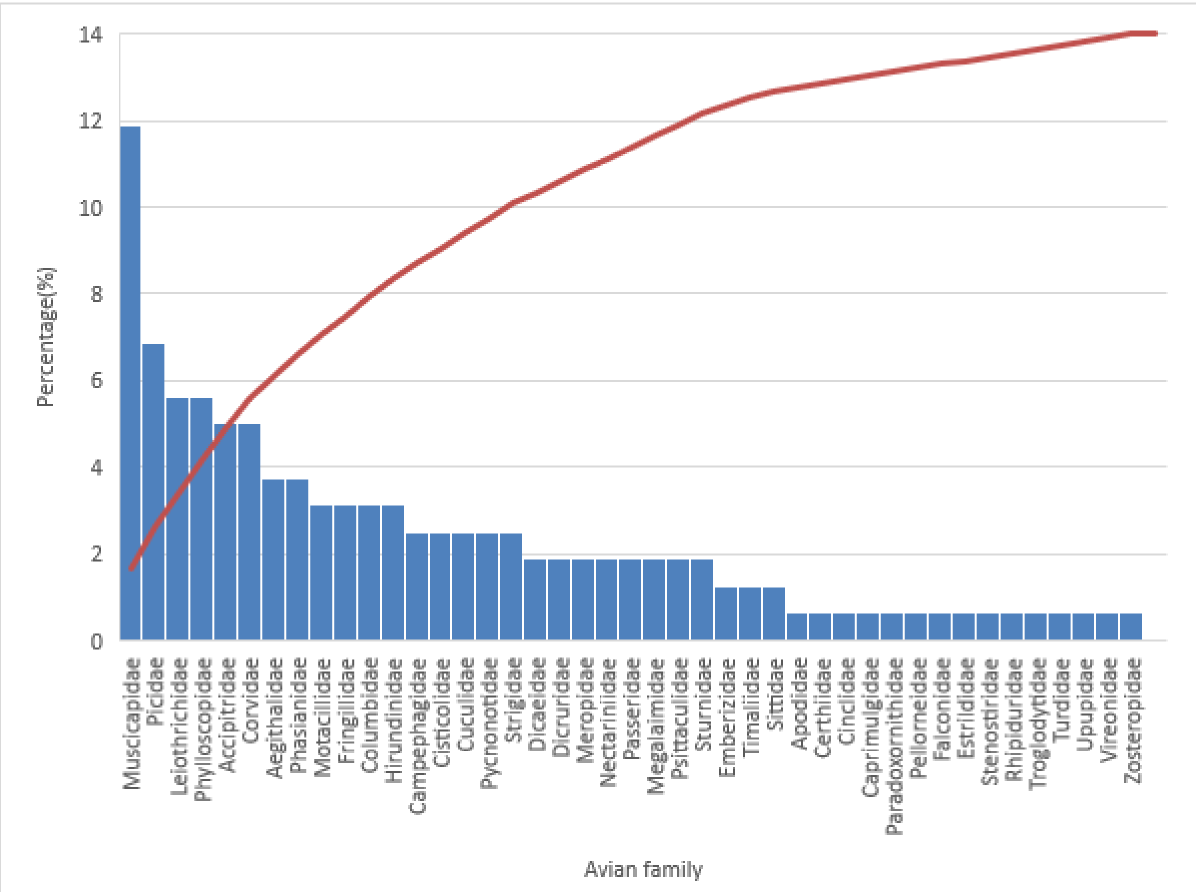


Figure 4.11 Percentile representation of familywise avian composition in CWS, Himachal Pradesh.

4.4.5 Density estimation using the point count method

Bird communities found in different habitat types such as agricultural field, alpine meadow, forest and streamlines showed significant difference in species compositions and densities. During winter and summer a total of 723 observations were from 48-point count stations. 322(93 from Agricultural fields, 91 from alpine meadows, 98 from forest and 119 from streamline) and 401(93 for Agricultural field, 61 from alpine meadows, 76 from forest, 92 from streamline) observations were recorded respectively during summer and winter. The best-fit model was selected based on Akaike Information Criteria (AIC). The selected models along with the key functions and other estimates have been mentioned in table. Agricultural fields were recorded to harbor the maximum density of birds (i.e. 251.6 birds/sq.km. in summer and 111 birds /sq.km. in winter). The lowest density i.e. 37.1 birds/sq. km. in summer and 83.9 birds/sq.km. in winter were recorded respectively from streamline and forest.

Table 4.4 Result of bird density estimation for CWS in summer; DS - estimate of density of clusters; E(S) - estimate of expected value of cluster size; D - estimate of density of animals.

Transect	Model	Key function	DS	E(S)	D	CV	Minimum AIC	Detection probability	Encounter rate	Cluster size
Agricultural field	Half normal	Hermite polynomial	102.14	2.46	251.65	19.28	164.96	55.3	24.6	20.1
Forest	Negative exponential	Hermite polynomial	37.04	5.4	200.24	37.51	113.02	54.3	4.3	41.4
Alpine meadow	Half normal	Simple polynomial	13.41	3.16	42.43	34.69	93.65	37.8	6.3	55.9
Streamline	Half normal	Cosine	14.05	2.64	37.12	23.16	107.4	71.1	6.2	22.8

Table 4.4 Result of bird density estimation for CWS in winter; DS - estimate of density of clusters; E(S) - estimate of expected value of cluster size; D - estimate of density of animals.

Transect	Model	Key function	DS	E(S)	D	CV	Minimum AIC	Detection probability	Encounter rate	Cluster size
Agricultural field	Half normal	Cosine	69.2	1.6	111.01	22.19	132.85	55	17	28
Forest	Half normal	Cosine	40	2.09	83.98	28.97	76.43	56.9	18.6	24.5
Alpine meadow	Half normal	Cosine	45.32	2.15	97.65	24.48	108.61	53	15.5	31.5
Streamline	Hazard rate	Cosine	62.79	1.7	107.29	23.98	103.03	67.6	18	14.4

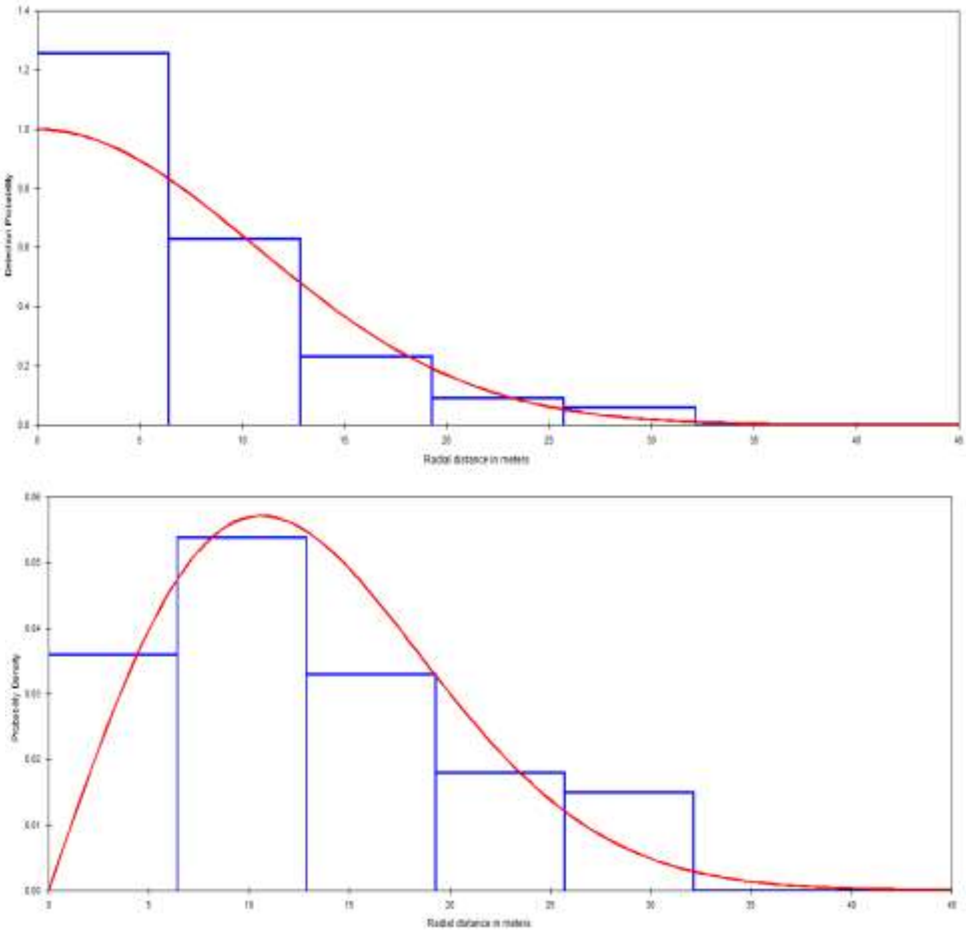
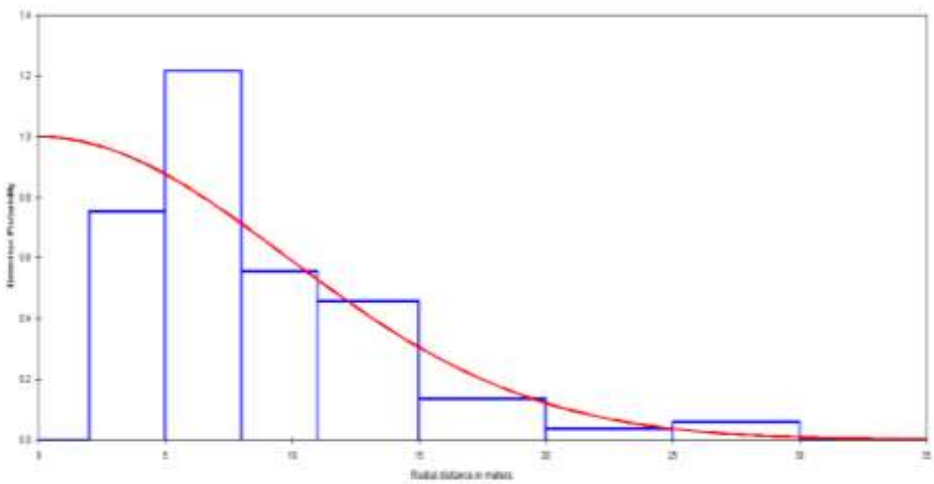


Figure 4.12 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for agricultural fields in CWS during summer respectively.



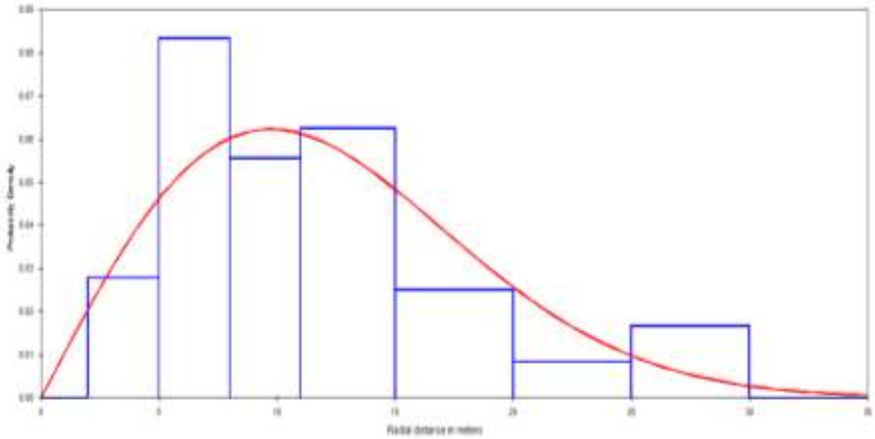


Figure 4.13 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for alpine meadows in CWS during summer respectively.

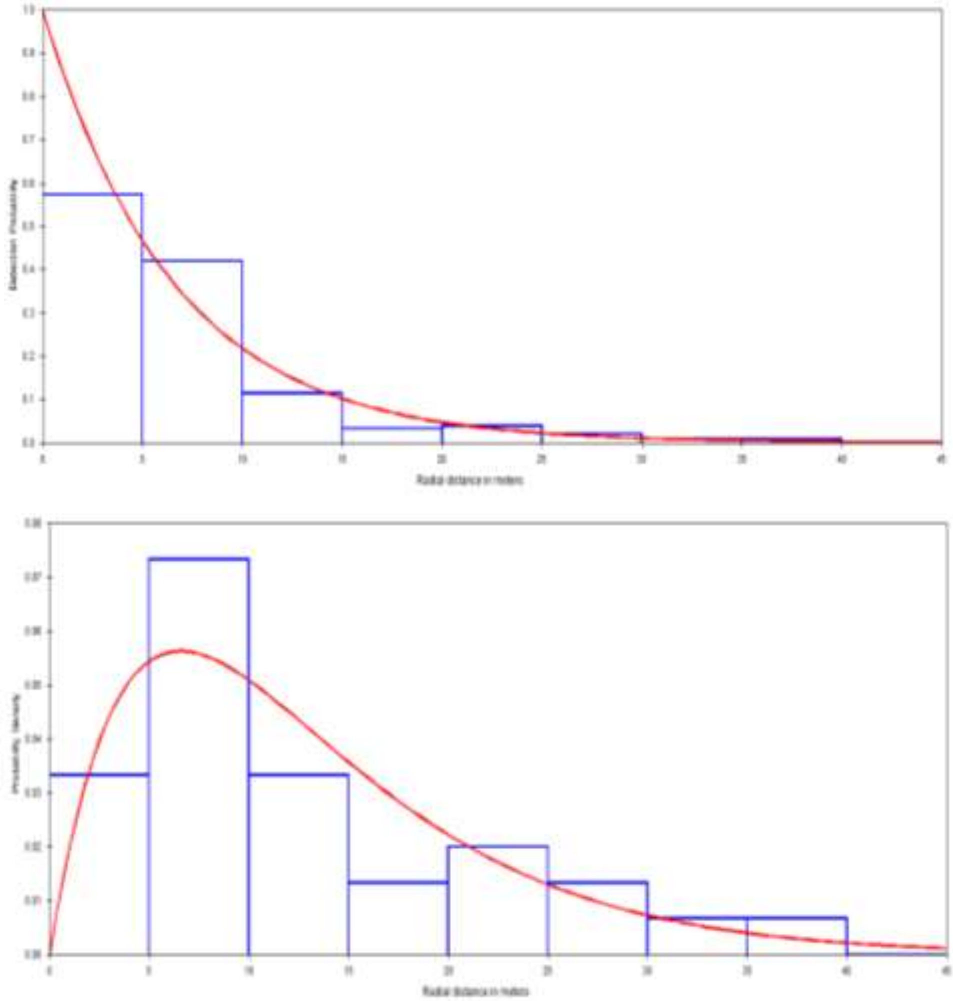


Figure 4.14 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for forests in CWS during summer respectively.

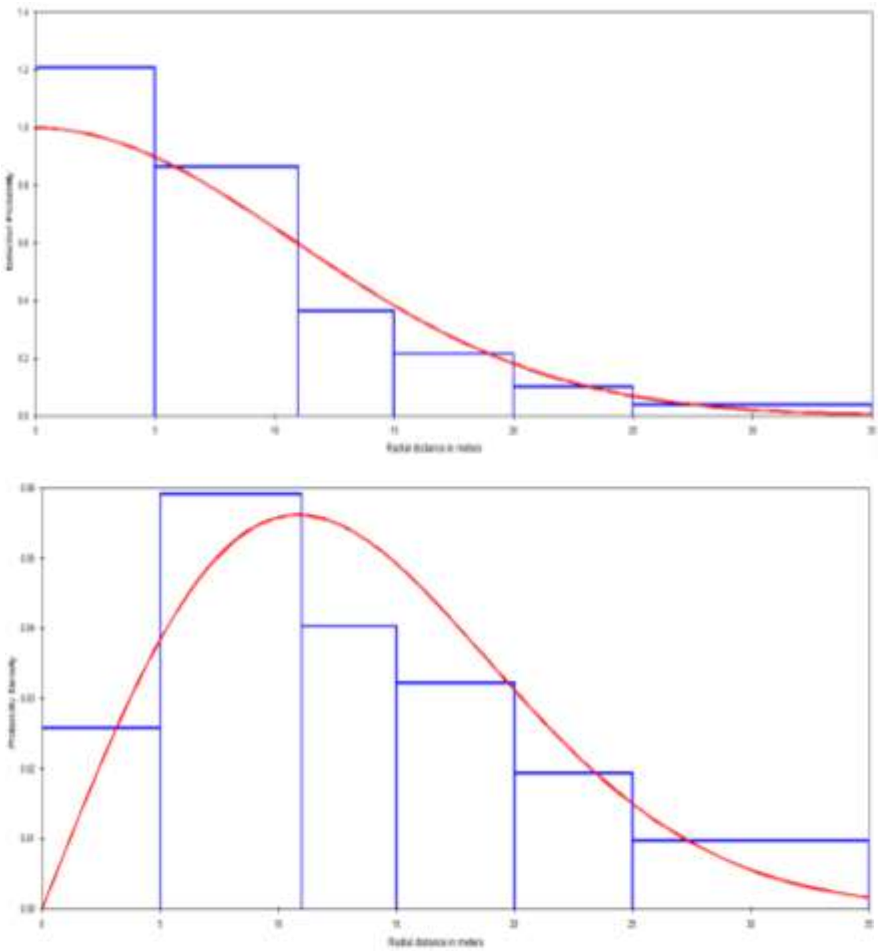
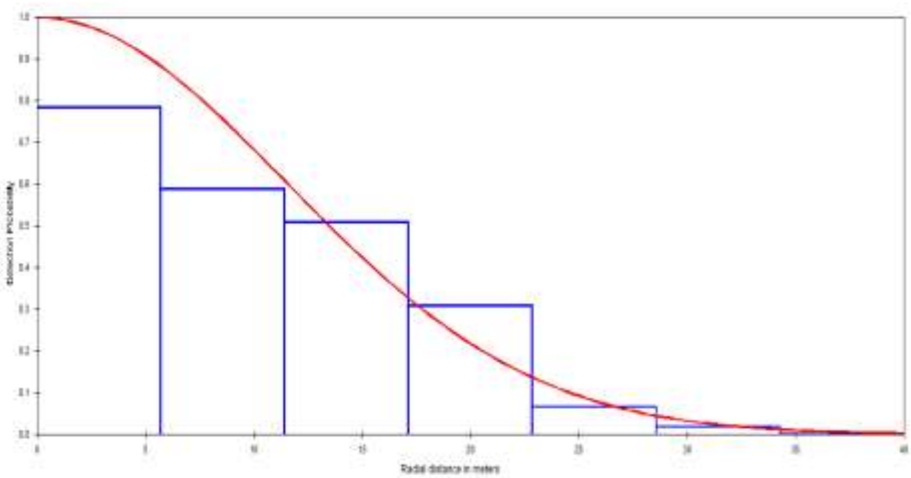


Figure 4.14 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for streamlines in CWS during summer respectively.



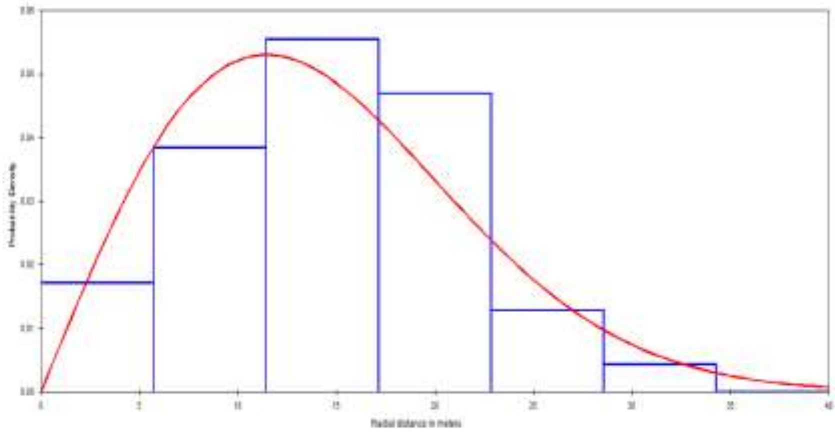


Figure 4.15 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for agricultural fields in CWS during winter respectively.

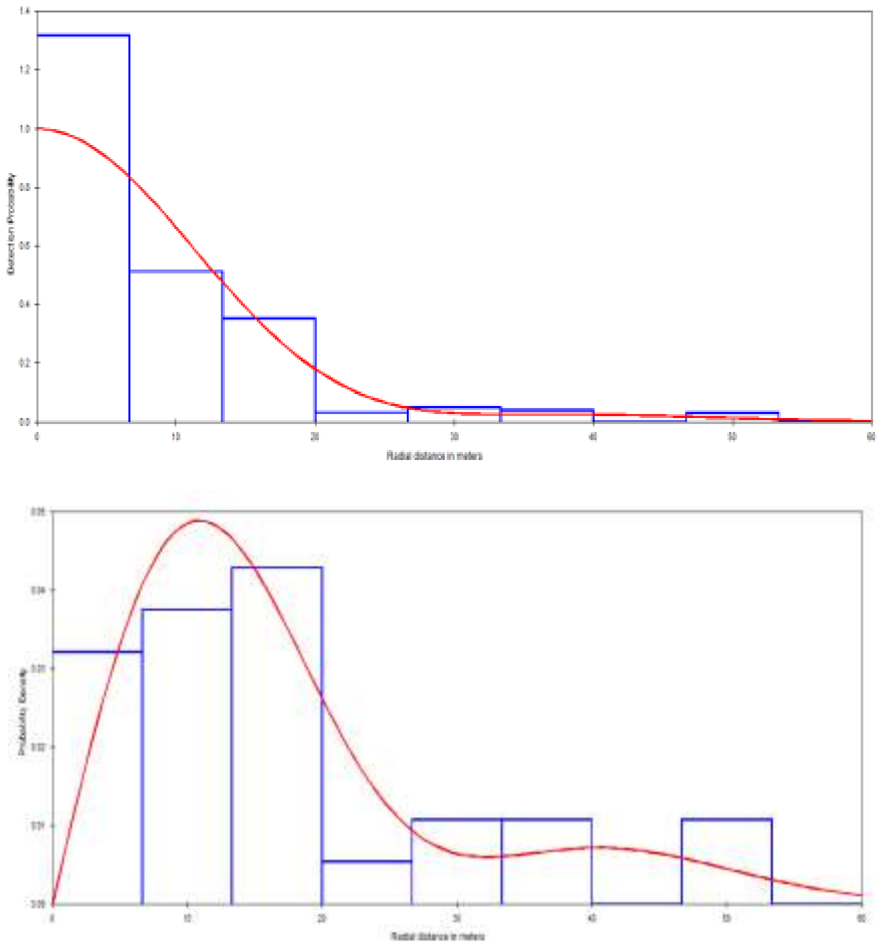


Figure 4.16 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for alpine meadows in CWS during winter respectively.

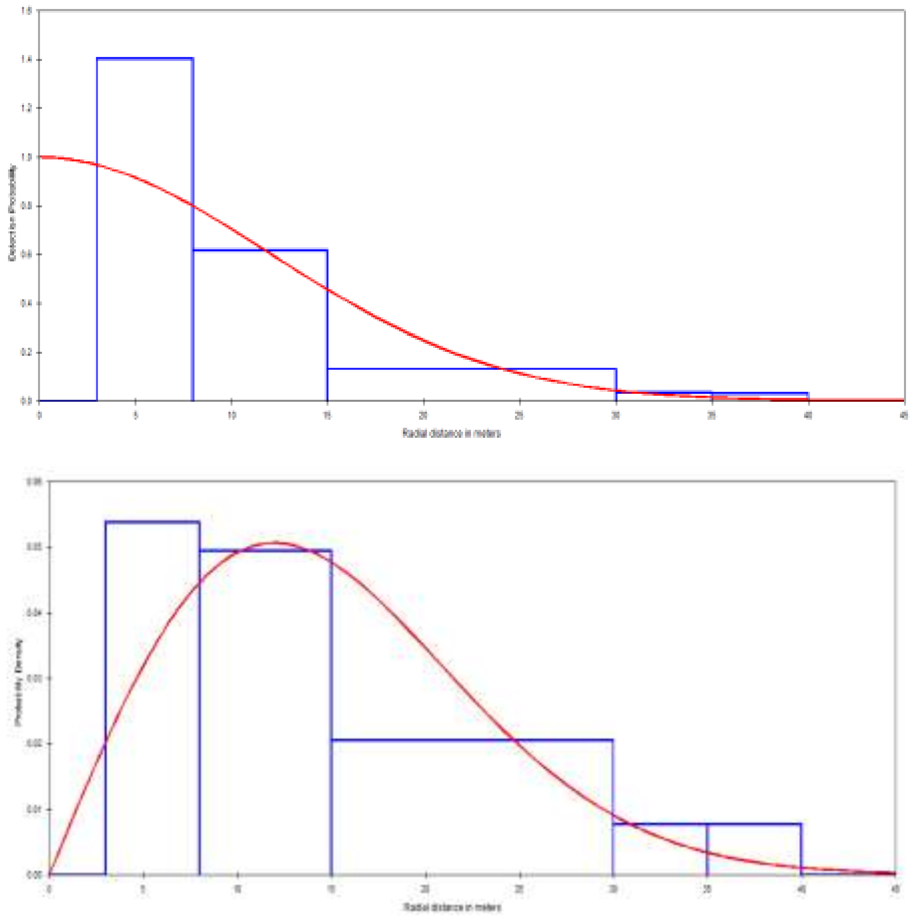
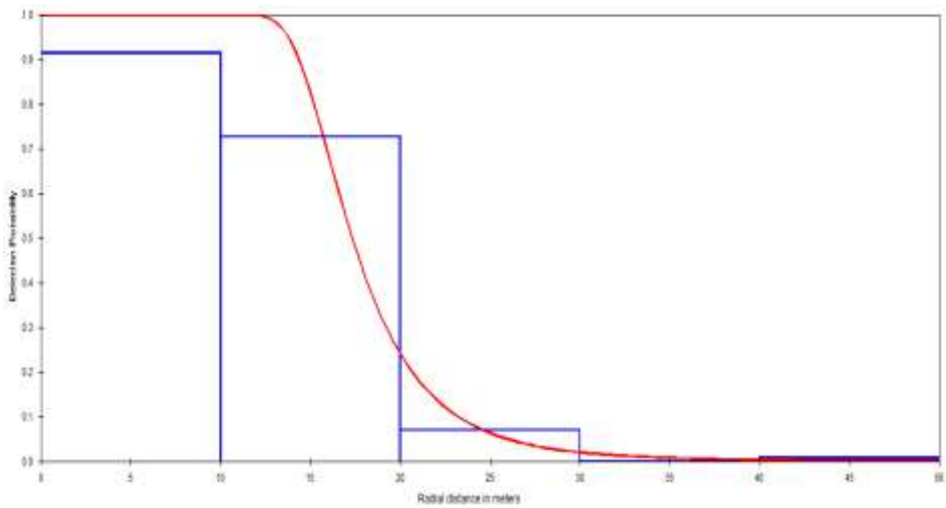


Figure 4.17 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for forests in CWS during winter respectively.



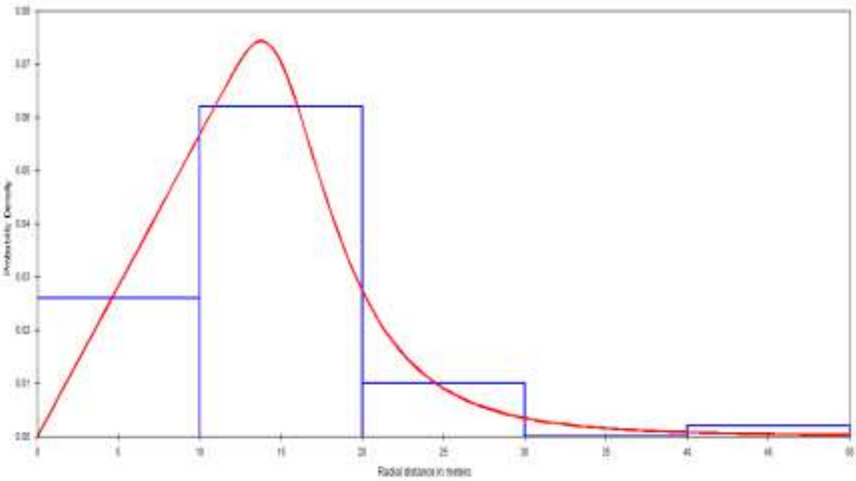


Figure 4.18 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for streamlines in CWS during winter respectively.

4.4.6 Feeding guild structure

During summer, insectivores (34.48% for agricultural field, 30.43% for alpine meadow, 34.48% for forest, 52.94% for streamline) and omnivores (27.59% for agricultural field, 34.78% for alpine meadow, 34.78% for forest, 20.59% for streamline) were found to be dominating over all the feeding guild representatives. Insectivore (52.94%) feeding guild was shown to possess the maximum number of representative species across all the habitats and feeding guilds. Frugivore, granivore and herbivores were shown absence respectively from alpine meadows, and streamline and agricultural fields. Whereas nectarivore (3.45%) and piscivore (2.94%) species were found only in forest and streamline respectively.

During winter, a similar species distribution pattern among feeding guilds were observed in the case of insectivore and omnivore like summer; showing dominance over other feeding guilds. Granivore, herbivore, nectarivore and scavenges were shown absence respectively from streamline, alpine meadow, alpine meadow and streamline. Piscivore was absent across all the habitat types.

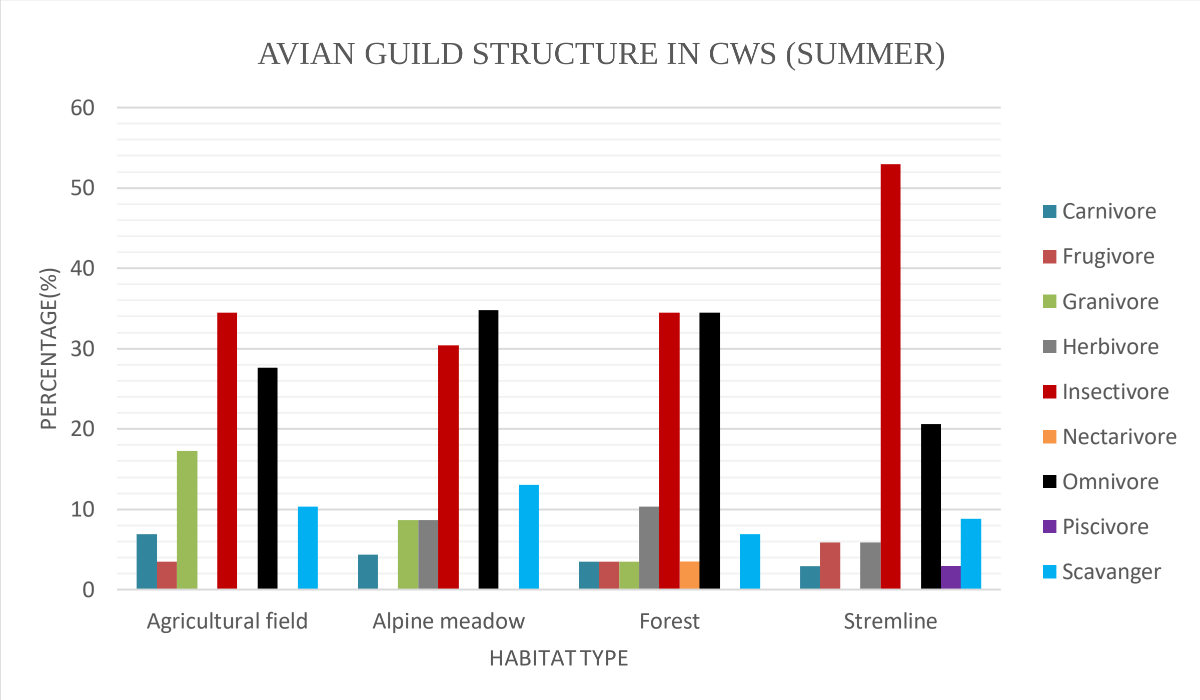


Figure 4.19 Percentages of avian feeding guild composition in different available habitat types in CWS during summer.

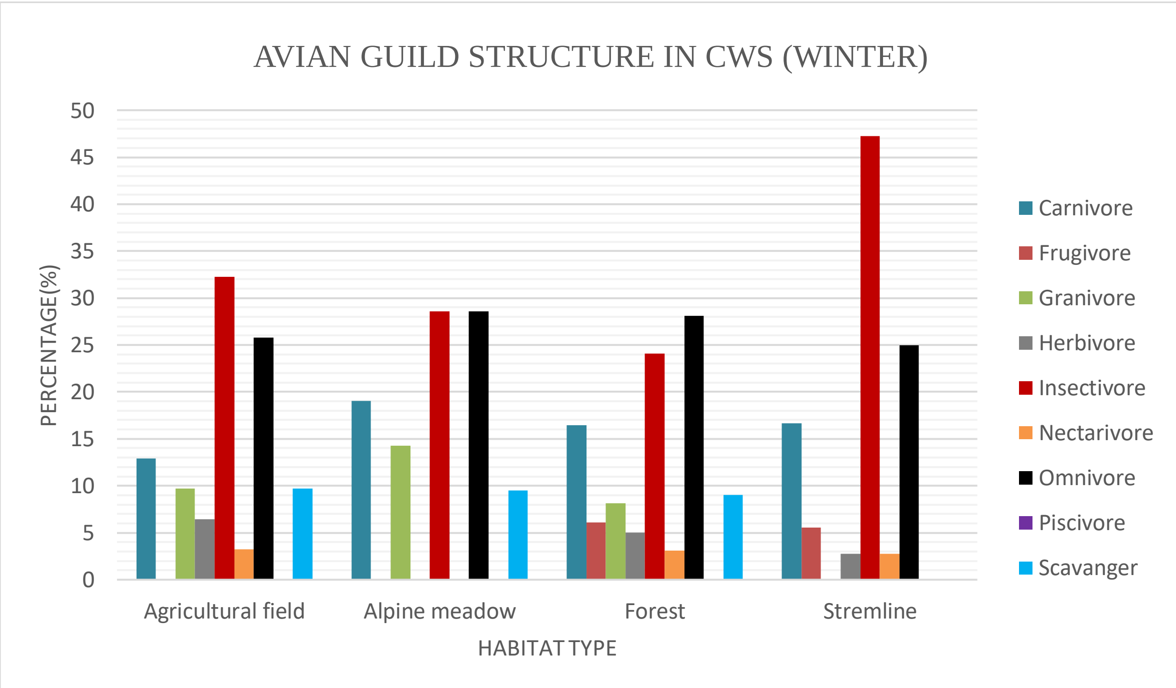


Figure 4.20 Percentages of avian feeding guild composition in different available habitat types in CWS during winter.

Table 4.6 Checklist of Birds found in CWS

Sl. No.	Family	Order	Scientific Name	Common name	IUCN Status
1	Accipitridae	Accipitriformes	*Gyps fulvus*	Eurasian vulture	LC
2		Accipitriformes	*Gyps himalayensis*	Himalayan vulture	NT
3		Accipitriformes	*Gypaetus barbatus*	Bearded vulture	NT
4		Accipitriformes	*Ictinaetus malaiensis*	Black eagle	LC
5		Accipitriformes	*Nisaetus nipalensis*	Mountain hawk eagle	NT
6		Accipitriformes	*Spilornis cheela*	Crested serpent eagle	LC
7	Aegithalidae	Passeriformes	*Aegithalos concinnus*	Black throated tit	LC
10		Passeriformes	*Parus monticolus*	Green backed tit	LC
11		Passeriformes	*Parus cinereus*	Cinereous tit	LC
12		Passeriformes	*Periparus ater*	Coal tit	LC
13	Apodidae	Apodiformes	*Apus affinis*	Little swift	LC
14	Caprimulgidae	Caprimulgiformes	*Caprimulgus indicus*	Jungle nightjar	LC
15	Certhiidae	Passeriformes	*Certhia himalayana*	Bar tailed treecreeper	LC
16	Cinclidae	Passeriformes	*Cinclus pallasii*	Brown dipper	LC
17	Cisticolidae	Passeriformes	*Prinia superciliaris*	Hill prinia	LC
18		Passeriformes	*Prinia hodgsonii*	Gray-breasted prinia	LC
19		Passeriformes	*Prinia crinigera*	Himalayan prinia	LC
20	Columbidae	Columbiformes	*Streptopelia orientalis*	Oriental turtle dove	LC
21		Columbiformes	*Spilopelia chinensis*	Spotted dove	LC

22		Columbiformes	*Treron sphenurus*	Wedge tailed green pigeon	LC
23		Columbiformes	*Columba livia*	Rock pigeon	LC
24	Corvidae	Passeriformes	*Nucifraga caryocatactes*	Spotted nutcracker	LC
25					
27		Passeriformes	*Garrulus glandarius*	Eurasian jay	LC
28		Passeriformes	*Garrulus lanceolatus*	Black headed jay	LC
29		Passeriformes	*Urocissa flavirostris*	Yellow-billed blue magpie	LC
30		Passeriformes	*Dendrocitta formosae*	Grey treepie	LC
31		Passeriformes	*Corvus macrorhynchos*	Large billed crow	LC
32	Cuculidae	Cuculiformes	*Cuculus micropterus*	Indian cuckoo	LC
33		Cuculiformes	*Cuculus canorus*	Common cuckoo	LC
34		Cuculiformes	*Hierococcyx varius*	Common hawk cuckoo	LC
35	Dicruridae	Passeriformes	*Dicrurus leucophaeus*	Ashy drongo	LC
36		Passeriformes	*Dicrurus hottentottus*	Hair-crested Drongo	LC
37	Emberizidae	Passeriformes	*Emberiza cia*	Rock bunting	LC
38	Estrildidae	Passeriformes	*Lonchura punctulata*	Scaly breasted munia	LC
39	Falconidae	Falconiformes	*Falco tinnunculus*	Common kestrel	LC
40	Fringillidae	Passeriformes	*Carpodacus erythrinus*	Common rosefinch	LC
41	Hirundinidae	Passeriformes	*Delichon nipalense*	Nepal house martin	LC
42		Passeriformes	*Ptyonoprogne concolor*	Dusky crag martin	LC

43		Passeriformes	*Cecropis daurica*	Red rumped swallow	LC
44		Passeriformes	*Petrochelidon luvicola*	Streaked throated swallow	LC
45		Passeriformes	*Hirundo rustica*	Barn swallow	LC
46					
47	Leiothrichidae	Passeriformes	*Grammatoptila striatus*	Striated laughingthrush	LC
53		Passeriformes	*Trochalopteron lineatum*	Streaked laughingthrush	LC
54		Passeriformes	*Trochalopteron variegatum*	Variegated laughingthrush	LC
55		Passeriformes	*Pterorhinus ruficeps*	Rufous crowned laughingthrush	LC
56		Passeriformes	*Pterorhinus albogularis*	White throated laughingthrush	LC
57		Passeriformes	*Actinodura strigula*	Chestnut-tailed Minla.	LC
58		Passeriformes	*Myophonus caeruleus*	Blue whistling-thrush	LC
60		Passeriformes	*Heterophasia capistrata*	Rufous Sibia	LC
61	Picidae	Piciformes	*Dendrocoptes auriceps*	Brown-fronted Woodpecker	LC
62		Piciformes	*Picus squamatus*	Scaly-bellied Woodpecker	LC
63		Piciformes	*Picumnus innominatus*	Speckled piculet	LC
64		Piciformes	*Picus chlorolophus*	Lesser yellownape	LC
65		Piciformes	*Chrysophlegma flavinucha*	Greater yellownape	LC

66		Piciformes	*Yungipicus nanus*	Brown capped pygmy woodpecker	LC
67		Piciformes	*Dendrocopos macei*	Fulvous breasted woodpecker	LC
68		Piciformes	*Chrysocolaptes guttacristatus*	Greater flameback woodpecker	LC
69		Piciformes	*Picus xanthopygaeus*	Streak throated woodpecker	LC
70		Piciformes	*Dendrocopos himalayensis*	Himalayan woodpecker	LC
71		Piciformes	*Dendrocopos hyperythrus*	Rufous bellied woodpecker	LC
72	Pycnonotidae	Passeriformes	*Hypsipetes leucocephalus*	Black bulbul	LC
73		Passeriformes	*Pycnonotus leucogenys*	Himalayan bulbul	LC
74		Passeriformes	*Pycnonotus cafer*	Red vented bulbul	LC
75		Passeriformes	*Pycnonotus jocosus*	Red whiskered bulbul	LC
76	Meropidae	Coraciiformes	*Nyctyornis athertoni*	Blue bearded bee eater	LC
77	Cisticolidae	Passeriformes	*Orthotomus sutorius*	Common tailorbird	LC
78	Phasianidae	Galliformes	*Lophophorus impejanus*	Himalayan Monal	LC
79		Galliformes	*Gallus gallus*	Red junglefowl	LC
80		Galliformes	*Prinia hodgsonii*	Kalij pheasant	LC
81		Galliformes	*Pucrasia macrolopha*	Koklass pheasant	LC

82		Galliformes	*Francolinus francolinus*	Black francolin	LC
83	Timaliidae	Passeriformes	*Cyanoderma pyrrhops*	Black Chinned babbler	LC
84					
85		Passeriformes	*Erythrogenys erythrogenys*	Rusty checked schimitar babbler	LC
86		Passeriformes	*Treron sphenurus*	White-browed Shrike-Babbler	LC
88	Fringillidae	Passeriformes	*Chloris spinoides*	Yellow-breasted Greenfinch	LC
89	Psittaculidae	Psittaciformes	*Psittacula cyanocephala*	Plum headed parakeet	LC
90		Psittaciformes	*Psittacula himalayana*	Slaty headed parakeet	LC
91		Psittaciformes	*Psittacula krameri*	Rose-ringed parakeet	LC
92	Muscicapidae	Passeriformes	*Phoenicurus fuliginosus*	Plumbeous water redstart	LC
93		Passeriformes	*Phoenicurus leucocephalus*	White capped redstart	LC
94	Phylloscopidae	Passeriformes	*Phylloscopus whistleri*	Whistler's warbler	LC
95		Passeriformes	*Phylloscopus chloronotus*	Lemon-rumped Warbler	LC
96		Passeriformes	*Phylloscopus humei*	Hume’s warbler	LC
97		Passeriformes	*Phylloscopus xanthoschistos*	Grey-hooded warbler	LC
98		Passeriformes	*Phylloscopus xanthoschistos*	Grey hooded warbler	LC
99		Passeriformes	*Phylloscopus humei*	Hume's leaf warbler	LC

100		Passeriformes	*Phylloscopus inornatus*	Yellow Browed warbler	LC
101		Passeriformes	*Phylloscopus pulcher*	Buff barred warbler	LC
102		Passeriformes	*Phylloscopus trochiloides*	Greenish warbler	LC
103		Passeriformes	*Phylloscopus reguloides*	Blyth's leaf warbler	LC
104	Accipitridae	Accipitriformes	*Nisaetus nipalensis*	Moutain hawk eagle	LC
105	Upupidae	Bucerotiformes	*Upupa epops*	Common Hoopoe	LC
106	Megalaimidae	Piciformes	*Psilopogon virens*	Great barbet	LC
107	Motacillidae	Passeriformes	*Motacilla cinerea*	Grey wagtail	LC
108		Passeriformes	*Anthus sylvanus*	Upland pipit	LC
109	Muscicapidae	Passeriformes	*Monticola cinclorhyncha*	Blue capped rock thrush	LC
110		Passeriformes	*Enicurus scouleri*	Little forktail	LC
111		Passeriformes	*Enicurus maculatus*	Spotted forktail	LC
112		Passeriformes	*Saxicola maurus*	Siberian stonechat	LC
113		Passeriformes	*Saxicola ferreus*	Grey bushchat	LC
114		Passeriformes	*Oenanthe fusca*	Brown rock chat	LC
115		Passeriformes	*Niltava sundara*	Rufous bellied niltava	LC
116		Passeriformes	*Eumyias thalassinus*	Verditer flycatcher	LC
117		Passeriformes	*Ficedula parva*	Red breasted flycatcher	LC
118		Passeriformes	*Phoenicurus ochruros*	Grey headed canary flycatcher	LC

119		Passeriformes	*Ficedula superciliaris*	Ultramarine flycatcher	LC
120		Passeriformes	*Tarsiger cyanurus*	Orange flanked bush robin	LC
121		Passeriformes	*Phoenicurus ochruros*	Black redstart	LC
122	Nectariniidae	Passeriformes	*Cinnyris asiaticus*	Purple sunbird	LC
123	Passeridae	Passeriformes	*Passer cinnamomeus*	Russet sparrow	LC
124		Passeriformes	*Passer domesticus*	House sparrow	LC
125	Strigidae	Strigiformes	*Glaucidium cuculoides*	Asian barred owlet	LC
126		Strigiformes	*Strix nivicolum*	Himlayan wood owl	LC
127	Sturnidae	Passeriformes	*Acridotheres tristis*	Common myna	LC
128	Troglodytidae	Passeriformes	*Troglodytes hiemalis*	Winter wren	LC
129	Turdidae	Passeriformes	*Turdus boulboul*	Grey winged blackbird	LC
130	Zosteropidae	Passeriformes	*Zosterops palpebrosus*	Oriental whiteeye	LC

Pin Valley National Park (PVNP)

4.4.7 Avian family composition

A total of 94 species belonging to 27 families from 10 orders were reported from PVNP (Table 4.9). Within the study area, the most dominant families were Fringillidae (10.63%), Corvidae (9.57%); Muscicapidae (9.57%), Accipitridae (7.44%); while the most recessive were species from the families Acrocephalidae, Anatidae, Apodidae, Cinclidae, Falconidae, Phasianidae, Turdidae (2.12% each); Ardeidae, Dicruridae, Laniidae, Oriolidae, Paridae, Sylviidae (1.06% each) (Fig. 4.21). We also encountered two Near Threatened (NT) species, namely Himalayan griffon (*Gyps himalayensis*) and bearded vulture (*Gypaetus barbatus*); one species Endangered (EN) species i.e. Egyptian vulture (*Neophron percnopterus*).

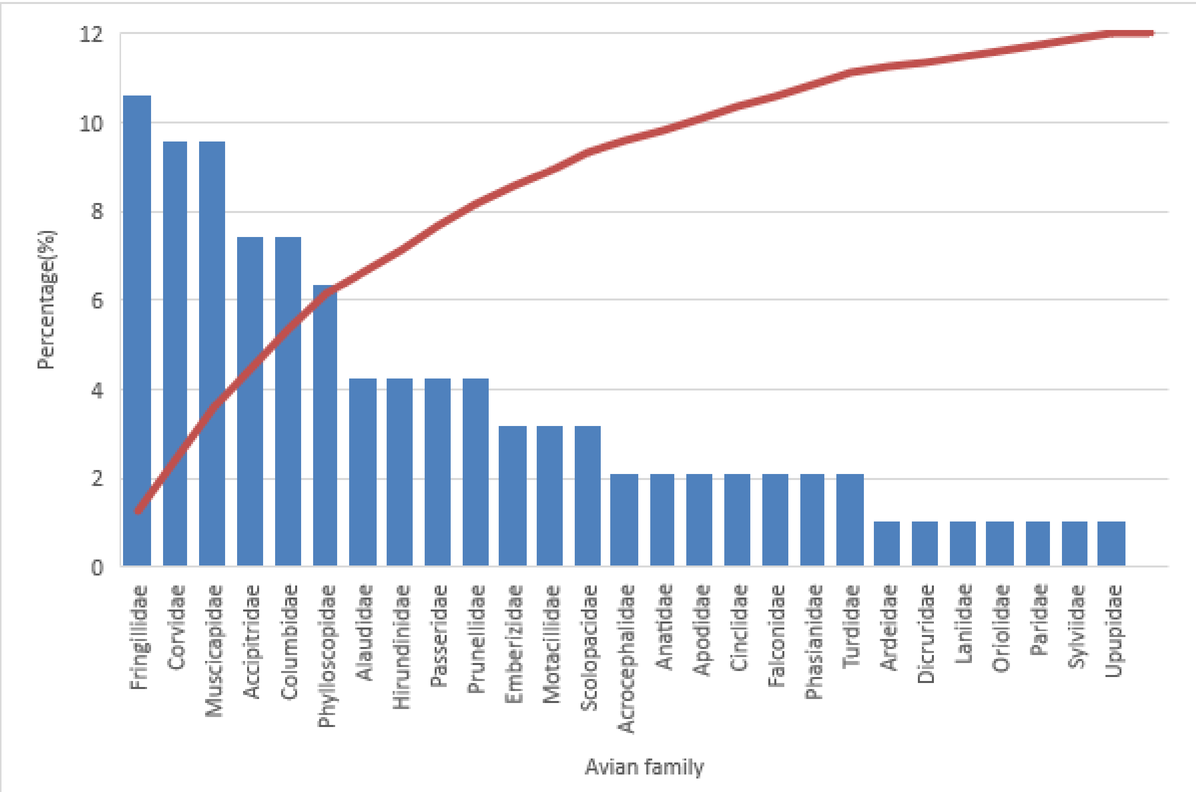


Figure 4.21 Percentile representation of familywise avian composition in PVNP, Himachal Pradesh.

4.4.8 Density estimation using point count method

Being a part of the trans-Himalayan landscape Spiti Valley offers an open landscape. Sampling in different locally segregated small-scale landscapes (i.e. barelands, shrublands, riverbed and agricultural fields) provided different species compositions. During winter and summer recorded a total of 501 observations were from 48-point count stations. 278 (61 from Agricultural fields, 91 from streamlines, 44 from shrublands and 61 from barelands) and 223(43 for Agricultural field, 51 from streamlines, 106 from shrublands, 23 from barelands) observations were recorded respectively during summer and winter. The best-fit model was selected based on Akaike Information Criteria (AIC). The selected models along with the key functions and other estimates have been mentioned in table 4.7 and table 4.8. In summer streamlines were shown to harbor the maximum density of birds (161.36 birds /sq.km.) and in winter shrubland holds the maximum density of birds (126.5 birds/sq.km.). The lowest density i.e. 106.23 birds/sq. km. in summer and 53.06 birds/sq.km. in winter were recorded from barelands.

Table 4.7 Result of bird density estimation for PVNP in summer; DS - estimate of density of clusters; E(S) - estimate of expected value of cluster size; D - estimate of density of animals.

Transect	Model	Key function	DS	E(S)	D	CV	Minimum AIC	Detection probability	Encounter rate	Cluster size
Agricultural field	Hazard rate	Simple polynomial	42.29	2.68	113.39	21.84	228.13	67.5	11.6	20.9
Streamline	Half normal	Simple polynomial	55.73	2.89	161.36	19.85	272.61	42.7	31.4	25.9
Shrubland	Hazard rate	Cosine	41.39	2.78	115.42	19.56	240.23	40.2	30.2	29.6
Bare land	Hazard rate	Cosine	8.09	2	106.23	20.48	185.9	75.3	5.2	19.5

Table 4.8 Result of bird density estimation for PVNP in winter; DS - estimate of density of clusters; E(S) - estimate of expected value of cluster size; D - estimate of density of animals.

Transect	Model	Key function	DS	E(S)	D	CV	Minimum AIC	Detection probability	Encounter rate	Cluster size
Agricultural field	Half normal	Simple polynomial	8.09	2.98	64.12	27.48	117.49	52.8	4.3	42.9
Streamline	Half normal	Simple polynomial	24.92	3.64	90.75	23.54	123	59.6	14.9	25.5
Shrubland	Half normal	Simple polynomial	53.53	2.36	126.5	20.13	131.01	67.2	11.1	21.8
Bare land	Half normal	Cosine	28.15	2.59	53.06	24.23	136.39	49.6	32.9	17.5

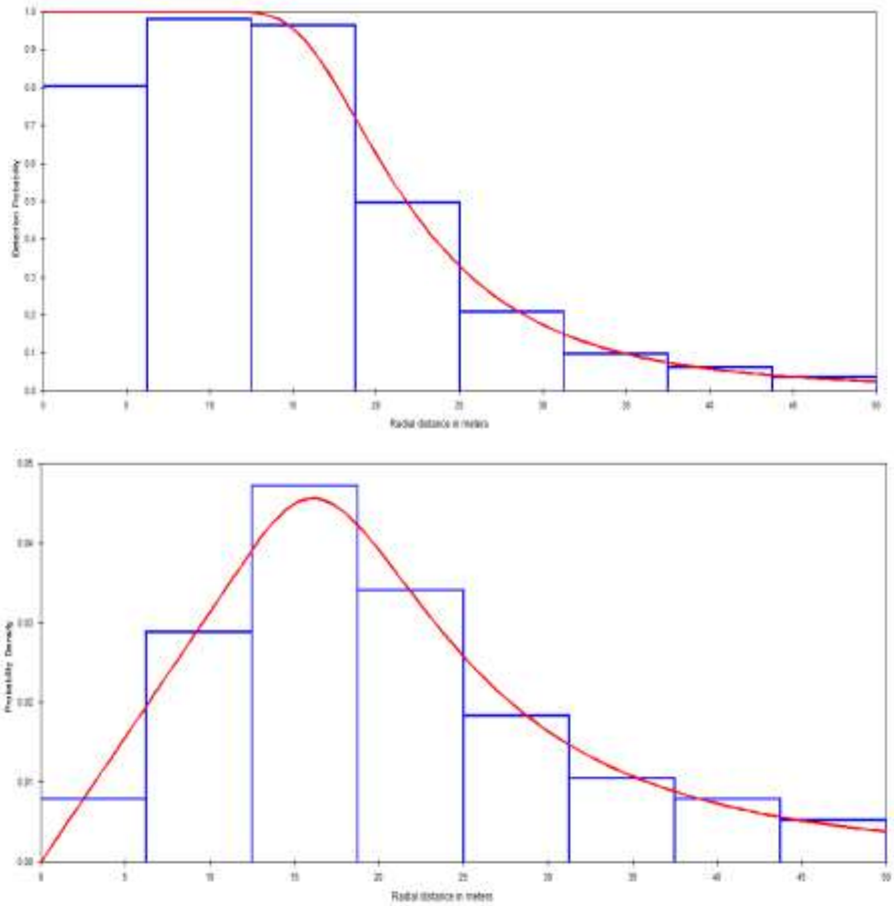
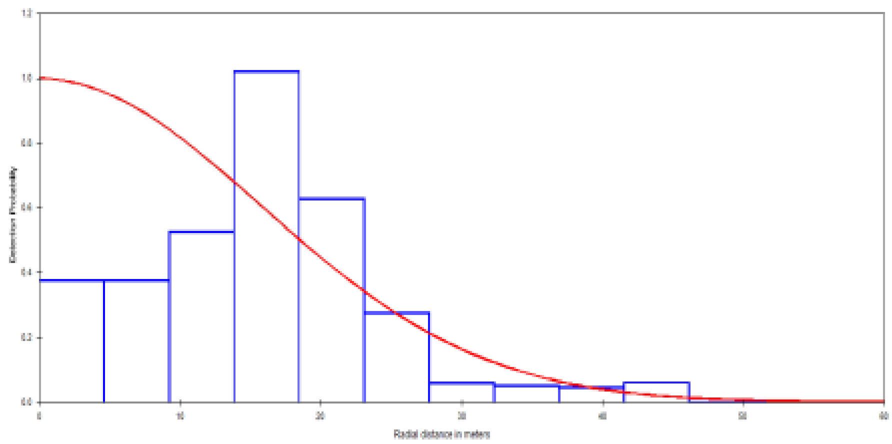


Figure 4.22 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for agricultural fields in PVNP during summer respectively.



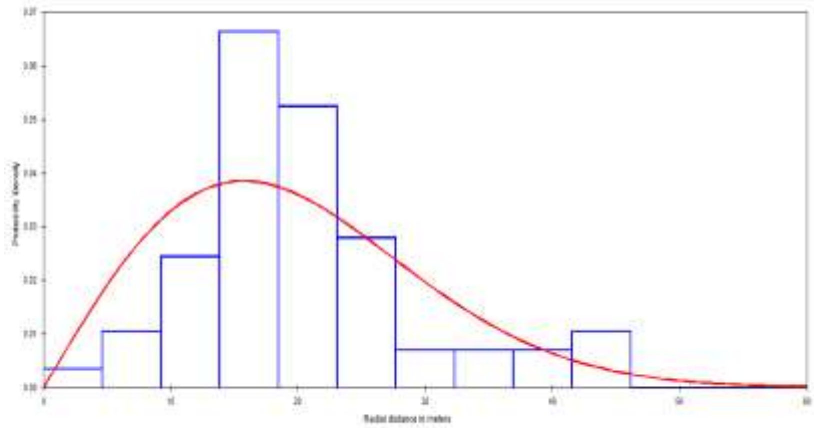


Figure 4.23 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis;0-50 mt) for streamlines in PVNP during summer respectively.

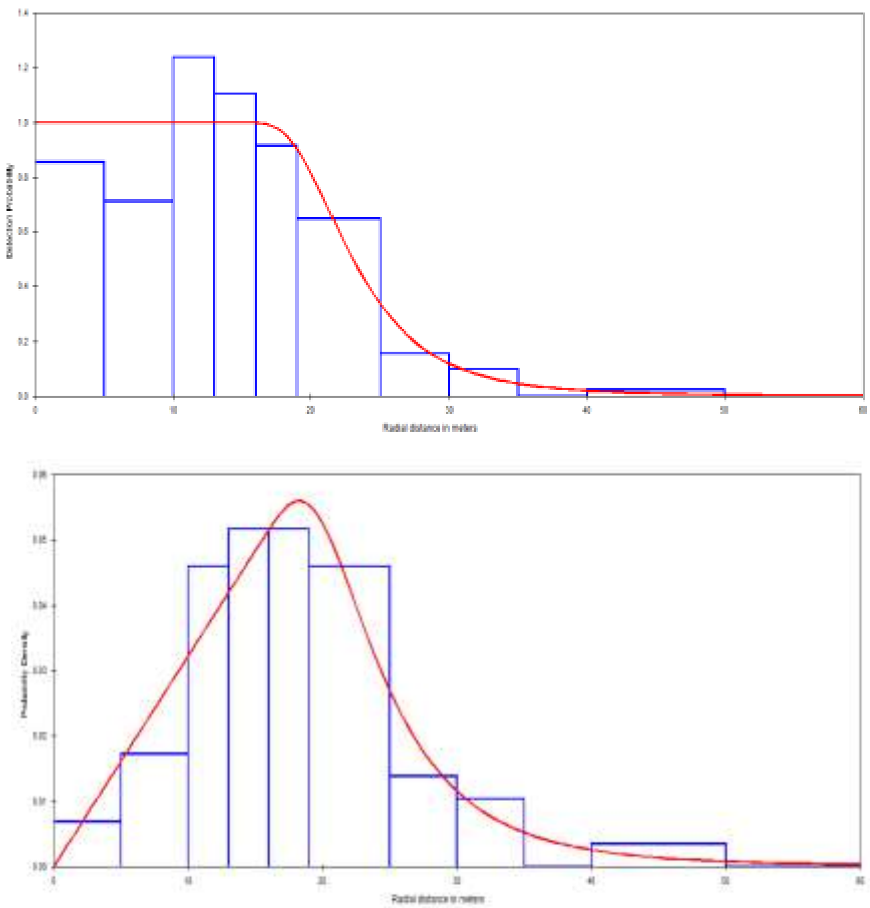


Figure 4.24 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for shrublands in PVNP during summer respectively.

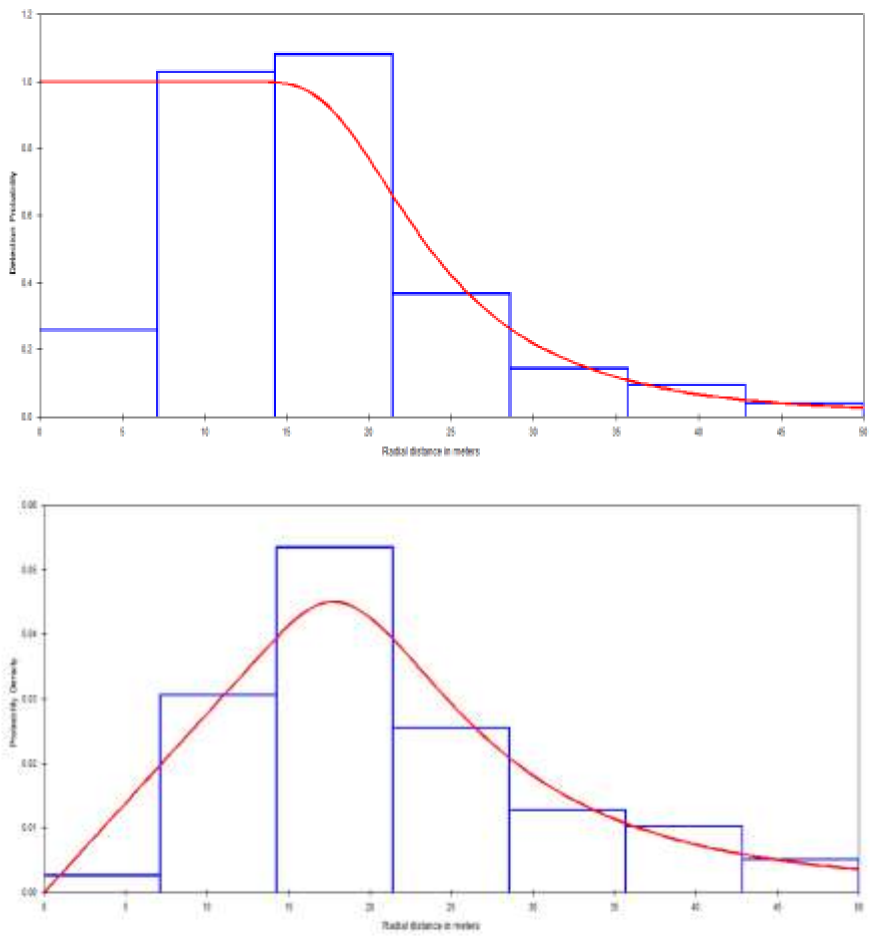
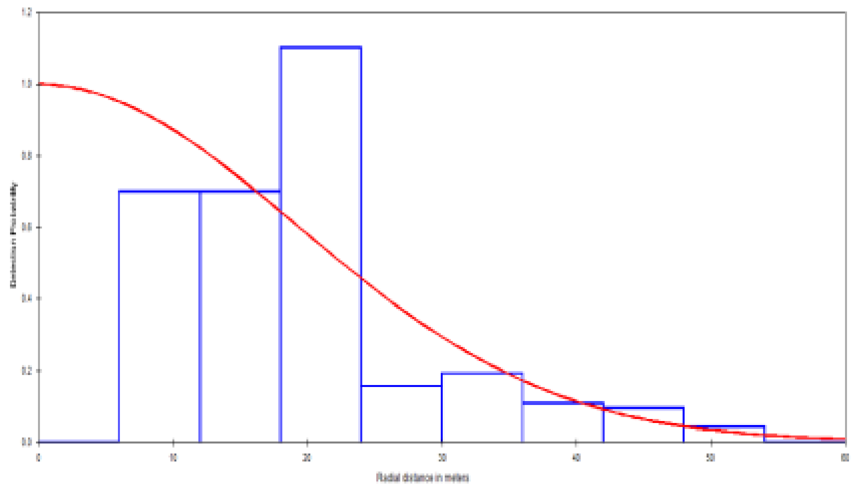


Figure 4.25 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for bare lands in PVNP during summer respectively.



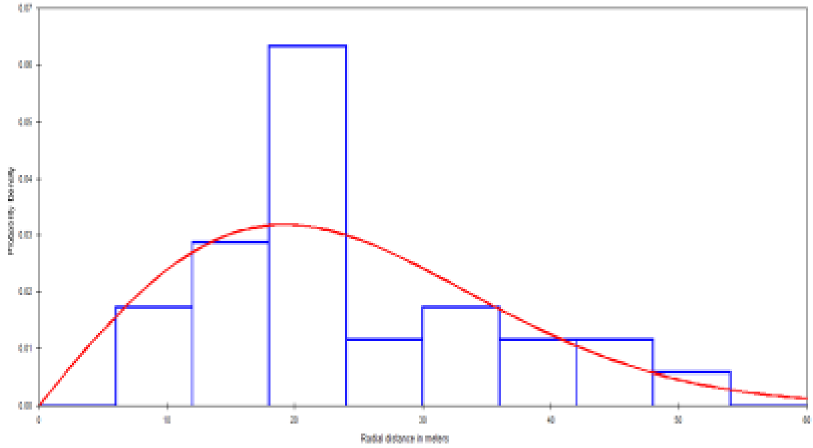


Figure 4.26 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for agricultural fields in PVNP during winter respectively.

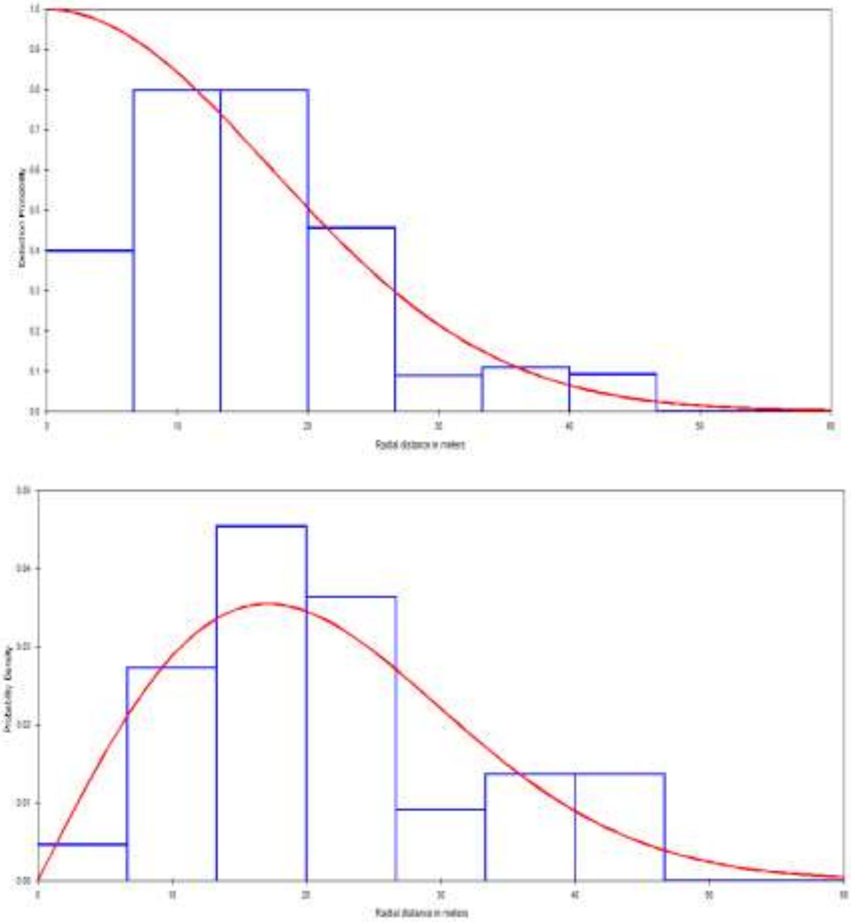


Figure 4.27 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for streamlines in PVNP during winter respectively.

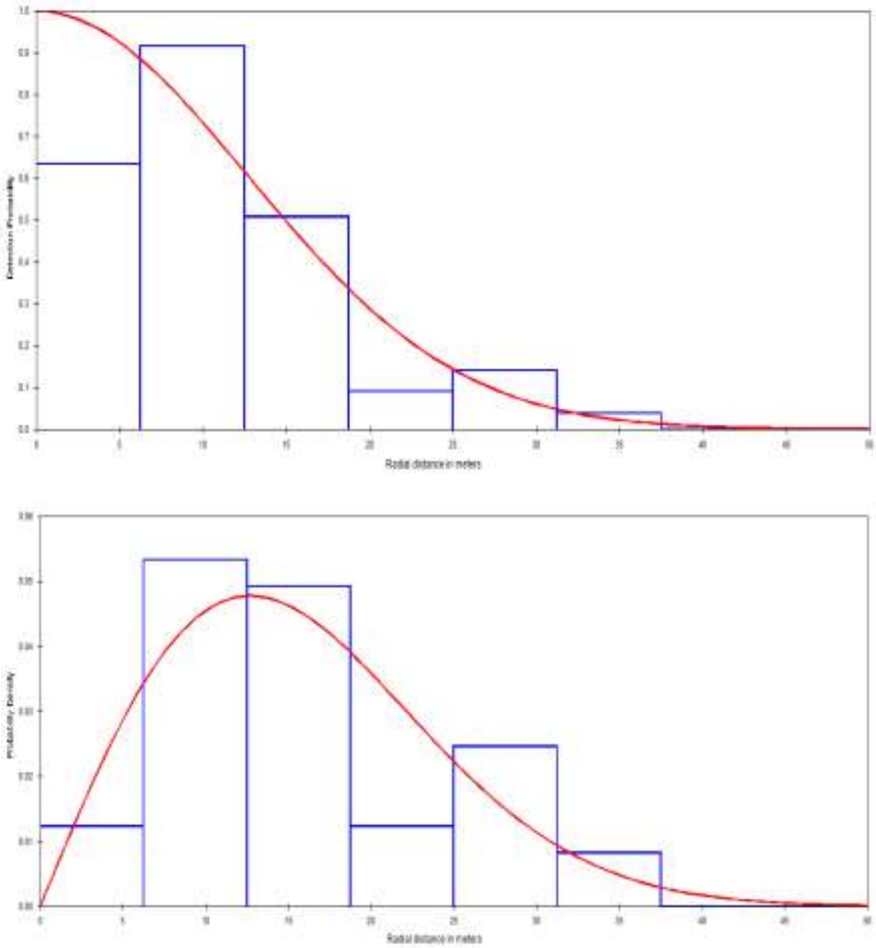
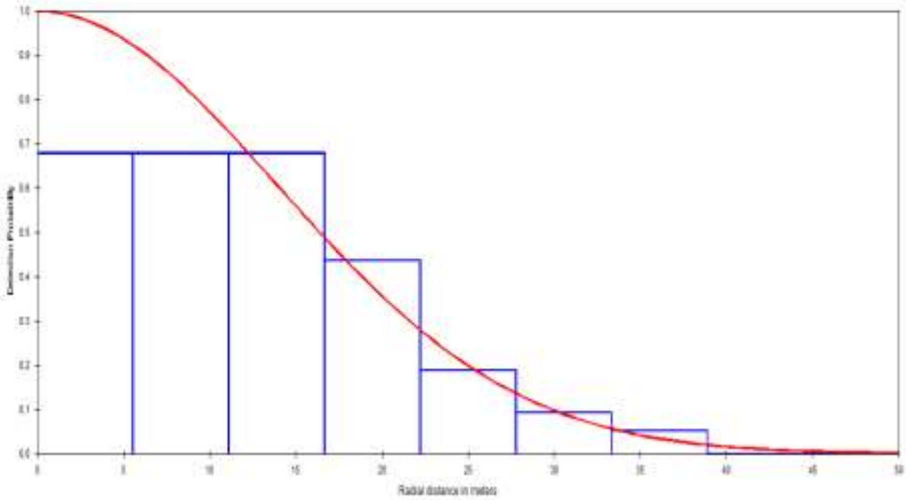


Figure 4.28 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for shrublands in PVNP during winter respectively.



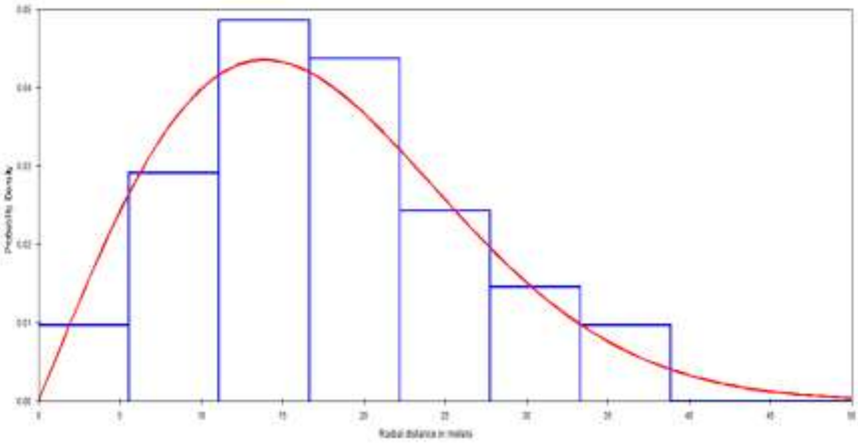


Figure 4.29 Graphs depicting detection probability and probability density (Y axis) along the increasing radial distance (X axis; 0-50 mt) for bare lands in PVNP during winter respectively.

4.4.9. Feeding guild structure

During summer, insectivores (40% for T1, 40.82% for T2, 38% for T3, 39.53% for T4) showed maximum number of species representative in each habitat type, followed by omnivore (24.44% for T1, 22.45% for T2, 26% for T3, 27.91% for T4). Frugivore, nectarivore and piscivore were completely absent from all the point count stations. The lowest total representative number of species were found under the feeding guild scavenger.

During winter, herbivore (33.33% for T1, 35.29% for T2, 25% for T3, 24% for T4) showed maximum number of species representative, followed by omnivore (33.33% for T1, 35.29% for T2, 29.17% for T3, 32% for T4). Frugivore, nectarivore and piscivore were completely absent from all the point count stations like the summer. No granivore species were found in T1 and T2. The total percentage of species from granivors were shown the least.

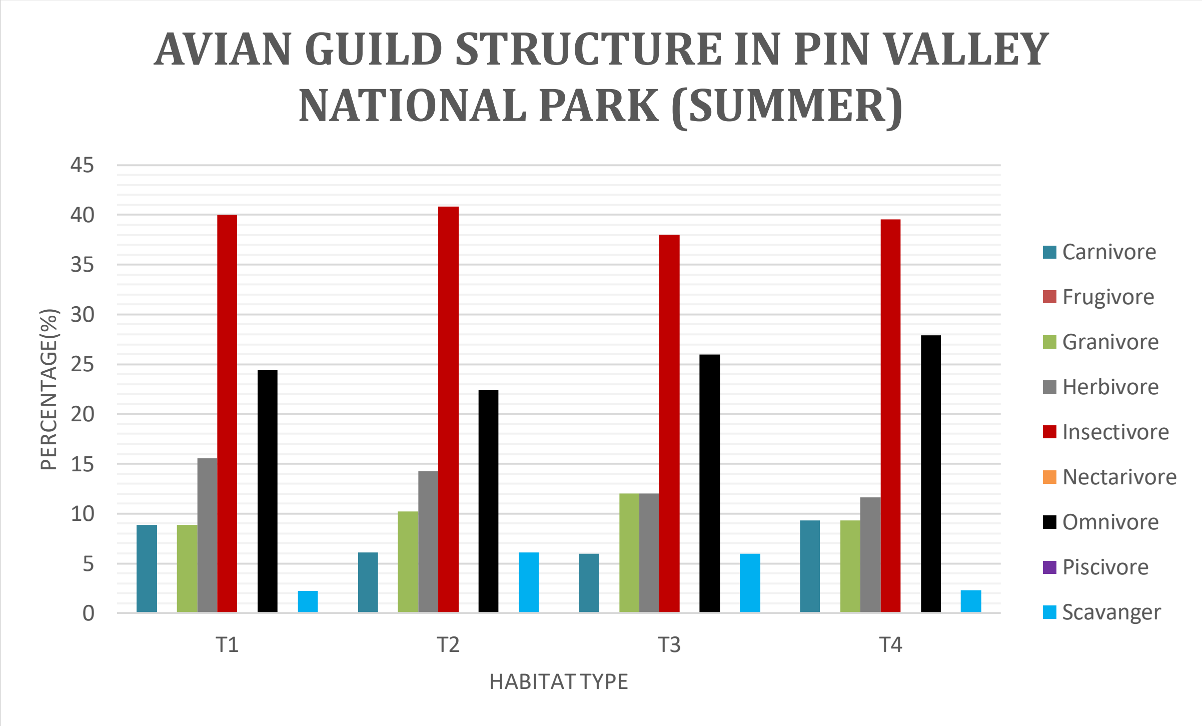


Figure 4.30 Percentages of avian feeding guild composition in different available habitat types in PVNP during summer.

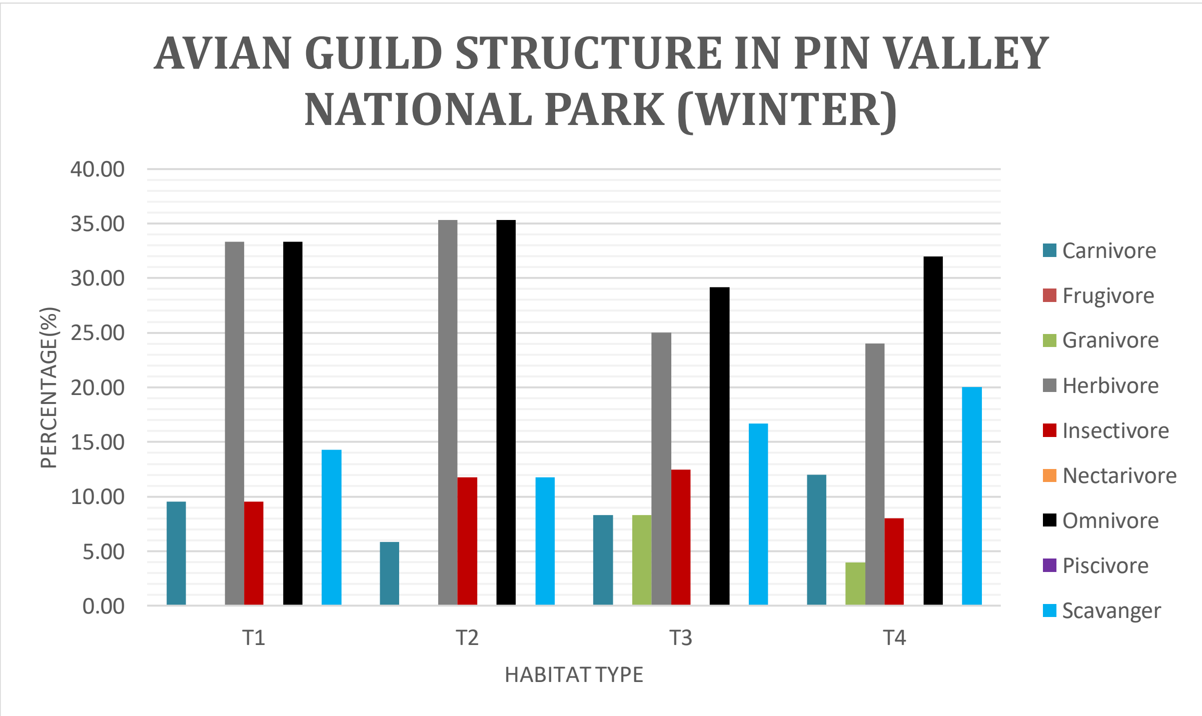


Figure 4.31 Percentages of avian feeding guild composition in different available habitat types in PVNP during winter.

Table 4.9. Checklist of Birds found in the PVNP.

Sl. No.	Family	Order	Scientific Name	Common Name	IUCN Status
1	Accipitridae	Accipitriformes	*Gyps himalayensis*	Himalayan Vulture	NT
2		Accipitriformes	*Gypaetus barbatus*	Bearded vulture	NT
3		Accipitriformes	*Gyps fulvus*	Griffon Vulture	LC
4		Accipitriformes	*Neophron percnopterus*	Egyptian Vulture	EN
5		Accipitriformes	*Aquila chrysaetos*	Golden Eagle	LC
6		Accipitriformes	*Buteo refectus*	Himalayan Buzzard	LC
7		Accipitriformes	*Accipiter nisus*	Eurasian Sparrow hawk	LC
8	Acrocephalidae	Passeriformes	*Iduna caligata*	Booted Warbler	LC
9		Passeriformes	*Acrocephalus dumetorum*	Blyth's Reed Warbler	LC
10	Alaudidae	Passeriformes	*Calandrella acutirostris*	Hume's Short Toed Lark	LC
11		Passeriformes	*Calandrella brachydactyla*	Greater Short Toed Lark	LC
12		Passeriformes	*Alauda arvensis*	Eurasian Skylark	LC
13	Anatidae	Anseriformes	*Spatula querquedula*	Garganey	LC
14	Apodidae	Apodiformes	*Apus apus*	Common Swift	LC
15	Cinclidae	Passeriformes	*Cinclus pallasii*	Brown Dipper	LC
16	Columbidae	Columbiformes	*Columba livia*	Rock Pigeon	LC
17		Columbiformes	*Columba leuconota*	Snow Pigeon	LC
18		Columbiformes	*Streptopelia orientalis*	Oriental Turtle Dove	LC
19		Columbiformes	*Spilopelia senegalensis*	Laughing Dove	LC

20	Corvidae	Passeriformes	*Pyrrhocorax pyrrhocorax*	Red Billed Chough	LC
21		Passeriformes	*Pyrrhocorax graculus*	Alpine Chough	LC
22		Passeriformes	*Corvus macrorhynchos*	Large Billed Crow	LC
23	Dicruridae	Passeriformes	*Dicrurus macrocercus*	Black Drongo	LC
24	Emberizidae	Passeriformes	*Emberiza cia*	Rock Bunting	LC
25		Passeriformes	*Emberiza rutila*	Chestnut Bunting	LC
26	Falconidae	Falconiformes	*Falco tinnunculus*	Eurasian Kestrel	LC
27		Falconiformes	*Falco subbuteo*	Eurasian Hobby	LC
28	Fringillidae	Passeriformes	*Leucosticte nemoricola*	Plain Mountain Finch	LC
29		Passeriformes	*Carpodacus erythrinus*	Common Rosefinch	LC
30		Passeriformes	*Carpodacus rubicilloides*	Streaked Rosefinch	LC
31		Passeriformes	*Carpodacus rubicilla*	Great Rosefinch	LC
32		Passeriformes	*Chloris spinoides*	Yellow Breasted Greenfinch	LC
33		Passeriformes	*Serinus pusillus*	Fire Fronted Serin	LC
34		Passeriformes	*Carduelis carduelis*	European Goldfinch	LC
35	Hirundinidae	Passeriformes	*Ptyonoprogne rupestris*	Eurasian Crag Martin	LC
36		Passeriformes	*Delichon dasypus*	Asian House Martin	LC
37	Prunellidae	Passeriformes	*Prunella collaris*	Alpine Accentor	LC
38		Passeriformes	*Prunella atrogularis*	Black-throated Accentor	LC
39		Passeriformes	*Prunella fulvescens*	Brown Accentor	LC
40		Passeriformes	*Delichon dasypus*	Asian House-Martin	LC

41		Passeriformes	*Leucosticte brandti*	Black-headed Mountain Finch	LC
42		Passeriformes	*Montifringilla adamsi*	Black-winged Snowfinch	LC
43	Alaudidae	Passeriformes	*Luscinia svecica*	Bluethroat	LC
44	Anatidae	Galliformes	*Alectoris chukar*	Chukar	LC
45	Apodidae	Passeriformes	*Motacilla citreola*	Citrine Wagtail	LC
46	Ardeidae	Passeriformes	*Corvus corax*	Common Raven	LC
47	Cinclidae	Charadriiformes	*Actitis hypoleucos*	Common Sandpiper	LC
48	Columbidae	Passeriformes	*Oenanthe deserti*	Desert Wheatear	LC
49		Passeriformes	*Ptyonoprogne rupestris*	Eurasian Crag-Martin	LC
50		Bucerotiformes	*Upupa epops*	Eurasian Hoopoe	LC
51	Corvidae	Passeriformes	*Serinus pusillus*	Fire-fronted Serin	LC
52		Passeriformes	*Grandala coelicolor*	Grandala	LC
53		Charadriiformes	*Tringa ochropus*	Green Sandpiper	LC
54		Columbidae	*Columba rupestris*	Hill Pigeon	LC
55		Passeriformes	*Calliope pectoralis*	Himalayan Rubythroat	LC
56	Emberizidae	Galliformes	*Tetraogallus himalayensis*	Himalayan Snowcock	LC
57	Fringillidae	Apodiformes	*Aerodramus brevirostris*	Himalayan Swiftlet	LC
58		Passeriformes	*Carpodacus thura*	Himalayan White-browed Rosefinch	LC
59		Passeriformes	*Eremophila alpestris*	Horned Lark	LC
60		Passeriformes	*Corvus splendens*	House Crow	LC
61	Hirundinidae	Passeriformes	*Passer domesticus*	House Sparrow	LC
62	Laniidae	Passeriformes	*Phylloscopus humei*	Hume's Warbler	LC
63	Motacillidae	Passeriformes	*Oriolus kundoo*	Indian Golden Oriole	LC

64		Pelecaniformes	*Ardeola grayii*	Indian Pond-Heron	LC
65		Passeriformes	*Corvus macrorhynchos*	Large-billed Crow	LC
66	Muscicapidae	Passeriformes	*Phylloscopus chloronotus*	Lemon-rumped Warbler	LC
67		Passeriformes	*Curruca curruca*	Lesser Whitethroat	LC
68		Charadriiformes	*Calidris minuta*	Little Stint	LC
69		Passeriformes	*Lanius schach*	Long-tailed Shrike	LC
70		Passeriformes	*Turdus viscivorus*	Mistle Thrush	LC
71		Passeriformes	*Phylloscopus sindianus*	Mountain Chiffchaff	LC
72		Columbiformes	*Streptopelia orientalis*	Oriental Turtle-Dove	LC
73		Passeriformes	*Oenanthe pleschanka*	Pied Wheatear	LC
74		Passeriformes	*Carpodacus rodochroa*	Pink-browed Rosefinch	LC
75	Oriolidae	Passeriformes	*Phoenicurus fuliginosus*	Plumbeous Redstart	LC
76	Paridae	Passeriformes	*Pyrrhocorax pyrrhocorax*	Red-billed Chough	LC
77	Passeridae	Passeriformes	*Prunella rubeculoides*	Robin Accentor	LC
78		Passeriformes	*Anthus roseatus*	Rosy Pipit	LC
79	Phasianidae	Anseriformes	*Tadorna ferruginea*	Ruddy Shelduck	LC
80		Passeriformes	*Periparus rufonuchalis*	Rufous-naped Tit	LC
81	Phylloscopidae	Passeriformes	*Passer cinnamomeus*	Russet Sparrow	LC
82		Passeriformes	*Ficedula ruficauda*	Rusty-tailed Flycatcher	LC
83		Passeriformes	*Saxicola maurus*	Siberian Stonechat	LC
84		Columbiformes	*Spilopelia chinensis*	Spotted Dove	LC

85		Passeriformes	*Phylloscopus griseolus*	Sulphur-bellied Warbler	LC
86		Passeriformes	*Phylloscopus affinis*	Tickell's Leaf Warbler	LC
87	Prunellidae	Passeriformes	*Linaria flavirostris*	Twite	LC
88	Scolopacidae	Passeriformes	*Phylloscopus occipitalis*	Western Crowned Warbler	LC
89		Passeriformes	*Motacilla alba*	White Wagtail	LC
90		Passeriformes	*Emberiza stewarti*	White-capped Bunting	LC
91	Sylviidae	Passeriformes	*Phoenicurus leucocephalus*	White-capped Redstart	LC
92	Turdidae	Passeriformes	*Cinclus cinclus*	White-throated Dipper	LC
93		Passeriformes	*Phoenicurus erythrogastrus*	White-winged Redstart	LC
94	Upupidae	Passeriformes	*Pyrrhocorax graculus*	Yellow-billed Chough	LC

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Appendix I: Checklist of tree species found in the selected protected areas of Himachal Pradesh.

Family	Tree Species	CSJNP	CWS	CTWS	PVNP	IUCN Status
Anacardiaceae	*Lannea grandis (Houtt.) Merr.*	✓	x	x	x	NE
	Mangifera indica L.	✓	x	x	x	NE
	Semecarpus anacardium L.f.	✓	x	x	x	LC
	Rhus chinensis Mill.	x	✓	x	x	LC
Annonaceae	*Miliusa velutina (Dunal) Hook. f. & Thomson*	✓	x	x	x	NE
Aqulifoliaceae	*Ilex dipyrena Wall.*	x	✓	x	x	LC
Arecaceae	*Phoenix humilis L.*	✓	x	x	x	LC
Boraginaceae	*Cordia dichotoma G. Forst*	✓	x	x	x	LC
	Ehretia laevis Roxb.	✓	x	x	x	DD
Cannabaceae	*Celtis tetrandra Roxb.*	x	✓	x	x	LC
Casuarinaceae	*Casuarina equisetifolia L.*	✓	x	x	x	LC
Celastraceae	*Euonymous lucidus D.don*	x	✓	x	x	LC
Combretaceae	*Anogeissus latifolia (Roxb. ex DC.) Wall. ex Guill. & Perr*	✓	x	x	x	NE
	Terminalia arjuna (Roxb.) Wigst & Arn	✓	x	x	x	NE
	Terminalia bellirica (Gaertn.) Roxb.	✓	x	x	x	LC
	Terminalia tomentosa /allata Heyne ex Roth	✓	x	x	x	NE
Dipterocarpaceae	*Shorea robusta Roth*	✓	x	x	x	LC
Ebenaceae	*Diospyros melanoxylon Roxb.*	✓	x	x	x	NE
Ericaceae	*Lyonia ovalifolia (Wall.) Drude*	x	✓	x	x	LC
	Rhododendron arboreum Sm.	x	✓	x	x	LC

	Rhododendron companulatum D.Don	x	✓	x	x	NE
Euphorbiaceae	*Mallotus philippennsis (Lam.) Muell.Arg.*	✓	x	x	x	NE
Fabaceae	*Acacia / Senegalia catechu (L.f.) P.J.H.Hurter & Mabb*	✓	x	x	x	LC
	Albizia procera (Roxb.) Benth.	✓	x	x	x	LC
	Albizia lebbeck (L.) Benth.	✓	x	x	x	LC
	Bauhinia variegata (L.) Benth.	✓	x	x	x	LC
	Butea monosperma (Lam.) Taub.	✓	x	x	x	LC
	Cassia fistula L.	✓	x	x	x	LC
	Dalbergia sissoo Roxb.	✓	x	x	x	LC
	Ougeinia oojeinensis (Roxb.) Hochr.	✓	x	x	x	NE
Fagaceae	*Quercus floribunda Lindl. ex A.Camus*	x	✓	x	x	LC
	Quercus leucotrichophora A.Camus	x	✓	x	x	NE
	Quercus semecarpifolia Sm.	x	✓	x	x	LC
Juglandaceae	*Juglans regia L.*	x	✓	x	x	LC
Lamiaceae	*Tectona grandis L.f.*	✓	x	x	x	EN
Lauraceae	*Litsea monopetela (Roxb.) Pers.*	✓	x	x	x	NE
Lauraceae	*Litsea consimilis (Nees) Nees*	x	✓	x	x	NE
	Machilus odoratissima Nees	x	✓	x	x	LC
Lecythidaceae	*Careya arborea Roxb.*	✓	x	x	x	NE
Leguminosae	*Robinia pseudoacacia L.*	x	✓	x	x	LC
Malvaceae	*Bombax ceiba L.*	✓	x	x	x	LC
	Grewia optiva J.R. Drumm. ex Burret	✓	x	x	x	LC

	Grewia oppositifolia Roxb. ex DC.	✓	x	x	x	NE
	Grewia optiva J.R. Drumm. ex Burret	x	✓	x	x	LC
Meliaceae	*Melia azedarach L.*	✓	x	x	x	LC
	Toona ciliata M. Roem.	✓	x	x	x	LC
	Toona serrata (Royle) M. Roem.	x	✓	x	x	NE
Moraceae	*Ficus benghalensis L.*	✓	x	x	x	NE
	Ficus semicordata Buch. -Ham. ex Sm.	✓	x	x	x	LC
	Ficus hispida L.f.	✓	x	x	x	LC
	Ficus racemosa L.	✓	x	x	x	LC
	Ficus religiosa L.	✓	x	x	x	LC
	Ficus auriculata Lour.	✓	x	x	x	LC
	Ficus virens Aiton	✓	x	x	x	LC
	Ficus rumphii Bl.	✓	x	x	x	NE
	Morus alba L.	✓	x	x	x	LC
	Morus serrata Roxb.	✓	✓	x	x	NE
	Ficus neriifolia Sm.	x	✓	x	x	LC
Moringaceae	*Moringa oleifera Lam.*	✓	x	x	x	LC
Myrtaceae	*Eucalyptus citriodora Labill.*	✓	x	x	x	LC
	Psidium guajava L.	✓	x	x	x	LC
	Syzygium cumini (L.) Skeels.	✓	x	x	x	LC
Phyllanthaceae	*Bridelia retusa (L.) A. Juss.*	✓	x	x	x	LC
	Phyllanthus emblica L.	✓	x	x	x	LC
Pinaceae	*Abies pindrow (Royle ex D.Don) Royle*	x	✓	x	x	LC
	Abies spectabilis (D. Don) Mirb.	x	✓	x	x	NT

	Cedrus deodara (Roxb. ex D.Don) G.Don	x	✓	x	x	LC
	Picea smithiana (Wall.) Boiss.	x	✓	x	x	LC
	Pinus wallichiana A.B. Jacks.	x	✓	x	x	LC
	Taxus contorta Griff.	x	✓	x	x	EN
Proteaceae	*Grevillea robusta A. Cunn. ex R. Br.*	✓	x	x	x	LC
Rhamnaceae	*Ziziphus jujuba Mill.*	✓	x	x	x	LC
	Ziziphus mauritiana Lam.	✓	x	x	x	LC
Rosaceae	*Prunus cerasoides Buch. -Ham. ex D.Don*	x	✓	x	x	LC
	Prunus persica (L.) Batsch	x	✓	x	x	NE
	Sorbus microphylla Wenz.	x	✓	x	x	NE
Rubiaceae	*Adina / Haldina cordifolia (Roxb.) Ridsdale*	✓	x	x	x	NE
	Mitragyna parvifolia (Roxb.) Korth	✓	x	x	x	NE
Rutaceae	*Limonia/Naringi crenulata (Roxb.)*	✓	x	x	x	LC
	Murraya paniculata (L.) Jack	✓	x	x	x	NE
	Murraya koenigii (L.) Sprenge	✓	x	x	x	LC
Salicaceae	*Casearia tomentosa (Roxb.)*	✓	x	x	x	NE
	Populus deltoides W.Bartram ex Marshall	✓	x	x	x	LC
	Populus ciliata Schur	x	✓	x	x	NE
	Salix alba L.	x	✓	x	x	NE
Sapindaceae	*Acer acuminatum Wall. ex D. Don*	x	✓	x	x	LC
	Acer caesium Wall. ex Brandis	x	✓	x	x	LC
	Acer oblongum Wall. ex DC.	x	✓	x	x	LC

	Aesculus indica (Wall. Ex Cambess.) Hook.	x	✓	x	x	LC
Sapotaceae	*Madhuca longifolia (J.Konig) J. F. Macbr.*	✓	x	x	x	NE
Symplocaceae	*Symplocos cochinchinensis (Lour.) S. Moore*	x	✓	x	x	LC
Ulmaceae	*Holoptelea integrifolia (Roxb.) Planch.*	✓	x	x	x	NE

Appendix II: Checklist of shrub species found in the selected protected area of Himachal Pradesh.

Family	**Shrub Species**	**CSJNP**	**CWS**	**CTWS**	**PVNP**	**IUCN Status**
Acanphaceae	*Pachystachys spicata L. Ruiz & Pav.*	✓	x	x	x	NE
Acanthaceae	*Eranthemum pulchellum Andrews*	✓	x	x	x	NE
cAcanthceae	*Justicia adhatoda L.*	✓	x	x	x	LC
Apocynaceae	*Asclepias curassavica L.*	✓	x	x	x	NE
Apocynaceae	*Carissa opaca L.*	✓	x	x	x	LC
Apocynaceae	*Calotropis procera (Aiton) W.T.Aiton*	✓	x	x	x	LC
Apocynaceae	*Nerium oleander L.*	✓	x	x	x	LC
Apocynaceae	*Holarrhena /Wrightia antidysenterica (L.) R.Br.*	✓	x	x	x	NE
Asparagaceae	*Asparagus racemosus Willd.*	✓	x	x	x	NE
Asparagaceae	*Agave americana L.*	✓	x	x	x	LC
Berberidaceae	*Berberis aristata DC.*	x	✓	x	x	LC
Berberidaceae	*Berberis coriaria Royle ex Lindl*	x	✓	x	x	NE
Berberidaceae	*Berberis jaeschkeana C.K. Schneid.*	x	✓	x	x	NE

Buxaceae	*Sarcococca saligna (D.Don) Mull.Arg.*	x	✓	x	x	NE
Buxaceae	*Lonicera angustifolia Raf.*	x	✓	x	x	NE
Buxaceae	*Lonicera hispida Pall. Ex Schult.*	x	✓	x	x	NE
Buxaceae	*Lonicera obovata Royle ex Hook f. & Thomson*	x	✓	x	x	NE
Convolvulaceae	*Ipomea carnea Jacq.*	✓		x	x	NE
Coriariaceae	*Coriaria nepalensis Wall.*	x	✓	x	x	NE
Cupressaceae	*Juniperus squamata D.Don*	x	✓	x	x	LC
Cupressaceae	*Juniperus recurva Buch.-Ham.ex D.Don*	x	✓	x	x	LC
Elaegnaceae	*Elaeagnus parvifolia Wall. ex Royle*	x	✓	x	x	NE
Elaegnaceae	*Cassiope fastigiata D.Don*	x	✓	x	x	NE
Elaegnaceae	*Rhododendron anthopogon D. Don*	x	✓	x	x	NE
Ericaceae	*Rhododendron lepidotum Wall.ex G. Don*	x	✓	x	x	NE
Fabaceae	*Desmodium gangeticum (L.) DC.*	✓	x	x	x	NE
Fabaceae	*Flemingia strobilifera (L.) W.T.Aiton*	✓	x	x	x	NE
Fabaceae	*Mimosa rubicaulis Lam.*	✓	x	x	x	NE
Fabaceae	*Phyllodium pulchellum (L.) Desv.*	✓	x	x	x	LC
Fabaceae	*Indigofera heterantha Wall.*	✓	x	x	x	LC
Fabaceae	*Senna occidentalis (L.) Link*	✓	x	x	x	LC
Fabaceae	*Phyllodium pulchellum Desv.*	x	✓	x	x	LC
Grossulariaceae	*Ribes alpestre Wall.ex Decne.*	x	✓	x	x	NE
Grossulariaceae	*Ribes glaciale Wall.*	x	✓	x	x	NE

Hypericaceae	*Hypericum choisyanum Wall. ex N.Robson*	x	✓	x	x	NE
Lamiaceae	*Clerodendrum infortunatum L.*	✓	x	x	x	LC
Lamiaceae	*Colebrookea oppositifolia Sm.*	✓	x	x	x	LC
Lamiaceae	*Pogostemon benghalensis (Burm. f.)*	✓	x	x	x	NE
Lamiaceae	*Vitex negundo L.*	✓	x	x	x	LC
Lamiaceae	*Vitex trifolia L.*	✓	x	x	x	NE
Lamiaceae	*Elsholtzia fruticosa (D.Don) Rehdr*	x	✓	x	x	NE
Leguminosae	*Desmodium elegans Benth.*	x	✓	x	x	LC
Leguminosae	*Desmodium multiflorum DC.*	x	✓	x	x	NE
Leguminosae	*Indigofera atropurpurea Hornem.*	x	✓	x	x	NE
Leguminosae	*Indigofera dosua Buck.- Ham.ex D.Don*	x	✓	x	x	NE
Leguminosae	*Indigofera heterantha Wall. Ex Brandis*	x	✓	x	x	LC
Leguminosae	*Lespedeza gerardiana Wall. Ex Maxim.*	x	✓	x	x	NE
Lythraceae	*Woodfordia fruticosa (L.) Kurz*	✓	x	x	x	LC
Malvaceae	*Sida acuta Burm.f.*	✓	x	x	x	NE
Malvaceae	*Urena lobata L.*	✓	x	x	x	LC
Oleaceae	*Chrysojasminum humile (L.)*	x	✓	x	x	NE
Phyllanthaceae	*Breynia retusa (Dennst.) Alston*	x	✓	x	x	NE
Primulaceae	*Ardisia solanacea Roxb.*	✓	x	x	x	NE
Primulaceae	*Myrsine Africana L.*	x	✓	x	x	NE
Rosaceae	*Rubus occidentalis L.*	✓	x	x	x	NE
Rosaceae	*Cotoneaster acuminatus Lindl.*	x	✓	x	x	NE
Rosaceae	*Cotoneaster acuminatus Lindl.*	x	✓	x	x	NE

Rosaceae	*Cotoneaster microphyllus Lodd.*	x	✓	x	x	NE
Rosaceae	*Prinsepia utilis Royle*	x	✓	x	x	NE
Rosaceae	*Pyracantha crenulata (D.Don) M. Roem*	x	✓	x	x	LC
Rosaceae	*Rosa brunonii Lindl.*	x	✓	x	x	NE
Rosaceae	*Rosa macrophylla Lindl.*	x	✓	x	x	NE
Rosaceae	*Rosa moschata Herrm.*	x	✓	x	x	NE
Rosaceae	*Rosa sericea Lindl.*	x	✓	x	x	NE
Rosaceae	*Rubus ellipticus Sm.*	x	✓	x	x	LC
Rosaceae	*Rubus niveus Wall.ex G. Don*	x	✓	x	x	NE
Rosaceae	*Spiraea canescens D.Don*	x	✓	x	x	LC
Rubiaceae	*Catunaregam spinosa Thunb, Tirveng.*	✓		x	x	LC
Rubiaceae	*Leptodermis lanceolata Wall.*	x	✓	x	x	NE
Rubiaceae	*Randia tetrasperma Benth. & Hook. f.*	x	✓	x	x	NE
Rubiaceae	*Rhamnus procumbens Edgew*	x	✓	x	x	NE
Rubiaceae	*Rhamnus purpurea Edgew.*	x	✓	x	x	NE
Rutaceae	*Skimmia laureola (DC.) Sieb. & Zucc. ex Walp.*	x	✓	x	x	NE
Rutaceae	*Zanthoxylum aramtum Druce*	x	✓	x	x	NE
Salicaceae	*Salix denticulata Andresson*	x	✓	x	x	NE
Salicaceae	*Salix lindleyana Wall.ex Andersson*	x	✓	x	x	NE
Scorphulariaceae	*Buddleja asiatica Lour.*	x	✓	x	x	NE
Solanaceae	*Solanum capsicoides All.*	✓	x	x	x	NE
Solanaceae	*Solanum verbascifolium L.*	✓	x	x	x	NE
Solanaceae	*Withania somnifera (L.) Dunal*	✓	x	x	x	NE
Thymealaceae	*Wikstroemia canescens Maxim.*	x	✓	x	x	NE

Thymealaceae	*Daphne papyracea Wall. Ex G. Don.*	x	✓	x	x	NE
Urticaceae	*Debregeasia longifolia Wedd.*	x	✓	x	x	LC
Verbenaceae	*Lantana camara*	✓	x	x	x	NE
Viburnaceae	*Viburnum grandiflorum Wall.*	x	✓	x	x	NE

Appendix III: Checklist of herb species found in the selected protected areas of Himachal Pradesh.

Family	**Species**	**CSJNP**	**CWS**	**CTWS**	**PVNP**	**IUCN Status**
Asteraceae	*Erigeron multiradiatus (Lindl. Ex DC.)*	x	✓	✓	x	NE
Asteraceae	*Anaphalis nepalensis (Spreng.) Hand.-Mazz.*	x	x	✓	x	NE
Fabaceae	*Astragalus munroi Benth. ex Bunge*	x	x	✓	x	NE
Chenopodiaceae	*Chenopodium foliosum Asch.*	x	x	✓	x	NE
Cyperaceae	*Carex nivalis Boott*	x	x	✓	x	NE
Cyperaceae	*Carex melanentha*	x		✓	x	NE
Poaceae	*Bromus sp.*	x		✓	x	NE
Primulaceae	*Glaux maritima L.*	x		✓	x	LC
Acanthaceae	*Diacliptera bupleuriodes Nees*	✓		x	x	NE
Acanthaceae	*Justicia procumbens L.*	x	✓	x	x	NE
Acanthaceae	*Strobilanthes atropurpurea Nees*	x	✓	x	x	NE
Acanthaceae	*Strobilanthes Wallichii Nees*	x	✓	x	x	NE
Acanthaceae	*Hygrophila lancea (Thunb.) Miq.*	x	x	✓	x	NE
Amaranthaceae	*Achyranthes aspera L.*	✓	x	x	x	NE
Amaranthaceae	*Achyranthes bidentata Blume*	✓	x	x	x	NE
Amaranthaceae	*Alternanthera sessilis (L.) R.Br. ex DC.*	✓	x	x	x	LC
Amaranthaceae	*Chenopodium album L.*	✓	x	x	x	NE
Amaranthaceae	*Cyathula capitata Moq.*	x	✓	x	x	NE
Amaranthaceae	*Dysphania botrys (L.)Mosyakin & Clemants*	x	✓	x	x	NE
Amaryllidaceae	*Allium humile Kunth*	x	✓	x	x	NE

Apiaceae	*Centella asiatica (L.) Urban*	✓		x	x	LC
Apiaceae	*Bupleurum aitchisonii H. Wolf*	x	✓	x	x	NE
Apiaceae	*Bupleurum candollei Wall. ex DC.*	x	✓	x	x	NE
Apiaceae	*Bupleurum falcatum L.*	x	✓	x	x	NE
Apiaceae	*Centella asiatica (L.) Urb.*	x	✓	x	x	LC
Apiaceae	*Chaerophyllum reflexum Lindl.*	x	✓	x	x	NE
Apiaceae	*Chaerophyllum villosum Wall. ex DC*	x	✓	x	x	NE
Apiaceae	*Heracleum candicans Wall. ex DC.*	x	✓	x	x	NE
Apiaceae	*Selinum vaginatum C.B. Clarke*	x	✓	x	x	NE
Araceae	*Arisaema caudatum Engl.*	x	✓	x	x	NE
Araceae	*Arisaema intermedium Blume*	x	✓	x	x	NE
Araceae	*Arisaema jacquemontii Blume*	x	✓	x	x	LC
Araceae	*Arisaema tortuosum (Wall.) Schott*	x	✓	x	x	NE
Araceae	*Remusatia pumila (D. Don) H. Li & A.Hay*	x	✓	x	x	NE
Araceae	*Sauromatum venosum (Dryand. ex Aiton) Kunth*	x	✓	x	x	LC
Arecaceae	*Calamus tenuis Roxb.*	✓	x	x	x	LC
Arecaceae	*Calamus viminalis Willd.*	✓	x	x	x	NE
Asparagaceae	*Asparagus racemosus Willd.*	x	✓	x	x	NE
Asparagaceae	*Maianthemum purpureum (Wall.) LaFrankie*	x	✓	x	x	NE
Asparagaceae	*Ophiopogon intermedius D.Don*	x	✓	x	x	NE
Asteraceae	*Ageratum conyzoides Sieber ex Steud.*	✓	x	x	x	NE
Asteraceae	*Ageratina adenophora (Spreng.) King & H.Rob.*	✓	x	x	x	NE
Asteraceae	*Anaphalis contorta (D.Don)*	✓	x	x	x	NE
Asteraceae	*Artemisia annua L.*	✓	x	x	x	NE
Asteraceae	*Bidens biternata (Lour.) Mer r. & Sherff*	✓	x	x	x	NE
Asteraceae	*Erigeron Canadensis L.*	✓	x	x	x	NE
Asteraceae	*Galinsoga parviflora Cav.*	✓	x	x	x	NE
Asteraceae	*Jacobaea nudicaulis Mill.*	✓	x	x	x	NE
Asteraceae	*Parthenium hysterophorus L.*	✓	x	x	x	NE
Asteraceae	*Sonchus wightianus DC.*	✓	x	x	x	NE
Asteraceae	*Tridax procumbens L.*	✓	x	x	x	NE

Asteraceae	*Xanthium strumarium L.*	✓	x	x	x	NE
Asteraceae	*Achillea millefolium L.*	x	✓	x	x	LC
Asteraceae	*Ageratina adenophora (Spreng.) R.M.King & H. Rob.*	x	✓	x	x	NE
Asteraceae	*Ageratum conyzoides (L.) L.*	x	✓	x	x	NE
Asteraceae	*Anaphalis nepalensis (Spreng.) Hand.- Mazz.*	x	✓	x	x	NE
Asteraceae	*Anaphalis royleana DC.*	x	✓	x	x	NE
Asteraceae	*Anaphalis triplinervis (Sims) Sims ex C.B. Clarke*	x	✓	x	x	NE
Asteraceae	*Ainsliaea latifolia (D.Don) Sch. Bip*	x	✓	x	x	NE
Asteraceae	*Artemisia indica Willd.*	x	✓	x	x	NE
Asteraceae	*Aster thomsonii C.B.Clarke*	x	✓	x	x	NE
Asteraceae	*Bidens pilosa L.*	x	✓	x	x	NE
Asteraceae	*Bidens tripartita L.*	x	✓	x	x	LC
Asteraceae	*Cirsium wallichii var. glabratum (Hook.f.) Wendelbo*	x	✓	x	x	NE
Asteraceae	*Duhaldea cuspidata (DC.) Anderb.*	x	✓	x	x	NE
Asteraceae	*Duhaldea nervosa Wall. ex DC.*	x	✓	x	x	NE
Asteraceae	*Erigeron alpinus L.*	x	✓	x	x	NE
Asteraceae	*Erigeron annuus L.*	x	✓	x	x	NE
Asteraceae	*Erigeron bonariensis L.*	x	✓	x	x	NE
Asteraceae	*Erigeron emodi I.M. Turner*	x	✓	x	x	NE
Asteraceae	*Erigeron multiradiatus (Lindl. Ex DC.)*	x	✓	x	x	NE
Asteraceae	*Galinsoga parviflora Cav.*	x	✓	x	x	NE
Asteraceae	*Gerbera gossypina (Royle) Beauv.*	x	✓	x	x	NE
Asteraceae	*Gnaphalium affine D. Don*	x	✓	x	x	NE
Asteraceae	*Himalaiella heteromalla (D.Don)*	x	✓	x	x	NE
Asteraceae	*Jacobaea analoga Veldkamp*	x	✓	x	x	NE
Asteraceae	*Lactuca brunoniana (Wall. ex DC.) C.B. Clarke*	x	✓	x	x	NE
Asteraceae	*Lactuca saligna L.*	x	✓	x	x	NE
Asteraceae	*Ligularia amplexicaulis DC.*	x	✓	x	x	NE
Asteraceae	*Melanoseris macrorhiza (Royle) N.Kilian*	x	✓	x	x	NE

Asteraceae	*Myriactis nepalensis Less.*	x	✓	x	x	NE
Asteraceae	*Saussurea piptathera Edgew.*	x	✓	x	x	NE
Asteraceae	*Saussurea taraxacifolia Wall. ex DC*	x	✓	x	x	NE
Asteraceae	*Scorzonera virgata DC.*	x	✓	x	x	NE
Asteraceae	*Senecio graciliflorus DC.*	x	✓	x	x	NE
Asteraceae	*Senecio kunthianus Wall. ex DC*	x	✓	x	x	NE
Asteraceae	*Senecio rufinervis DC.*	x	✓	x	x	NE
Asteraceae	*Sigesbeckia orientalis L.*	x	✓	x	x	NE
Asteraceae	*Tagetes minuta (L.)*	x	✓	x	x	NE
Asteraceae	*Tanacetum longifolium Wall. ex DC.*	x	✓	x	x	NE
Asteraceae	*Taraxacum officinale (L.) Weber ex F.H. Wigg.*	x	✓	x	x	NE
Asteraceae	*Aster flaccidus Bung*	x	x	✓	x	NE
Asteraceae	*Cirsium arvense (L.) Scop.*	x	x	✓	x	NE
Asteraceae	*Crementhodium decaisnei*	x	x	✓	x	NE
Asteraceae	*Jurinea ceratocarpa (Dcne.) Benth. & Hook.f.*	x	x	✓	x	NE
Asteraceae	*Launaea aspleniifolia (Willd.) Hook.f.*	x	x	✓	x	NE
Asteraceae	*Leontopodium ochroleucum Beauverd*	x	x	✓	x	NE
Asteraceae	*Saussurea jacea (Klotzsch) C.B.Clarke*	x	x	✓	x	NE
Asteraceae	*Taraxacum officinale (L.) Weber ex F.H.Wigg.*	x	x	✓	x	NE
Asteraceae	*Waldheimia glabra (Decne.) Regel*	x	x	✓	x	NE
Asteraceae	*Waldheimia tomentosa (Decne.) Regel*	x	x	✓	x	NE
Asteraceae	*Erigeron sp.*	x	x	x	✓	-
Asteraceae	*Artemisia maritima L.*	x	x	x	✓	NE
Asteraceae	*Cousinia thomsonii C.B.Clarke*	x	x	x	✓	NE
Asteraceae	*Tanacetum gracile Hook.f. & Thomson*	x	x	x	✓	NE
Balsaminaceae	*Impatiens amplexicaulis Edgew*	x	✓	x	x	NE
Balsaminaceae	*Impatiens glandulifera Royle H*	x	✓	x	x	NE
Balsaminaceae	*Impatiens laxiflora Edgew.*	x	✓	x	x	NE
Balsaminaceae	*Impatiens bicolor Royle*	x	✓	x	x	NE
Balsaminaceae	*Impatiens scabrida DC.*	x	✓	x	x	NE
Balsaminaceae	*Impatiens sulcata Wall.*	x	✓	x	x	NE

Begoniaceae	*Begonia picta Sm.*	x	✓	x	x	NE
Boraginaceae	*Cynoglossum microglochin var. nervosum (Benth. ex C.B. Clarke) Y.J. Nasir*	x	✓	x	x	NE
Boraginaceae	*Cynoglossum wallichii var. glochidiatum (Wall. ex Benth.) Kazmi*	x	✓	x	x	NE
Boraginaceae	*Cynoglossum uncinatum Royle ex Benth.*	x	✓	x	x	NE
Boraginaceae	*Lindelofia longiflora (Benth.) Baill.*	x	✓	x	x	NE
Boraginaceae	*Arnebia euchroma (Royle.)Johnst.*	x	x	✓	x	NE
Boraginaceae	*Lindelofia stylosa (Kar. & Kir.) Brand*	x	x	✓	x	NE
Boraginaceae	*Arnebia euchroma (Royle ex Benth.) I.M.Johnst.*	x	x	x	✓	NE
Boraginaceae	*Lindelofia stylosa subsp. pterocarpa (Rupr.) Kamelin*	x	x	x	✓	NE
Brassicaceae	*Eruca vesicaria (L.) Cav.*	✓	x	x	x	NE
Brassicaceae	*Arabis amplexicaulis Edgew.*	x	✓	x	x	NE
Brassicaceae	*Capsella bursa-pastoris (L.) Medik.*	x	✓	x	x	NE
Brassicaceae	*Cardamine impatiens L.*	x	✓	x	x	NE
Brassicaceae	*Lepidium sativum L.*	x	✓	x	x	NE
Brassicaceae	*Arabis collina Ten.*	x	x	✓	x	NE
Brassicaceae	*Lepidium latifolium L.*	x	x	x	✓	NE
Brassicaceae	*Sisymbrium brassiciforme C.A.Mey.*	x	x	x	✓	NE
Campanulaceae	*Campanula argyrotricha Wall. Ex A. DC.*	x	✓	x	x	NE
Campanulaceae	*Campanula pallida Wall.*	x	✓	x	x	NE
Cannabaceae	*Cannabis sativa L.*	✓		x	x	NE
Cannabaceae	*Cannabis sativa L.*	x	✓	x	x	NE
Caprifoliaceae	*Dipsacus inermis Wall.*	x	✓	x	x	NE
Caprifoliaceae	*Morina longifolia Wall. ex DC.*	x	✓	x	x	NE
Carophyllaceae	*Gypsophila cerastoides D.Don*	x	✓	x	x	NE
Carophyllaceae	*Silene viscosa (L.) Pers.*	x	✓	x	x	NE
Carophyllaceae	*Silene vulgaris (Moench) Garcke*	x	✓	x	x	LC
Carophyllaceae	*Silene indica Roxb. ex Otth*	x	✓	x	x	NE
Carophyllaceae	*Silene himalayensis (Rohrb.) Majumdar*	x	✓	x	x	NE
Carophyllaceae	*Stellaria himalayensis Majumdar*	x	✓	x	x	NE

Carophyllaceae	*Silene rupestris Jacq.*	x	x	x	✓	NE
Caryophyllaceae	*Stellaria media (L.) Vill.*	✓	x	x	x	NE
Caryophyllaceae	*Silene himalayensis (Rohrb.) Majumdar*	x	x	✓	x	NE
Caryophyllaceae	*Minuartia kashmirica (Edgew. & Hook. f.) Mattf.*	x	x	✓	x	NE
Celastraceae	*Parnassia nubicola Wall. ex Royle*	x	✓	✓	x	NE
Commelinaceae	*Tradescantia pallida (Rose) D.R.Hunt*	✓	x		x	NE
Convolvulaceae	*Convolvulus arvensis L.*	x	x	✓	x	NE
Costaceae	*Costus curvibracteatus Maas*	✓	x	x	x	LC
Crassulaceae	*Hylotelephium ewersii (Ledeb.) H. ohba*	x	✓	x	x	NE
Crassulaceae	*Rhodiola himalensis (D. Don) S.H. Fu*	x	✓	x	x	NE
Crassulaceae	*Rosularia adenotricha (Wall. Ex Edgew.) C.A. Jansson*	x	✓	x	x	NE
Crassulaceae	*Sedum multicaule Wall. ex Lindl*	x	✓	x	x	NE
Crassulaceae	*Sedum oreades (Decne.) Raym.-Hamet*	x	✓	x	x	NE
Crassulaceae	*Sedum trifidum Hook. f. & Thomson*	x	✓	x	x	NE
Crassulaceae	*Rhodiola imbricata Edgew.*	x	x	✓	x	NE
Crassulaceae	*Rhodiola tibetica (Hook. f. & Thomson) S.H. Fu*	x	x	✓	x	NE
Crassulaceae	*Sedum ewersii Ledeb.*	x	x	✓	x	NE
Crassulaceae	*Rhodiola heterodonta (Hook.f. & Thomson) Boriss.*	x	x	x	✓	NE
Crassulaceae	*Rhodiola sp.*	x	x	x	✓	-
Cyperaceae	*Carex hirta L.*	✓	x	x	x	NE
Cyperaceae	*Cyperus rotundus L.*	✓	x	x	x	LC
Cyperaceae	*Carex inanis Kunth*	x	✓	x	x	NE
Cyperaceae	*Carex nubigena D.Don ex Tilloch & Taylor*	x	✓	x	x	NE
Cyperaceae	*Carex obscura Nees*	x	✓	x	x	NE
Cyperaceae	*Carex nivalis Boott*	x	✓	x	x	NE
Cyperaceae	*Cyperus niveus Retz.*	x	✓	x	x	NE
Cyperaceae	*Eleocharis congesta D. Don*	x	✓	x	x	LC
Cyperaceae	*Kobresia nepalensis (Nees) Kük.*	x	✓	x	x	NE
Cyperaceae	*Schoenoplectiella juncoides*	x	✓	x	x	NE

Cyperaceae	*Eleocharis obusta (Willd.) Schult.*	x	x	✓	x	NE
Cyperaceae	*Kobresia royleana (Nees) Boeckeler*	x	x	✓	x	NE
Cyperaceae	*Scirpus cuneata Schouw ex Kunze*	x	x	✓	x	NE
Ephedraceae	*Ephedra sp.*	x	x	x	✓	-
Euphorbiaceae	*Euphorbia hirta. L.*	✓	x	x	x	NE
Euphorbiaceae	*Euphorbia prostrate Aiton*	✓	x	x	x	NE
Euphorbiaceae	*Euphorbia wallichii Hook.f.*	x	✓	x	x	NE
Fabaceae	*Chamaecrista nomame (Sieber) H. Ohashi*	x	✓	x	x	LC
Fabaceae	*Desmodium triflorum (L.) DC.*	x	✓	x	x	NE
Fabaceae	*Trifolium pratense L.*	x	✓	x	x	LC
Fabaceae	*Trifolium repens L.*	x	✓	x	x	NE
Fabaceae	*Chesneya cuneata (Benth.) Ali*	x	x	✓	x	NE
Fabaceae	*Medicago falcata L.*	x	x	✓	x	NE
Fabaceae	*Oxytropis microphylla (Pall.) DC.*	x	x	✓	x	NE
Fabaceae	*Trifolium repens L.*	x	x	✓	x	NE
Fabaceae	*Astragalus zanskarensis Benth. ex Bunge*	x	x	x	✓	NE
Fabaceae	*Astragulus sp.*	x	x	x	✓	-
Fabaceae	*Cicer microphyllum Royle ex Benth*	x	x	x	✓	NE
Fabaceae	*Trigonella emodi Benth.*	x	x	✓	x	LC
Gentianaceae	*Gentiana algida Pall.*	x	✓	x	x	NE
Gentianaceae	*Gentiana argentea Royle ex D.Don*	x	✓	x	x	NE
Gentianaceae	*Halenia elliptica D.Don*	x	✓	x	x	NE
Gentianaceae	*Swertia ciliata (D.Don ex G. Don) B.L. Burtt*	x	✓	x	x	NE
Gentianaceae	*Swertia cordata (G. Don) Wall. ex C.B. Clarke*	x	✓	x	x	NE
Gentianaceae	*Swertia speciosa D.Don*	x	✓	x	x	NE
Gentianaceae	*Lomatogonium carinthiacum (Wulfen) A.Braun*	x	x	✓	x	NE
Geraniaceae	*Geranium himalayense Klotzsch*	x	✓	x	x	NE
Geraniaceae	*Geranium nepalense Sweet*	x	✓	x	x	NE
Geraniaceae	*Geranium wallichianum D.Don ex Sweet*	x	✓	x	x	LC
Geraniaceae	*Geranium himalayense Klotzsch*	x	x	✓	x	NE
Geraniaceae	*Geranium pratense L.*	x	x	x	✓	NE

Gesneriaceae	*Commelina benghalensis L.*	x	✓	x	x	LC
Gesneriaceae	*Cyanotis cristata (L.) D.Don*	x	✓	x	x	NE
Haloragaceae	*Myriophyllum verticillatum L.*	x	x	✓	x	NE
Hypoxidaceae	*Hypoxis aurea Lour.*	x	✓	x	x	NE
Juncaceae	*Juncus himalensis Klotzsch*	x	✓	x	x	NE
Juncaceae	*Juncus thomsonii Buchenau*	x	✓	x	x	NE
Lamiaceae	*Ajuga bracteosa Wall ex Benth*	✓	x	x	x	NE
Lamiaceae	*Callicarpa macrophylla Vahl*	✓	x	x	x	LC
Lamiaceae	*Mentha piperita L.*	✓	x	x	x	NE
Lamiaceae	*Pogostemon benghalensis (Burm.f.)*	✓	x	x	x	NE
Lamiaceae	*Perilla frutescens (L.) Britton*	✓	x	x	x	LC
Lamiaceae	*Ajuga bracteosa Wall. ex Benth.*	x	✓	x	x	NE
Lamiaceae	*Ajuga parviflora Benth.*	x	✓	x	x	NE
Lamiaceae	*Clinopodium vulgare L.*	x	✓	x	x	NE
Lamiaceae	*Coleus barbatus (Andrews) Benth. ex G.Don*	x	✓	x	x	NE
Lamiaceae	*Craniotome furcata (Link) Kuntze*	x	✓	x	x	NE
Lamiaceae	*Elsholtzia eriostachya (Benth.) Benth.*	x	✓	x	x	NE
Lamiaceae	*Elsholtzia strobilifera (Benth.) Benth.*	x	✓	x	x	NE
Lamiaceae	*Micromeria biflora (Buch. -Ham. ex D.Don) Benth.*	x	✓	x	x	NE
Lamiaceae	*Nepeta connata Royle ex Benth.*	x	✓	x	x	NE
Lamiaceae	*Nepeta podostachys Benth.*	x	✓	x	x	NE
Lamiaceae	*Origanum vulgare L.*	x	✓	x	x	NE
Lamiaceae	*Phlomoides bracteosa (Royle ex Benth.)*	x	c	x	x	NE
Lamiaceae	*Phlomoides macrophylla (Benth.) Kamelin & Makhm.*	x	✓	x	x	NE
Lamiaceae	*Prunella vulgaris L.*	x	✓	x	x	LC
Lamiaceae	*Salvia cana Wall. ex. Benth*	x	✓	x	x	NE
Lamiaceae	*Salvia nubicola Wall. ex Sweet*	x	✓	x	x	NE
Lamiaceae	*Scutellaria scandens D. Don*	x	✓	x	x	NE
Lamiaceae	*Stachys melissifolia Benth.*	x	✓	x	x	NE
Lamiaceae	*Teucrium quadrifarium Buch. -Ham. Ex D.Don*	x	✓	x	x	NE

Lamiaceae	*Thymus serphyllum L.*	x	✓	x	x	NE
Lamiaceae	*Mentha longifolia (L.) L.*	x	x	✓	x	NE
Lamiaceae	*Nepeta longibracteata Benth.*	x	x	✓	x	NE
Lamiaceae	*Thymus serphyllum (Ronniger) Ronniger*	x	x	✓	x	NE
Lamiaceae	*Eriophyton sp.*	x	x	x	✓	-
Lamiaceae	*Hyssopus officinalis L.*	x	x	x	✓	NE
Lamiaceae	*Nepeta longibracteata Benth.*	x	x	x	✓	NE
Lamiaceae	*Nepeta sp.*	x	x	x	✓	-
Lamiaceae	*Thymus serpyllum L.*	x	x	x	✓	NE
Liliaceae	*Fritillaria cirrhosa D.Don*	x	✓	x	x	VU
Liliaceae	*Polygonatum cirrhifolium (Wall.) Royle*	x	✓	x	x	NE
Liliaceae	*Polygonatum verticillatum (L.) All.*	x	✓	x	x	NE
Lythraceae	*Rotala rotundifolia (Buch. -Ham. ex Roxb.) Koehne*	x	x	✓	x	LC
Malvaceae	*Sida acuta Burm.f.*	✓	x	x	x	NE
Malvaceae	*Malva neglecta Wallr.*	x	✓	x	x	NE
Melanthiaceae	*Trillium govanianum Wall. ex D.Don*	x	✓	x	x	EN
Onagraceae	*Circaea alpina L.*	x	✓	x	x	NE
Onagraceae	*Epilobium brevifolium D. don*	x	✓	x	x	NE
Onagraceae	*Epilobium laxum Royle*	x	✓	x	x	NE
Onagraceae	*Epilobium royleanum Hausskn. H*	x	✓	x	x	NE
Onagraceae	*Oenothera rosea L'Her. ex Aiton*	x	✓	x	x	NE
Onagraceae	*Epilobium angustifolium L.*	x	x	✓	x	LC
Orchidaceae	*Calanthe tricarinata Lindl.*	x	✓	x	x	NE
Orchidaceae	*Dactylorhiza hatagirea (D.Don) Soó*	x	✓	x	x	EN
Orchidaceae	*Epipactis gigantea Douglas ex Hook.*	x	✓	x	x	LC
Orchidaceae	*Peristylus elisabethae (Duthie) R.K. Gupta*	x	✓	x	x	NE
Orchidaceae	*Goodyera fusca (Lindl.) Hook. f.*	x	✓	x	x	NE
Orchidaceae	*Goodyera repens (L.) R.Br.*	x	✓	x	x	NE
Orchidaceae	*Maianthemum purpureum*	x	✓	x	x	NE

Orchidaceae	*Platanthera edgeworthii (Hook. f. ex Collett) R.K. Gupta*	x	✓	x	x	NE
Orchidaceae	*Ponerorchis chusua (D.Don) Soó*	x	✓	x	x	NE
Orchidaceae	*Satyrium nepalense D.Don*	x	✓	x	x	NE
Orobanchaceae	*Leptorhabdos parviflora (Benth.) Benth.*	x	✓	x	x	NE
Orobanchaceae	*Pedicularis gracilis Wall. ex Benth*	x	✓	x	x	NE
Orobanchaceae	*Pedicularis hoffmeisteri Klotzsch*	x	✓	x	x	NE
Orobanchaceae	*Pedicularis pectinata Wall. Ex Benth.*	x	c	x	x	NE
Orobanchaceae	*Pedicularis punctata Decne.*	x	✓	x	x	NE
Orobanchaceae	*Pedicularis siphonantha D.Don*	x	✓	x	x	NE
Oxalidaceae	*Oxalis corniculata L.*	✓	x	x	x	NE
Oxalidaceae	*Oxalis acetosella L.*	x	✓	x	x	NE
Oxalidaceae	*Oxalis corniculata L.*	x	✓	x	x	NE
Papaveraceae	*Corydalis cornuta Royle*	x	✓	x	x	NE
Papaveraceae	*Corydlais filiformis Royle*	x	✓	x	x	NE
Papaveraceae	*Corydalis govaniana Wall.*	x	✓	x	x	NE
Papaveraceae	*Meconopsis aculeata Royle*	x	✓	x	x	NE
Phytolaccaceae	*Phytolacca acinosa Roxb.*	x	✓	x	x	NE
Plantaginaceae	*Scoparia dulcis L.*	✓	x	x	x	NE
Plantaginaceae	*Plantago lanceolata L.*	x	✓	x	x	NE
Plantaginaceae	*Plantago major L.*	x	✓	x	x	LC
Plantaginaceae	*Veronica biloba schreb. ex L.*	x	✓	x	x	NE
Plantaginaceae	*Agrostis munroana Aitch. & Hemsl.*	x	✓	x	x	NE
Plantaginaceae	*Hippuris vulgaris L.*	x	x	✓	x	LC
Plantaginaceae	*Plantago depressa Willd.*	x	x	✓	x	NE
Poaceae	*Apluda mutica L.*	✓	x	x	x	NE
Poaceae	*Arthraxon lanceolatus (Roxb.)*	✓	x	x	x	NE
Poaceae	*Arundinaria gigantea (Walter) Nuhl.*	✓	x	x	x	NE
Poaceae	*Arthraxon lanceolatus (Roxb.)*	✓	x	x	x	NE
Poaceae	*Bothriochloa pertusa (L.) A.Camus*	✓	x	x	x	NE
Poaceae	*Chrysopogon aciculatus (Retz.) Trin.*	✓	x	x	x	NE

Poaceae	*Chrysopogon zizanioides (L.) Roberty*	✓	x	x	x	NE
Poaceae	*Cymbopogon citratus (DC.) Stapf*	✓	x	x	x	NE
Poaceae	*Cymbopogon schoenanthus Spreng.*	✓	x	x	x	NE
Poaceae	*Cynodon dactylon (L.) Pers.*	✓	x	x	x	NE
Poaceae	*Dendrocalamus hamiltonii Gamble*	✓	x	x	x	NE
Poaceae	*Dendrocalamus strictus (Roxb.) Nees*	✓	x	x	x	NE
Poaceae	*Dicanthium annulatum (Forssk.) Stapf*	✓	x	x	x	NE
Poaceae	*Digitaria sanguinalis (L.) Scop.*	✓	x	x	x	LC
Poaceae	*Echinochloa colona (L.) Link*	✓	x	x	x	NE
Poaceae	*Eulaliopsis binate (Retz.) C.E. Hubb.*	✓	x	x	x	NE
Poaceae	*Ischaemum angustifolium (Trin.) Hack.*	✓	x	x	x	NE
Poaceae	*Oplismenus hirtellus (L.) P.Beauv.*	✓	x	x	x	NE
Poaceae	*Phalaris minor Retz.*	✓	x	x	x	NE
Poaceae	*Phalaris minor Retz.*	✓	x	x	x	NE
Poaceae	*Setaria italica (L.) P. Beauvois*	✓	x	x	x	NE
Poaceae	*Agrostis pilosula Trin.*	x	✓	x	x	NE
Poaceae	*Andropogon munroi C.B.Clarke*	x	✓	x	x	NE
Poaceae	*Arundinella bengalensis (Spreng.) Druce*	x	✓	x	x	NE
Poaceae	*Brachiaria villosa (Lam.) A. Camus*	x	✓	x	x	NE
Poaceae	*Thamnocalamus spathiflorus (Trin.) Munro*	x	✓	x	x	NE
Poaceae	*Chrysopogon serrulatus Trin.*	x	✓	x	x	NE
Poaceae	*Cymbopogon distans (Nees ex Steud.) Will.Watson*	x	✓	x	x	NE
Poaceae	*Cynodon dactylon (L.) Pers.*	x	✓	x	x	NE
Poaceae	*Dactylis glomerata L.*	x	✓	x	x	NE
Poaceae	*Drepanostachyum falcatum (Nees) Keng f.*	x	✓	x	x	NE
Poaceae	*Digitaria cruciata (Nees) A. Camus*	x	✓	x	x	NE
Poaceae	*Echinochloa colona (L.) Link*	x	✓	x	x	LC
Poaceae	*Eulalia mollis (Griseb.) Kuntze*	x	✓	x	x	NE
Poaceae	*Koeleria macrantha (Ledeb.) Schult.*	x	✓	x	x	NE
Poaceae	*Phacelurus speciosus (Steud.) C.E.Hubb.*	x	✓	x	x	NE

Poaceae	*Phleum alpinum L.*	x	✓	x	x	LC
Poaceae	*Poa alpina L.*	x	✓	x	x	NE
Poaceae	*Poa annua L.*	x	✓	x	x	LC
Poaceae	*Saccharum rufipilum Steud.*	x	✓	x	x	NE
Poaceae	*Setaria pumila (Poir.) Roem. & Schult.*	x	✓	x	x	NE
Poaceae	*Stipa roylei (Nees) Duthie*	x	✓	x	x	NE
Poaceae	*Thamnocalamus spathiflorus (Trin.) Munro*	x	✓	x	x	NE
Poaceae	*Themeda anathera (Nees ex Steud.)*	x	✓	x	x	NE
Poaceae	*Elymus nutans Griseb.*	x	x	✓	x	NE
Poaceae	*Leymus secalinus (Georgi) Tzvelev*	x	x	✓	x	NE
Poaceae	*Poa alpigena Lindm.*	x	x	✓	x	NE
Poaceae	*Pucinellia himalaica*	x	x	✓	x	NE
Poaceae	*Festuca altaica Trin.*	x	x	x	✓	NE
Poaceae	*Grass (risa hard)*	x	x	x	✓	NE
Poaceae	*Grass Risa tong tong*	x	x	x	✓	NE
Poaceae	*Melica persica Kunth*	x	x	x	✓	NE
Poaceae	*Stipa capillata L.*	x	x	x	✓	NE
Podophyllaceae	*Podophyllum hexandrum Royle*	x	✓	x	x	NE
Polemonicaceae	*Polemonium caeruleum L*	x	✓	x	x	NE
Polygonaceae	*Persicaria glabra (Willd.) M.Gomez*	✓	x	x	x	LC
Polygonaceae	*Aconogonon rumicifolium (Royle ex Bab.) H.Hara*	x	✓	x	x	NE
Polygonaceae	*Bistorta affinis (D. Don) Greene*	x	✓	x	x	NE
Polygonaceae	*Fagopyrum esculentum Moench*	x	✓	x	x	NE
Polygonaceae	*Polygonum delicatulum Meisn.*	x	✓	x	x	NE
Polygonaceae	*Polygonum filicaule Wall. ex Meisn.*	x	✓	x	x	NE
Polygonaceae	*Persicaria amplexicaulis (D.Don) Ronse Decr.*	x	✓	x	x	NE
Polygonaceae	*Persicaria capitata (Buch. -Ham. ex D.Don) H.Gross*	x	✓	x	x	NE
Polygonaceae	*Persicaria chinensis (L.) H. Gross*	x	✓	x	x	NE
Polygonaceae	*Persicaria hydropiper (L.) Delarbe*	x	✓	x	x	LC

Polygonaceae	*Persicaria nepalensis (Meisn) H. Gross*	x	✓	x	x	NE
Polygonaceae	*Persicaria orientalis (L.) Spach*	x	✓	x	x	NE
Polygonaceae	*Rheum australe D. Don*	x	✓	x	x	NE
Polygonaceae	*Rumex hastatus D. Don*	x	✓	x	x	NE
Polygonaceae	*Rumex nepalensis Spreng.*	x	✓	x	x	NE
Polygonaceae	*Bistorta affinis (D.Don) Greene*	x	x	✓	x	NE
Polygonaceae	*Oxyria digyna (L.) Hill*	x	x	✓	x	NE
Polygonaceae	*Polygonum plebeium R.Br.*	x	x	✓	x	NE
Polygonaceae	*Rumex nepalensis Spreng.*	x	x	✓	x	NE
Polygonaceae	*Aconogonon tortuosum (D.Don) H.Hara*	x	x	x	✓	NE
Polygonaceae	*Bistorta affinis (D.Don) Greene*	x	x	x	✓	NE
Polygonaceae	*Polygonum cognatum Meisn.*	x	x	x	✓	NE
Polygonaceae	*Rheum australe D.Don*	x	x	x	✓	NE
Polygonaceae	*Rheum webbianum Royle*	x	x	x	✓	NE
Polygonaceae	*Rumex nepalensis Spreng.*	x	x	x	✓	NE
Portulacaceae	*Portulaca pilosa L.*	✓	x	x	x	NE
Primulaceae	*Androsace sarmentosa Wall.*	x	✓	x	x	NE
Primulaceae	*Primula denticulata Sm.*	x	✓	x	x	NE
Primulaceae	*Primula gracilipes Craib*	x	✓	x	x	NE
Primulaceae	*Primula reidii Duthie*	x	✓	x	x	NE
Primulaceae	*Primula macrophylla D.Don*	x	x	x	✓	NE
Rannunculaceae	*Anemone vitifolia Buch. -Ham. ex DC.*	✓	x	x	x	NE
Ranunculaceae	*Anemone rivularis Buch. -Ham. ex DC.*	x	✓	x	x	NE
Ranunculaceae	*Anemonastrum obtusilobum (D.Don) Mosyakin*	x	✓	x	x	NE
Ranunculaceae	*Anemone tetrasepala Royle*	x	✓	x	x	NE
Ranunculaceae	*Aquilegia pubiflora Wall. ex Royle*	x	✓	x	x	NE
Ranunculaceae	*Caltha palustris L.*	x	✓	x	x	LC
Ranunculaceae	*Delphinium vestitum Wall. Ex Royle*	x	✓	x	x	NE
Ranunculaceae	*Ranunculus distans D.Don*	x	✓	x	x	NE
Ranunculaceae	*Ranunculus pulchellus C.A. Mey*	x	✓	x	x	NE
Ranunculaceae	*Thalictrum foliolosum DC.*	x	✓	x	x	NE

Ranunculaceae	*Thalictrum reniforme Wall.*	x	✓	✓	x	NE
Ranunculaceae	*Delphinium brunonianum Royle*	x	x	✓	x	NE
Ranunculaceae	*Rannunculus repens L.*	x	x	✓	x	NE
Ranunculaceae	*Ranunculus hyperboreus Rottb.*	x	x	✓	x	LC
Ranunculaceae	*Thalictrum cultratum Wall.*	x	x	x	✓	NE
Rosaceae	*Agrimonia pilosa Ledeb.*	x	✓	x	x	NE
Rosaceae	*Duchesnea indica (Jacks.) Focke*	x	✓	x	x	NE
Rosaceae	*Fragaria nubicola (Lindl. ex Hook.f.) Lacaita.*	x	✓	x	x	NE
Rosaceae	*Filipendula vestita (Wall. ex G.Don) Maxim*	x	✓	x	x	NE
Rosaceae	*Geum elatum Wall. Ex G. Don*	x	✓	x	x	NE
Rosaceae	*Potentilla atrosanguinea G. Lodd. ex D.Don*	x	✓	x	x	NE
Rosaceae	*Potentilla indica (Andrews) Th.Wolf*	x	✓	x	x	NE
Rosaceae	*Potentilla lineata Trevir.*	x	✓	x	x	NE
Rosaceae	*Potentilla nepalensis Hook.*	x	✓	x	x	NE
Rosaceae	*Sibbaldia cuneata Edgew.*	x	✓	x	x	NE
Rosaceae	*Potentilla argyrophlla Wall.*	x	x	✓	x	NE
Rosaceae	*Sibbaldia cuneata Schouw ex Kunze*	x	x	✓	x	NE
Rosaceae	*Potentilla argyrophylla Wall. ex Lehm.*	x	x	x	✓	NE
Rosaceae	*Potentilla multifida L.*	x	x	x	✓	NE
Rosaceae	*Potentila sp.*	x	x	x	✓	-
Rosaceae	*Potetilla sp.*	x	x	x	✓	-
Rubiaceae	*Galium aparine L.*	✓		x	x	NE
Rubiaceae	*Galium aparine L.*	x	✓	x	x	NE
Rubiaceae	*Rubia cordifolia L.*	x	✓	x	x	NE
Saxifragaceae	*Astilbe rivularis Buch. -Ham. ex D.Don*	x	✓	x	x	NE
Saxifragaceae	*Bergenia ciliata (Haw.) Sternb.*	x	✓	x	x	LC
Saxifragaceae	*Bergenia stracheyi (Hook.f. & Thomson) Engl.*	x	✓	x	x	NE
Saxifragaceae	*Saxifraga granulifera Harry Sm.*	x	✓	x	x	NE
Saxifragaceae	*Saxifraga parnassifolia D.Don*	x	✓	x	x	NE
Saxifragaceae	*Berginea stracheyi (Hook.f. & Thomson) Engl.*	x	x	✓	✓	NE
Saxifragaceae	*Saxifraga stenophylla Royle*	x	x	✓	x	NE

Scrophulariaceae	*Scrophularia himalensis ex. Benth*	x	✓	x	x	NE
Scrophulariaceae	*Verbascum thapsus L.*	x	✓	✓	✓	NE
Solanaceae	*Solanum nigrum L.*	✓	✓	x	x	NE
Solanaceae	*Datura stramonium (L.)*	x	✓	x	x	NE
Solanaceae	*Nicandra physalodes (L.)*	x	✓	x	x	NE
Solanaceae	*Solanum villosum Mill.*	x	✓	x	x	NE
Urticaceae	*Urtica dioica L.*	✓	✓	x	x	LC
Urticaceae	*Girardinia diversifolia (Link) Friis*	x	✓	x	x	NE
Urticaceae	*Gonostegia hirta (Blume) Miq.*	x	✓	x	x	NE
Urticaceae	*Lecanthus peduncularis (Royle)Wedd.*	x	✓	x	x	NE
Urticaceae	*Pilea scripta (Buch. – Ham. Ex D.Don)*	x	✓	x	x	NE
Urticaceae	*Pilea umbrosa Wedd. Ex Blume*	x	✓	x	x	NE
Violaceae	*Viola biflora L.*	x	✓	x	x	NE
Violaceae	*Viola canescens Wall.*	x	✓	x	x	NE
Violaceae	*Viola pilosa Blume*	x	✓	x	x	NE
Zingiberaceae	*Hedychium spicatum Sm.*	x	✓	x	x	NE
Zingiberaceae	*Roscoea alpina Royle*	x	✓	x	x	NE
Zingiberaceae	*Roscoea purpurea Sm.*	x	✓	x	x	NE

Appendix IV: Checklist of climber species found in the selected protected areas of Himachal Pradesh.

Family	**Climber Species**	**CSJNP**	**CWS**	**CTWS**	**PVNP**	**IUCN Status**
Fabaceae	*Millettia extensa (Benth.) Baker*	✓	x	x	x	NE
Fabaceae	*Bauhinia vahlii Wight & Arn*	✓	x	x	x	NE
Menispermaceae	*Cissampelos pareira L.*	✓	x	x	x	NE
Fabaceae	*Mucuna pruriens (L.) DC.*	✓	x	x	x	LC

Fabaceae	*Pueraria tuberosa (Willd.) DC.*	✓	x	x	x	NE
Ranunculaceae	*Clematis gouriana Roxb. ex DC.*	✓	x	x	x	NE
Dioscoreaceae	*Dioscorea deltoidea Wall. ex Griseb.*	✓	x	x	x	NE
Araliaceae	*Aralia parasitica (D. Don) Buch. -Ham. ex Bosse*	x	✓	x	x	NE
Araliaceae	*Hedera nepalensis K.Koch*	x	✓	x	x	NE
Convolvulaceae	*Cuscuta reflexa Roxb*	x		x	x	LC
Cucurbitaceae	*Solena amplexicaulis (Lam.) Gandhi*	x	✓	x	x	NE
Dioscoreaceae	*Dioscorea deltoidea Wall. ex Griseb.*	x	✓	x	x	NE
Moraceae	*Ficus hederacea Roxb.*	x	✓	x	x	NE
Oleaceae	*Jasminum dispermum Wall.*	x	✓	x	x	NE
Ranunculaceae	*Clematis barbellata Edgew.*	x	✓	x	x	NE
Ranunculaceae	*Clematis montana Buch. -Ham. ex DC.*	x	✓	x	x	NE
Smilacaceae	*Smilax aspera L*	x	✓	x	x	LC
Vitaceae	*Parthenocissus semicordata (Wall.) Planch.*	x	✓	x	x	NE
Vitaceae	*Tetrastigma serrulatum (Roxb.) Planch.*	x	✓	x	x	NE

Appendix V: Checklist of ferns and fern-allies found in the selected protected area of Himachal Pradesh.

Family	**Fern Species**	**CSJNP**	**CWS**	**CTWS**	**PVNP**	**IUCN Status**

Aspleniaceae	*Asplenium dalhousiae Hook.*	x	✓	x	x	NE
Aspleniaceae	*Asplenium ensiforme Wall. ex Hook. & Grev.*	x	✓	x	x	NE
Athyriaceae	*Athyrium foliolosum T. Moore ex R. Sim*	x	✓	x	x	NE
Dennstaedtiaceae	*Pteridium aquilinum (L.) Kuhn*	x	✓	x	x	LC
Dryopteridaceae	*Polystichum acrostichoides (Michx.) Schott*	✓	x	x	x	NE
Dryopteridaceae	*Dryopteris barbigera (T. Moore ex Hook.) Kuntze*	x	✓	x	x	NE
Dryopteridaceae	*Polystichum bakerianum (Atk. ex C.B. Clarke) Diels*	x	✓	x	x	NE
Polypodiaceae	*Drynaria mollis Bedd.*	x	✓	x	x	NE
Pteridaceae	*Adiantum incisum Forssk.*	✓	x	x	x	NE
Pteridaceae	*Adiantum capillus-veneris L.*	✓	✓	x	x	LC
Pteridaceae	*Adiantum philippense. L.*	✓	x	x	x	NE
Pteridaceae	*Adiantum caudatum L.*	x	✓	x	x	NE
Pteridaceae	*Adiantum venustum D. Don*	x	✓	x	x	NE
Pteridaceae	*Onychium japonicum (Thunb.) Kunze*	x	✓	x	x	NE
Pteridaceae	*Onychium lucidum (D.Don) Spreng.*	x	✓	x	x	NE
Pteridaceae	*Pteris cretica L.*	x	✓	x	x	NE

Appendix VI: Table. List of floral species recorded in CSJNP, Himachal Pradesh - including species from current research and previous studies. Blue highlighting indicates species newly recorded in the CSJNP during the current research.

S.No.	**Family**	**Species**
	Trees	
1	Anacardiaceae	*Lannea coromandelica*

2		*Mangifera indica*
3	Annonaceae	*Miliusa velutina*
4	Arecaceae	*Phoenix humilis*
5	Ebenaceae	*Diospyros melanoxylon*
6	Euphorbiaceae	*Mallotus philippensis*
7	Lamiaceae	*Gmelina arborea*
8	Meliaceae	*Melia azedarach*
9	Meliaceae	*Toona ciliata*
10	Rhamnaceae	*Ziziphus jujuba*
11	Rhamnaceae	*Ziziphus mauritiana*
12	Sapotaceae	*Madhuca longifolia*
13	Simaroubaceae	*Ailanthus excelsa*
14		*Cordia dichotoma*
15	Boraginaceae	*Ehretia laevis*
16		*Anogeissus latifolia*
17		*Terminalia alata*
18		*Terminalia arjuna*
19		*Terminalia chebula*
20		*Terminalia bellirica*
21	Combretaceae	*Terminalia tomentosa*
22	Dipterocarpaceae	*Shorea robusta*
23	Fabaceae	*Acacia catechu*

24		*Acacia nilotica*
25		*Albizia procera*
26		*Albizia lebbeck*
27		*Bauhinia malabarica*
28		*Bauhinia variegata*
29		*Butea monosperma*
30		*Cassia fistula*
31		*Dalbergia sissoo*
32		*Leucenealeucophala*
33		*Melilotus indicus*
34		*Pongamia pinnata*
35		*Prosopis juliflora*
36		*Ougeinia oojeinensis*
37		*Tamarindus indica*
38	Lamiaceae	*Tectona grandis*
39	Lauraceae	*Litsea glutinosa*
40		*Bombax ceiba*
41		*Grewia optiva*
42	Malvaceae	*Grewia oppositifolia*

43		*Grewia elastic*
44		*Kydia calycina*
45		*Ficus benghalensis*
46		*Ficus glomerata*
47		*Ficus hispida*
48		*Ficus lacor*
49		*Ficus racemosa*
50		*Ficus religiosa*
51		*Ficus roxburghii*
52		*Ficus semicordata*
53		*Ficus auriculata*
54		*Ficus virens*
55		*Ficus rumphii*
56		*Artocarpus lacucha*
57		*Morus alba*
58	Moraceae	*Morus nigra*
59	Moringaceae	*Moringa oleifera*
60		*Eucalyptus tereticornis*
61	Myrtaceae	*Syzygium cumini*

62		*Psidium guajava*
63		*Bridelia retusa*
64	Phyllanthaceae	*Phyllanthus emblica*
65		*Adina cardifolia*
66		*Haldina cordifolia*
67	Rubiaceae	*Mitragyna parvifolia*
68		*Limonia/Naringi crenulata*
69		*Murraya paniculata*
70	Rutaceae	*Murraya koenigii*
71		*Casearia tomentosa*
72		*Flacourtia indica*
73	Salicaceae	*Populus deltoids*
	Shrubs	
1		*Adhatoda Vasica*
2	Acanthaceae	*Barleria strigosa*
3		*Calotropis procera*
4		*Carissa opaca*
5		*Holarrhena antidysenterica*
6	Apocynaceae	*Holarrhena pubescens*
7	Arecaceae	*Calamus tenuis*

8		*Eupatorium adenophorum*
9	Asteraceae	*Xanthium strumarium*
10		*Colebrookea oppositifolia*
11	Lamiaceae	*Vitex negundo*
12		*Phlogacanthus thyrsiflorus*
13		*Eranthemum pulchellum*
14		*Pachystachys spicata*
15	Acanthaceae	*Justicia adhatoda*
16		*Carissa spinarum*
17		*Nerium oleander*
18		*Holarrhena /Wrightia antidysenterica*
19	Apocynaceae	*Asclepias curassavica*
20		*Agave cantula*
21		*Asparagus adscendens*
22		*Asparagus racemosus*
23	Asparagaceae	*Agave americana*
24		*Ipomea atropurpurea*
25	Convolvulaceae	*Ipomea carnea*
26	Euphorbiaceae	*Baliospermum montanum*
27	Fabaceae	*Cassia occidentalis*

28		*Dendrolobium triangulare*
29		*Desmodiumga ngeticum*
30		*Desmodium pulchellum*
31		*Flemingia bracteata*
32		*Flemingia chappar*
33		*Indigofera gerardiana*
34		*Phyllodium pulchellum*
35		*Senna occidentalis*
36		*Mimosa rubicaulis*
37		*Indigofera heterantha*
38		*Callicarpa macrophylla*
39		*Vitex trifolia L.*
40	Lamiaceae	*Pogostemon benghalensis*
41	Lythraceae	*Woodfordia fruticosa*
42		*Gossypium arboreum*
43		*Urena lobata*
44	Malvaceae	*Sida acuta*
45		*Ardisia solanacea*
46	Primulaceae	*Ardisia solanacea*

47	Rhamnaceae	*Ziziphus nummularia*
48		*Rubus ellipticus*
49	Rosaceae	*Rubus occidentalis*
50		*Coffea benghalensis*
51		*Randia uliginosa*
52	Rubiaceae	*Catunaregam spinosa*
53	Rutaceae	*Toddalia asiatica*
54		*Solanum hispidum*
55		*Solanum torvum*
56		*Solanum capsicoides*
57		*Solanum verbascifolium*
58		*Withania somnifera*
59	Solanaceae	*Brugmansia suaveolens*
60	Urticaceae	*Boehmeria frutescens*
61	Verbenaceae	*Lantana camara*
	Herbs	
1	Acanthaceae	*Dicliptera bupleuroides*
2		*Achyranthes aspera*
3		*Chenopodium album*
4	Amaranthaceae	*Achyranthes bidentata*

5		*Alternanthera sessilis*
6	Apiaceae	*Centella asiatica*
7		*Calamus viminalis*
8	Arecaceae	*Calamus tenuis*
9		*Galinsoga parviflora*
10		*Artemisia annua*
11		*Jacobaea nudicaulis*
12		*Anaphalis contorta*
13		*Ageratina adenophora*
14		*Ageratum conyzoides*
15		*Bidens biternata*
16		*Blumea laciniata*
17		*Eclipta prostrata*
18		*Emilia sanchifolia*
19		*Sigesbeckia orientalis*
20		*Spilanthes paniculata*
21		*Synedrella vialis*
22		*Tridax procumbens*
23	Asteraceae	*Vernonia cinerea*

24		*Xanthium indicum*
25		*Erigeron Canadensis*
26		*Xanthium strumarium*
27		*Sonchus wightianus*
28		*Parthenium hysterophorus*
29	Boraginaceae	*Cynoglossum lanceolatum*
30	Brassicaceae	*Eruca vesicaria*
31	Cannabaceae	*Cannabis sativa*
32	Caryophyllaceae	*Stellaria media*
33		*Commelina benghalensis*
34	Commelinaceae	*Tradescantia pallida*
35	Costaceae	*Costus curvibracteatus*
36		*Cyperus distans*
37		*Cyprus kyllingia*
38		*Cyperus nireus*
39		*Cyperus rotundus*
40	Cyperaceae	*Kyllinga nemoralis*
41		*Euphorbia hirta*
42	Euphorbiaceae	*Euphorbia prostrata*
43	Fabaceae	*Desmodium heterocarpon*

44		*Desmodium triflorum*
45		*Mimosa pudica*
46		*Trifolium alexandrinum*
47	Hypoxidaceae	*Curculigo orchioides*
48		*Mentha piperita*
49		*Ajuga bracteosa*
50		*Acrocephalus capitatus*
51		*Nepeta hindostana*
52		*Perilla frutescens*
53	Lamiaceae	*Pogostemon benghalensis*
55		*Corchorus aestuans*
56		*Malvastrum coromandelianum*
57		*Sida acuta*
58		*Sida cordata*
59		*Sida cordifolia*
60		*Sida rhomboidea*
61	Malvaceae	*Triumfetta rhomboidea*
62	Mazaceae	*Mazus rugosus*
63	Oxalidaceae	*Oxalis corniculata*

64	Papaveraceae	*Fumaria parviflora*
65		*Phyllanthus virgatus*
66	Phyllanthaceae	*Phyllanthus urinaria*
67	Piperaceae	*Peperomia pellucid*
68	Plantaginaceae	*Scoparia dulcis*
69		*Chrysopogon aciculatus*
70		*Chrysopogon zizanioides*
71		*Cymbopogon citratus*
72		*Cymbopogon schoenanthus*
73		*Cynodon dactylon*
74		*Cyperus rotundus*
75		*Dendrocalamus hamiltonii*
76		*Dendrocalamus strictus*
77		*Dichanthium annulatum*
78		*Digitaria sanguinalis*
79		*Echinochloa colona*
80		*Eulaliopsis binate*
81		*Coix lacryma*
82	Poaceae	*Cymbopogon schoenanthus*

83		*Digitaria ciliaris*
84		*Eragrostis tremula*
85		*Eragrostis minor*
86		*Eulaliopsis binata*
87		*Eleusine indica*
88		*Hordeum vulgare*
89		*Oplismenus composites*
90		*Oryza sativa*
91		*Paspalidium flavidum Grass*
92		*Phalaris minor*
93		*Saccharum officinarum*
94		*Saccharum spontaneum*
95		*Setaria italica*
96		*Triticum aestivum*
97		*Zea mays*
98		*Ischaemum angustifolium*
99	Polygonaceae	*Persicaria glabra*
100	Portulacaceae	*Portulaca pilosa*
101	Rubiaceae	*Galium aparine*

102		*Borreria articularis*
103	Solanaceae	*Solanum nigrum*
104		*Boehmeria macrophylla*
105	Urticaceae	*Urtica dioica*
	ferns	
1	Dryopteridaceae	*Polystichum acrostichoides*
2		*Adiantum incisum*
3		*Adiantum venustum*
4		*Cheilanthes farinosa*
5		*Adiantum capillus-veneris*
6	Pteridaceae	*Adiantum philippense*
	Climbers	
1	Capparaceae	*Capparis zeylanica*
2	Dioscoreaceae	*Dioscorea deltoidea*
3		*Millettia auriculata*
4		*Pueraria tuberosa*
5		*Millettia extensa*
6		*Bauhinia vahlii*
7		*Millettia extensa*
8	Fabaceae	*Mucuna pruriens*

9	Loranthaceae	*Helixanthera ligustrina*
10	Menispermaceae	*Cissampelos pareira*
11	Ranunculaceae	*Clematis gouriana*

Appendix VII: List of floral species recorded in CTWS, Himachal Pradesh - including species from current research and previous studies. Blue highlighting indicates species newly recorded in the sanctuary during the current research

S. No.	**Family**	**Species**
1	Acanthaceae	*Hygrophila lancea*
2		*Bupleurum falcatum*
3	Apiaceae	*Vicatia coniifolia*
4		*Allardia tomentosa*
5		*Anaphalis nepalensis*
6		*Anaphalis triplinervis*
7		*Aster flaccidus Bunge*
8		*Cirsium arvense*
9		*Cremanthodium decaisnei*
10		*Crepis multicaulis*
11		*Erigeron multiradiatus*
12		*Jurinea ceratocarpa*
13		*Lactuca macrorhiza*
14	Asteraceae	*Launaea aspleniifolia*

15		*Leontopodium brachyactis*
16		*Leontopodium himalayanum*
17		*Leontopodium nanum*
18		*Launaea aspleniifolia*
19		*Leontopodium ochroleucum*
20		*Richteria pyrethroides*
21		*Saussurea jacea*
22		*Sericocarpus asteroides*
23		*Taraxacum eriopodum*
24		*Taraxacum leucanthum*
25		*Taraxacum officinale*
26		*Waldheimia glabra*
27		*Waldheimia tomentosa*
28		*Arnebia euchroma*
29		*Eritrichium nanum*
30		*Lindelofia stylosa*
31	Boraginaceae	*Myosotis sylvatica*
32	Brassicaceae	*Arabis amplexicaulis*

33		*Arabis collina*
34		*Arabis recta*
35		*Crucihimalaya tibetica*
36		*Crucihimalaya wallichii*
37		*Draba glomerata*
38		*Draba lanceolata*
39	Campanulaceae	*Cyananthus lobatus*
40	Caprifoliaceae	*Lonicera spinosa*
41	Chenopodiaceae	*Chenopodium foliosum*
42		*Dichodon cerastoides*
43		*Eremogone kansuensis*
44		*Minuartia kashmirica*
45		*Silene gonosperma*
46		*Silene graminifolia*
47		*Silene uralensis*
48		*Silene himalayensis*
49		*Stellaria decumbens*
50		*Stellaria longifolia*
51	Caryophyllaceae	*Stellaria williamsiana*

52		*Rhodiola crenulata*
53		*Rhodiola himalensis*
54		*Rhodiola imbricata*
55		*Rhodiola tibetica*
56		*Rosularia alpestris*
57	Crassulaceae	*Sedum ewersii*
58	Convolvulaceae	*Convolvulus arvensis*
59		*Carex nivalis*
60		*Carex melanantha*
61		*Carex micropoda*
62		*Carex pamirensis*
63		*Eleocharis obusta*
64		*Eleocharis palustris*
65		*Kobresia royleana*
66	Cyperaceae	*Scirpus cuneata*
67	Ephedraceae	*Ephedra intermedia*
68		*Astragalus cariensis*
69		*Astragalus himalayanus*
70	Fabaceae	*Astragalus munroi*

71		*Astragalus strictus*
72		*Chesneya cuneata*
73		*Cicer microphyllum*
74		*Medicago falcata*
75		*Oxytropis humifusa*
76		*Oxytropis lapponica*
77		*Oxytropis microphylla*
78		*Oxytropis mollis*
79		*Trigonella emodi*
80		*Trifolium repens*
81		*Comastoma tenellum*
82		*Gentiana argentea*
83		*Gentiana coronata*
84		*Gentiana leucomelaena*
85		*Gentiana nivalis*
86		*Gentiana phyllocalyx*
87		*Gentianella aurea*
88	Gentianaceae	*Gentiana membranulifera*

89		*Gentianella moorcroftiana*
90		*Gentianopsis detonsa*
91		*Gentianopsis paludosa*
92		*Lomatogonium carinthiacum*
93		*Geranium pratense*
94		*Geranium himalayense*
95	Geraniaceae	*Geranium wallichianum*
96	Haloragaceae	*Myriophyllum verticillatum*
97		*Juncus allioides*
98		*Juncus himalensis*
99	Juncaceae	*Juncus leucomelas*
100	Juncaginaceae	*Triglochin maritima*
101		*Elsholtzia eriostachya*
102		*Mentha longifolia*
103		*Nepeta eriostachya*
104		*Nepeta longibracteata*
105		*Thymus linearis*
106	Lamiaceae	*Thymus serphyllum*
107	Lythraceae	*Rotala rotundifolia*
108	Onagraceae	*Epilobium angustifolium*

109		*Epilobium laxum*
110		*Epilobium palustre*
111		*Epilobium royleanum*
112		*Euphrasia himalayica*
113		*Pedicularis hoffmeisteri*
114		*Pedicularis longiflora*
115		*Pedicularis pectinata*
116	Orobanchaceae	*Pedicularis rhinanthoides*
117	Papaveraceae	*Corydalis meifolia*
118		*Hippuris vulgaris*
119		*Plantago depressa*
120		*Veronica beccabunga*
121	Plantaginaceae	*Veronica biloba*
122		*Agrostis castellana*
123		*Bromus sp.*
124		*Elymus nutans*
125		*Leymus secalinus*
126		*Melica persica*
127	Poaceae	*Phleum alpinum*

128		*Poa alpigena*
129		*Poa alpina*
130		*Poa supina*
131		*Pucinellia himalaica*
132		*Trisetum spicatum*
133		*Bistorta affinis*
134		*Bistorta vivipara*
135		*Oxyria digyna*
136		*Polygonum aviculare*
137		*Polygonum cognatum*
138		*Polygonum paronychioides*
139		*Polygonum plebeium*
140		*Polygonum recumbens*
141		*Polygonum rottboellioides*
142		*Rheum spiciforme*
143	Polygonaceae	*Rumex nepalensis*
144		*Potamogeton crispus*
145	Potamogetonaceae	*Potamogeton natans*

146		*Potamogeton nodosus*
147		*Stuckenia pectinata*
148		*Androsace sempervivoides*
149		*Glaux maritima*
150	Primulaceae	*Primula minutissima*
151		*Aconitum violaceum*
152		*Delphinium brunonianum*
153		*Halerpestes tricuspis*
154		*Ranunculus hyperboreus*
155		*Ranunculus pulchellus*
156		*Rannunculus repens*
157		*Ranunculus trichophyllus*
158	Ranunculaceae	*Ranunculus trivedii*
159		*Potentilla argyrophylla*
160		*Potentilla crantzii*
161		*Potentilla multifida*
162		*Sibbaldia cuneata*
163	Rosaceae	*Sibbaldia parviflora*
164	Rubiaceae	*Galium acutum*

165		*Galium aparine*
166	Scrophulariaceae	*Verbascum thapsus*
167		*Bergenia ciliata*
168		*Berginea stracheyi*
169		*Saxifraga flagellaris*
170		*Saxifraga hirculus*
171		*Saxifraga sibirica*
172		*Saxifraga stenophylla*
173	Saxifragaceae	*Saxifraga jacquemontiana*

Appendix VIII: List of floral species recorded in PVNP, Himachal Pradesh - including species from current research and previous studies. Blue highlighting indicates species newly recorded in the PVNP during the current research.

S.No.	**Family**	**Species**
	Shrub	
1	Ephedraceae	*Ephedra gerardiana*
2	Elaeagnaceae	*Hippophae rhamnoids*
3	Rosaceae	*Rosa webbiana*
4	Tamaricaceae	*Myricaria squamosa*
	Herb	
1		*Bupleurum falcatum*
2	Apiaceae	*Carum carvi*

3		*Ferula jaeschkeana*
4		*Artemisia maritima*
5		*Cousinia thomsonii*
6		*Cremanthodium ellisii .*
7		*Crepis tenuifolia*
8		*Picris hieracioides*
9		*Saussurea bracteata*
10		*Tanacetum gracile*
11		*Taraxacum officinale*
12	Asteraceae	*Waldheimia stoliczkai*
13		*Arnebia euchroma*
14	Boraginaceae	*Lindelofia stylosa*
15		*Lepidium latifolium*
16	Brassicaceae	*Sisymbrium brassiciforme*
17	Campanulacea e	*Codonopsis clematidea*
18	Caryophyllacea e	*Silene rupestris*
19		*Rhodiola heterodonta*
20	Crassulaceae	*Rhodiola tibetica*
21	Fabaceae	*Astragalus zanskarensis*

22		*Cicer microphyllum*
23		*Thermopsis inflata*
24	Fumariaceae	*Corydalis govaniana*
25		*Gentiana tianschanica*
26		*Gentianella moorcroftiana*
27		*Gentianopsis detonsa*
28		*Gentiana tubiflora*
29		*Gentiana leucomelaena*
30	Gentianaceae	*Gentianopsis paludosa*
31	Geraniaceae	*Geranium pratense*
32		*Eriophyton*
33		*Hyssopus officinale*
34		*Nepeta longibracteata*
35	Lamiaceae	*Thymus serpyllum*
36	Malvaceae	*Malva pusilla*
37	Onagraceae	*Epilobium angustifolium*
38	Orchidaceae	*Dactylorhiza hatagirea*
39	Plantaginaceae	*Plantago major*
40		*Festuca altaica*
41	Poaceae	*Melica persica*

42		*Stipa capillata*
43	Polygonaceae	*Oxyria digyna*
44		*Rheum emodi*
45		*Rheum moorcroftianum*
46		*Rumex dentatus*
47		*Aconogonum tortuosum*
48		*Bistorta affinis*
49	Polygonaceae	*Polygonum cognatum*
50	Primulaceae	*Primula macrophylla*
51		*Aconitum heterophyllum*
52		*Aconitum violaceum*
53		*Aquilegia fragrans*
54		*Clematis orientalis*
55		*Delphinium brunonianum*
56	Ranunculaceae	*Thalictrum cultratum*
57		*Geum elatum*
58		*Potentilla argyrophylla*
59	Rosaceae	*Potentilla multifida*
60	Saxifragaceae	*Bergenia stracheyi*

61	Scrophulariaceae	*Verbascum thapsus*
62	Solanaceae	*Hyoscyamus niger*

Appendix IX: Supplementary Table 1. Ecological attributes of tree, sapling and seedling layers in various beats of CSJNP, Himachal Pradesh

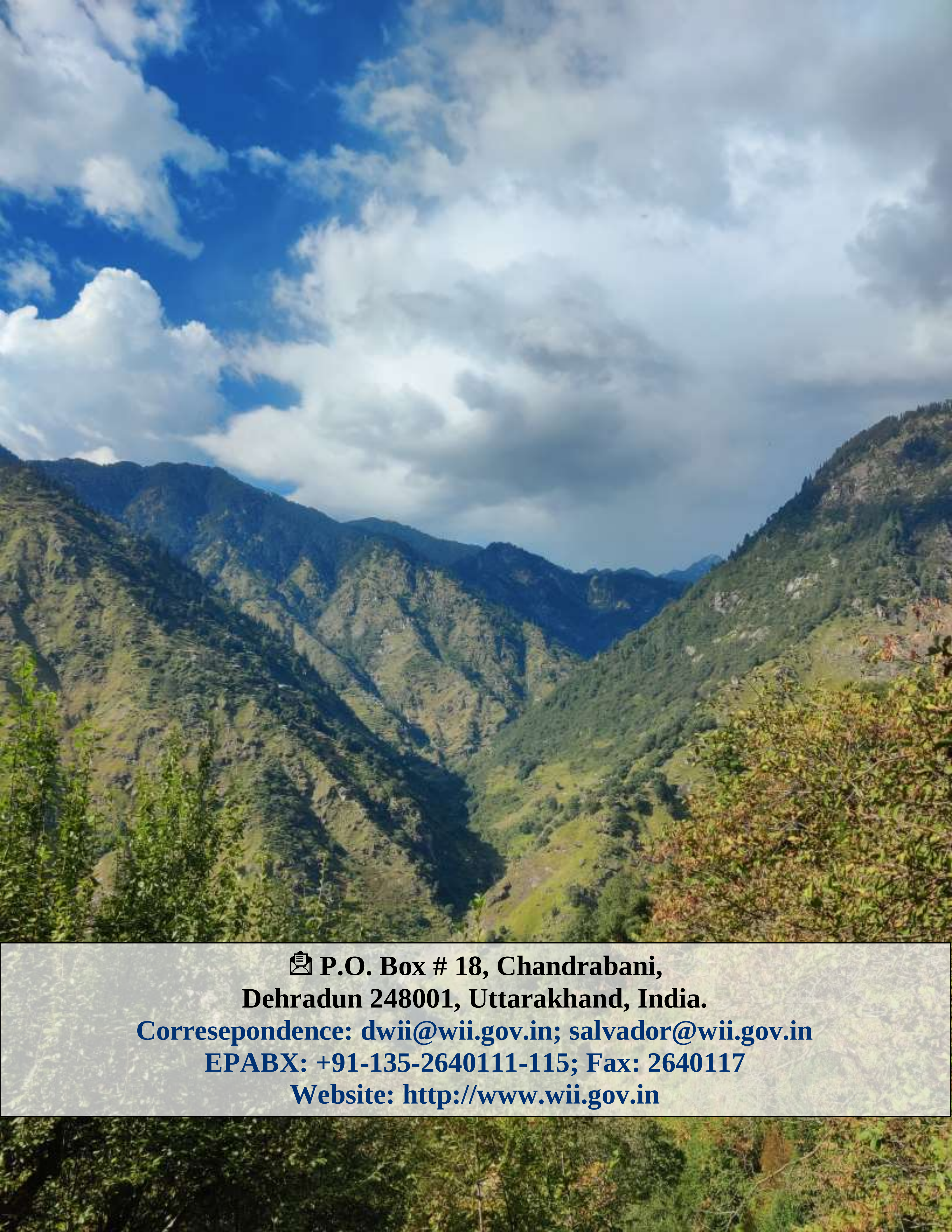
Species	**Tree**				**Sapling**				**Seedling**			
	Garuk	Kaludev	Marusidh	Danda	Garuk	Kaludev	Marusidh	Danda	Garuk	Kaludev	Marusidh	Danda
A. catechu	2.7±2.6	-	17.1±3.1	-	-	-	17.4±11.4	-	4.3±1.5	-	-	-
A. cordifolia	2.7±2.4	-	-	-	-	-	-	-	-	-	-	-
A. procera	-	-	3.1±0.4	-	-	-	-	-	-	-	-	-
A. lebbeck	1.8±1.8	-	-	-	-	-	-	-	-	-	-	-
A. latifolia	16.5±2.4	9.9±3.9	4.4±6.2	12.0±3.2	-	-	-	-	-	-	-	-
B. retusa	7.5±7.5	2.3±3.2	11.1±3.4	4.1±5.9	-	-	-	5.9±5.9	-	-	-	1.9±0.3
C. tomentosa	1.5±1.5	5.2±0.6	-	1.4±2.0	-	-		-	5.1±2.9	-	-	5.6±2.0
C. arborea	2.8±2.0	-	-	-	-	-	-	-	-		-	1.5±0.2
C. fistula	-	0.8±1.2	-	5.1±4.9	-	-	-	10.1±0.1	-	-	-	3.4±1.4

C. dichotoma	1.9±1.4	3.5±5.0	6.0±3.2	6.9±5.1	6.0±2.0	9.7±1.7	6.8±0.8	-	2.5±0.4	15.5±4.0	3.9±3.7	6.1±0.1
D. sissoo	1.3±1.3	7.7±10.9	-	-	-	-	-	-	-	-	-	-
D. melanoxylon	6.7±6.7	8.6±1.3	4.6±1.6	10.0±3.3	19.0±1.0	19.0±11.0	21.4±7.2	8.3±1.3	12.8±2.8	13.1±4.7	12.1±5.4	6.9±4.5
E. laevis	5.7±5.7	4.1±0.8	11.3±1.8	6.7±4.90	8.1±2.1	7.3±1.3	9.6±9.6	8.2±3.1	9.5±6.1	18.7±6.2	9.1±3.3	10.1±3.9
E. citriodora	8.8±5.3	22.4±9.2	12.7±3.0	24.0±8.5	25.7±17.4	14.2±8.4	12.9±2.9	25.5±7.4	3.5±3.5	13.1±6.1	8.4±2.8	4.8±1.0
F. racemosa	-	-	-	31.1±6.6	-	-	-	-	-	-	-	-
F. benghalensis	-	8.8±5.2	-	20.6±7.9	-	-	-	-	-	5.0±1.8		1.5±0.4
F. hispida	-	1.6±2.3	-	1.9±0.7	-	-	-	-	-	-	-	-
F. racemosa	32.6±2.5	26.1±8. 4	20.7±7.3	-	-	-	-	-	-	-	-	-
F. religiosa	4.1±4.1	-	-	-	-	-	-	-	-	-	-	-

F.semicordata	3.0±3.0	-	-	3.3±0.9	-	-	-	-	-	-	-	3.9±0.6
F.variegata	-	-	-	5.4±1.7	-	-	-	-	-	-	-	-
F. virens	6.1±6.1	2.3±3.0	5.6±0.5	5.1±3.1	-	-	-	-	-	-	-	-
G. opositifolia	-	3.3±1.3	1.5±01	1.9±0.8	-	-	-	-	-	-	-	-
G. optiva	-	-	2.4±0.5	-	-	-	-	-	-	-	-	-
H. integrifolia	-	1.7±2.5	-	1.6±1.2	-	-	-	-	-	-	-	-
L.grandis	2.9±2.7	1.3±1.9	2.1±3.0	-	-	-	-	-	-	-	-	-
L. crenulata	1.4±1.1	-	-	-	-	-	-	-	-	-	-	-
L. monoptelea	1.5±1.5	-	-	-	-		-	-	-	-	-	-
M. philippensis	42.1±10.9	40.8±2.1	44.5±4.5	34.5±7.5	97.2±11.5	67.5±22.6	85.7±9.3	93.6±4.7	64.6±4.9	63.2±7.9	68.9±2.4	66.2±8.6
M. indica	-	6.6±2.4	2.4±3.4	2.2±1.1	-	6.1±6.1	-	-	-	5.0±1.8	2.1±2.1	-
M. azadirach	-	-	-	1.4±2.0	-	-	-	-	-	-	-	-

M. paniculata	16.6±9.8	3.1±1.8		8.9±3.0	-	-	-	23.3±4.4	2.2±1.2	15.0±4.0	-	-
O. oojeinensis	15.0±4.5	7.0±3.1	13.4±4.7	3.9±5.8	16.6±10.1	-	-	11.0±1.0	4.0±1.0	5.0±1.6	7.2±4.2	3.4±0.4
P. humilis	3.6±4.1	6.1±1.5	9.2±1.0	3.0±1.2	-	-	-	-	-	-	-	-
S. anacardium	-	7.0±2.1	-	5.0±7.2	-	-	-	-	-	-	-	-
P. emblica	-	-	-	-	-	-	-	-	1.7±0.7	2.5±1.3	-	1.8±0.3
S. robusta	59.5±3.7	74.1±5.4	69.8±5.3	45.0±2.3	82.0±9.5	107.2±13.8	95.1±7.8	89.3±9.3	44.1±1.1	55.1±1.4	72.9±5.1	51.6±7.9
S. cumini	15.5±2.8	11.6±0.3	3.2±4.5	18.3±6.6	70.7±10.2	44.7±28.5	20.3±11.8	35.1±2.2	39.6±7.0	34.4±7.6	6.5±3.7	30.7±5.4
T. alata	31.1±3.4	22.7±2.1	24.7±2.3	28.0±2.8	-	11.4±1.4	19.3±11.5	-	-	-	7.4±4.3	-
T. bellerica	-	-	21.4±4.9	5.6±2.8	-	-	-	-	-	-	-	-
T. ciliata	-	9.1±3.4	-	-	-	-	-	-	-	-	-	-

Z. jujuba	2.8±1.6	-	5.7±0.8	-	10.4±1.4	-	-	12.4±7.3	5.2±1.7	-	-	-
Z. mauritiana	2.2±0.2	-	2.1±2.9	-	-	-	-	-	-	-	-	-



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