

# **Conservation Breeding of Western Tragopan in Himachal Pradesh:**

*Reproductive Biology, Behavior and Habitat Suitability*



भारतीय वन्यजीव संस्थान  
Wildlife Institute of India



**Final Report**

**2014**

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in Himachal Pradesh:**  
*Reproductive Biology, Behavior and Habitat Suitability*

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**2014**

Citation: Ramesh K., Nigam P., Lakshminarasimha R., Upadhyay V., Bose S., Dhiman S., and Mohan L. 2014. Conservation breeding of Western tragopan (*Tragopan melanocephalus*) in Himachal Pradesh: reproductive biology, behavior and habitat suitability. Final Report. Wildlife Institute of India and Wildlife Wing of Himachal Pradesh Forest Department. Pp 137.

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## CHAPTER - I INTRODUCTION

### 1.1. Species Profile

Western tragopan (*Tragopan melanocephalus*) is among the rare pheasant species that are endemic to the Western Himalaya. The genus *Tragopan* comprises of five species; Western tragopan, Satyr's tragopan (*T. satyra*), Blyth's tragopan (*T. blythii*), Temminck's tragopan (*T. temminckii*) and Cabot's tragopan (*T. caboti*) and represents the family Phasianidae. Tragopans are medium sized, stocky, terrestrial birds with vibrant plumage and complex courtship display. The mating call of these birds resemble the bleating of goat and hence the name 'Tragopan' ['Tragus' (goat) and 'Pan' (half goat deity of Greek mythology)]. These birds are also called 'horned pheasants' due to the presence of brightly coloured, erectile fleshy horns on either side of the head of the male birds that become conspicuous during the courtship display. Present distributions of the tragopans are bounded by some of the major fluvial watersheds of the region (Johnsgard 1986); e.g. the distribution of *T. melanocephalus* corresponds to the basin of the Indus River, *T. satyra* inhabits the entire watershed of the Ganges River, and *T. blythii* occurs on the western (*T. b. blythii*) and eastern (*T. b. molesworthi*; known only from three specimens) sides of the Brahmaputra River.

Historically, Western tragopan was reported to occur from Hazara in northern Pakistan through Kashmir and Himachal Pradesh to Garhwal and possibly Kumaon in Uttaranchal, India (Jerdon 1862). It occupied a habitat range of 700km long and 50-100 km wide stretch along the temperate region of the Himalaya. However, Sharma (1993) reported complete absence of the species from several outer mountain areas, which were previously inhabited by the birds. Gaston (1983a) reported two major breeding populations of the pheasant; the Neelum or Kishenganga valley and adjacent areas of Pakistan and the Kishtwar national Park in the Chenab Valley of Kashmir and estimated the wild population to be ranging between 1600-4800 birds. Being a habitat specialist, this bird was known to be scarce and localized in mixed conifer forest, mixed broadleaf forest and broadleaf forest even during the start of nineteenth century. However, such low population estimation of the birds in the wild reported by Gaston (1983a) brought the conservation status of the bird to be revised and a number of studies (McGowan and Garson, 1995; Whale, 1996; Nawaz and Ghafoor, 1999; Ramesh, 2003; Ashraf et. al., 2005 and Singh and Tu, 2007) to assess the proper population estimation and habitat use have been taken up since. These studies, and the

detection of a large breeding population (about 1000 birds) in Palas, Pakistan, have taken up the population estimation of the birds to a modest 6000 (approximately). Currently, the range has diminished considerably with only 2,000-3,000 sq. km area of potential habitat being available and the present population is distributed in five fragmented units; (1) Neelam Valley, (2) Kishtwar National Park and (3) Palas in Jammu and Kashmir, (4) Kulu (including Great Himalayan National Park) in Himachal Pradesh and (5) Bhilinguna in Garwhal, Uttarakhand. Despite the conservation measures, all the wild populations show a decreasing trend.

Once abundant, this bird species has been extensively hunted for its attractive plumage and meat. With few fragmented populations and threatened status, this species was listed as vulnerable to extinction by IUCN (Gaston *et al.* 1983; Johnsgard 1986; IUCN 2000; Birdlife International 2001, Ramesh 2007). In addition, it is also listed in Appendix I of CITES and Schedule I of WPA, 1987. In recent decades, much of its preferred habitat has been destroyed or degraded by various anthropogenic factors, which led to the population fragmentation of the species. However, Himachal Pradesh is supposed to harbour the second largest wild population of this threatened pheasant species. But with a 12.5% growth in rural population over the last decade (Census Data, 2011) in Himachal Pradesh, it is a serious matter of concern. Most of the rural populations earn their livelihood by collecting forest resources (mostly timber, mushroom locally known as guchhi and medicinal herbs), which compounded with a low reproductive success of the bird (due to destruction of nests during the process of NTFP collection) resulted in severe decline in the wild populations. The tragopans being a habitat specialist have been severely affected by the detrimental changes in their limited range. The scarcity of habitat along with the anthropogenic pressure has made these birds extremely vulnerable to extinction.

As explained elsewhere above, the state of Himachal Pradesh is a stronghold for this species as it is distributed widely in sizable populations in all three major catchments (Beas, Satluj and Ravi) and also serves 'flagship' value on account of socio-cultural linkages with the traditional people. These attributes essentially guided the successful declaration of Western tragopan as 'the State Bird' of Himachal Pradesh. Although hunting of the species is reduced to a large extent, threats from habitat loss particularly in the winter habitats in lower elevations, disturbances in the breeding habitats and habitat degradation by livestock grazing and other resource uses continue to pose major challenges for the conservation of this species (Fuller and Garson 2000). The species is relatively less studied specifically on the behavioral ecology, primarily on account of elusive

behaviour, small population size, rare sightings and the complex habitat characteristics. Only few studies (Ashraf et al. 2004, Gaston et al. 1983a, Islam and Crawford 1987, Miller 2010, Ramesh et al. 2008, Singh and Tu 2006) discuss aspects pertaining to the ecology of the birds on a quantitative level. However, various authors have discussed qualitative accounts on the feeding and breeding behaviours of Western tragopan, based on observations in the wild and confinement (Baker 1932, Beebe 1918, Delacour and Harrison 1951, Hume 1873, Johnsgard 1986). The data available on the behavioral ecology of western tragopan is indicative that they mostly thrive in forests characterized by dense canopy and presence of short coniferous and deciduous vegetation (Islam and Crawford 1987). Gaston (1981) reported that in Himachal Pradesh these birds are primarily found in altitudes ranging between 2500-3000m, with birds sighted up to an altitude of 2900m during winters. Information from literature concerning the feeding habits of western tragopan indicate that they tend to be herbivorous species specialized to feed mostly on the vegetative parts on the plants like leaves, flowers, and buds (Sheppard et al. 1998). Fruits and berries form an important component of their natural diet, supplemented with animal matter. Their specific appetitive behaviors consisting primarily of vegetative materials could be linked to their digestibility, alimentary tract morphology and probably has important implications for their nutritional requirements. Among pheasants, tragopans are generally classified by their distinct behavior of nesting on elevated grounds (Ali and Ripley 1968, Beebe 1918, Delacour and Harrison 1951, Johnsgard 1986) although few authors report to have found nests on the ground (Humes and Oats 1889, Baker 1921). The mating system, incubation patterns and brooding behaviour have not been studied. The vegetation structure of their preferred habitat, which mostly comprises of 'shorter life-forms' as termed and observed by Islam & Crawford (1987), has ecological advantages in terms of feeding, predator avoidance and breeding.

The long term persistence of pheasants, like many other animal species, is affected by various human disturbances. A number of studies (Bhattacharya et al. 2009, Deng and Zheng 2004, Gaston et al. 1983b, Jolli V and Pandit 2011a, Jolli Virat and Pandit 2011b, Kaul et al. 2004, Wang et al. 2008) discuss the effects of human-induced habitat alterations on Himalayan pheasants. A report by Gaston, et al., (1983b) on Himalayan fauna, indicated severe habitat degradation due to uncontrolled grazing and decreasing pheasant numbers due to hunting. A study in the trans-Himalayas by Wang et al., (2008) attribute increased land-use activities to accelerated ecological degradation, resulting in a rapid decline of wild animals and gallinaceous

birds. Bhattacharya et al., (2009) report live-stock grazing, tourism and collection of minor forest produce as the major factors affecting pheasants, as most of these activities are concentrated during the breeding season of these birds. Hunting of pheasants which are already rare and threatened by habitat fragmentation is another concern pointed out by Kaul et al. (2004), which can have adverse effects on their numbers in the wild. A study by Jolli and Pandit (2011a) which involved estimating abundances under high and low levels of human activities, indicated low abundances in disturbed habitats and higher abundances when human activity was suspended in the same areas. In their study on Cabot's tragopan by Deng and Zheng (2004), reduced affinity of the species to small and isolated fragments and higher preference to large and less isolated habitat patches was demonstrated. With a small population remaining, which is threatened with habitat fragmentation leading to habitat loss across its range and a decreasing population, Western tragopan indeed deserves special attention towards conserving the species and its habitat.

## **1.2. Conservation Management**

The State Government of Himachal Pradesh has all along instituted a series of conservation measures for wildlife conservation, especially for threatened species such as Western tragopan (WII 1999). A large number of Protected Areas have been established, human livelihood options have been created to reduce disturbances in natural habitats and exclusion of anthropogenic activities has also been done to preserve the natural setting in its entirety (Pandey 2008). However, like elsewhere, these conservation measures have met with variable successes due to socio political reasons, insufficient scientific knowledge to garner support from policy makers and local people, and limitation of trained man-power (Miller et al. 2008). While concerted efforts are continuing for *in-situ* management within the limits of resource pool (both fiscal and trained man-power), conservation breeding of Western tragopan has long been included in the conservation agenda of the State, attributed to (a) small population size of the species in the wild, (b) virtually no captive population anywhere in the world, and (c) no credible technical know-how for breeding the species in captivity. The goals were to captive breed and subsequently establish a 'reserve' population of the species in captivity. A pair of wild-born rescued birds (1 male and 1 female) housed at a breeding centre in Himachal Pradesh, during the early 1990's was the earliest official record of this species to be maintained in captivity. With the addition of more rescued birds at the centre and subsequent breeding, a small population of Western tragopan was established at the centre located at Sarahan, Himachal Pradesh. Currently there are only two

institutions globally housing these species in captivity, with total population of 34 individuals as of July 2014 (14 males, 14 females and 06 juveniles) [32 in Sarahan pheasantry and 02 adult males in Kufri Zoological Park]. However, the captive breeding program encountered significant problems like low numbers, low reproductive output, sporadic breeding and mortalities during breeding season. Since 2007, the captive breeding centre is a designated centre for the conservation breeding of Western tragopan by the Central Zoo Authority.

One of the limiting factors for formulating conservation plans for Western tragopans is the lack of information on their behavioural ecology. In this background, a collaborative research project titled 'Reproductive biology and behavior of captive and wild populations of Western tragopan in Himachal Pradesh' between Wildlife Institute of India and Himachal Pradesh Forest Department was initiated in 2011 looking into biology and reproductive behaviour of Western tragopan in captive conditions (and in wild when the birds will be released from the captive population) and to identify potential release sites. The study on the captive population was initiated to address various issues faced by the captive population and to develop science-based methods for the management of this species in captivity. The *in-situ* study aimed at generating information concerning the population status in the wild in the state of Himachal Pradesh, generate distribution maps for the species and identify potential sites for reintroduction. The overall project goals were to assist in the establishment of a "reserve" population of the species in captivity targeted at reintroduction and to map potential habitats where reintroduction can be planned. The original project was conceived for five years as Phase I with budget outlay of Rs. 69,35,500/-, but due to administrative reasons, it was revised for three years with budget outlay of Rs. 34,56,000/- with following objectives primarily to strengthen the captive population.

### **1.3. Objectives**

The specific objectives of the project were to:

- a) Maintain a studbook with information on genetic and demographic parameters.
- b) Record breeding chronology and growth pattern.
- c) Assess nutrition, body condition and stress factors.
- d) Determine activity budget and vocalizations.
- e) Carry out field surveys to estimate the population status in wild.
- f) Undertake Population Viability Analysis to determine suitable founder populations and reintroduction strategy.
- g) Monitor and study the habitat occupancy, behavior and population growth of released birds.

## CHAPTER – II

### STUDY AREA

#### 2.1. *Ex-situ* study (Captive Population)

The *ex-situ* study was carried out at the only conservation-breeding centre for the species i.e. Sarahan pheasantry in the district Shimla of the state Himachal Pradesh. The centre was established during 1990 as a rescue centre of Himalayan pheasants. Subsequently, it was re-assigned as a conservation-breeding centre for the Western tragopan in 2007. The centre is situated in a fence-protected forestland positioned distantly from human settlements. The fenced land (Geographic coordinates: 31° 30' 25.53" N, 77° 47' 46.95") encompasses an area of nearly 12 hectares (Figure 2.1) and lies within the natural distributional range of the species.

Sarahan pheasantry is located adjacent to Daranghati Wildlife Sanctuary, a key distributional area for the species in Himachal Pradesh. This vicinity offers unique opportunities to understand the habitat characteristics of the species to further improve the quality of captive habitat on the same lines. Located approximately 60 km away from the center is Rupi-Bhaba Wildlife Sanctuary. This sanctuary contains areas where the species currently occur and also those where they occurred historically and have currently gone extinct. This could prove as a valuable site in case experimental reintroductions are planned. Many areas in these sanctuaries are geographically isolated from human settlements and are hence less disturbed. Sarahan pheasantry is administratively managed by the Divisional Forest Office located in Sarahan.



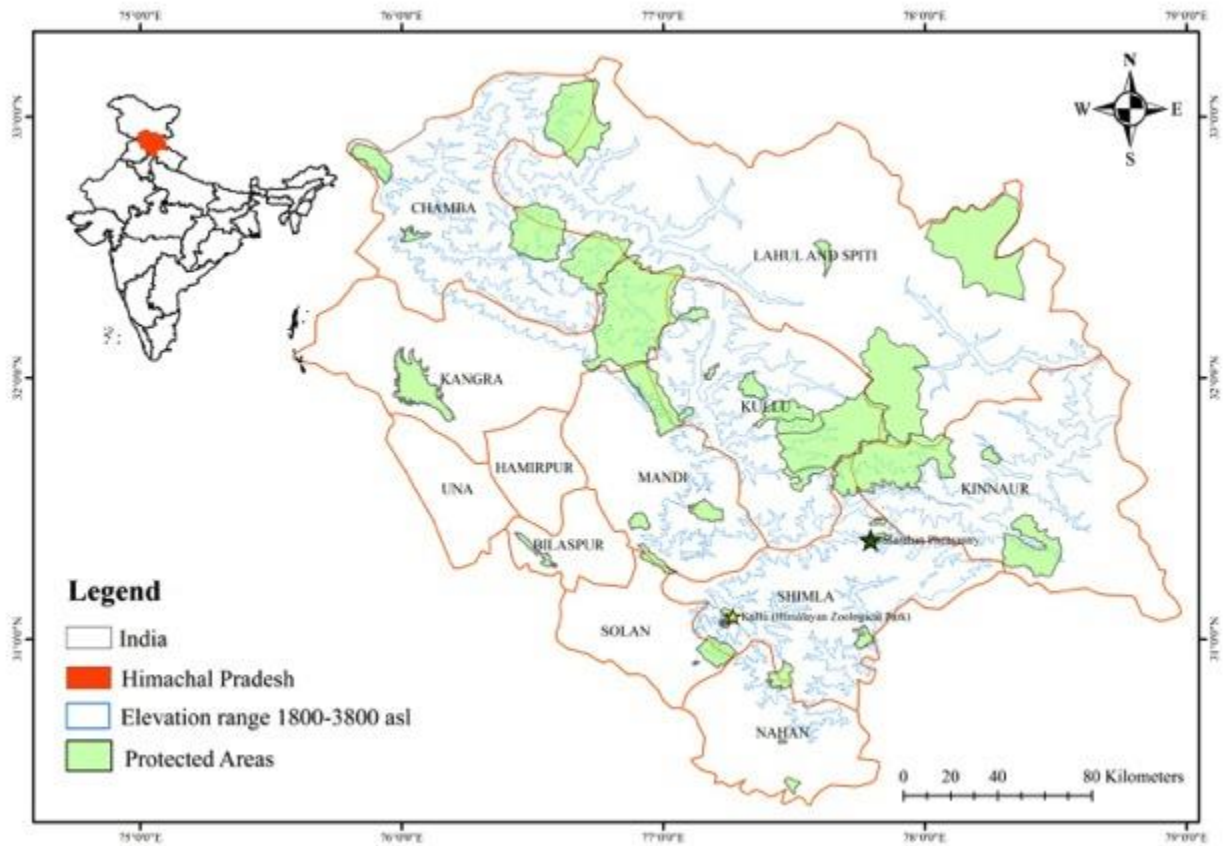
**Figure 2.1: Location of Sarahan pheasantry**

## 2.2. *In-situ* study (Wild Population)

The study area is entire Himachal Pradesh, a small hill state situated in the northern part of India. The focus is on the Himalayan region of this state ranging 1800m to 3800m altitude as potential habitat (both winter and summer) for our study. Himachal Pradesh, bounded by 30° 22' 40" N to 33° 12' 40" N latitudes and 75° 45' 55" E to 79° 04' 20" E longitudes (Figure 2.2), encompasses an area of 55,673 sq. km (as on 2001). With an altitudinal variation ranging from 350m asl to 6975m asl, the state has a very rich floral and faunal diversity due to its diverse range of forest types. The state has recorded forest area of 37033 sq km, which is 66.52% of its geographical area (FSI 2011). From which 5.13% area classified under reserve forest, 89.46% under protected forest and 5.4% is un-classed forest (FSI 2011). The Protected Area Network comprises of 33 Wildlife Sanctuaries and 2 National Parks covering 0.76 million ha which constitutes 13.65% area of the state. The state is divided into five zones, viz. (i) wet sub-temperate zone, (ii) humid sub-temperate zone, (iii) dry temperate alpine high lands, (iv) humid subtropical zone, and (v) sub-humid subtropical zone. This great variation in climatic conditions of Himachal is due to extreme range in elevation. Topographically from south to north, H.P. is divided into three zones a) Shivaliks or outer Himalayas with altitudinal range up to 1500m, b) inner Himalayas or mid-mountains with altitudinal range up to 3000m and c) Alpine zone or greater Himalayas with altitudinal range higher than 3000. The state has areas like Dharamsala that receive very heavy rainfall, as well as those like Lahul and Spiti that are cold and almost rainless. The average annual rainfall in the state is about 160 cm. Summer lasts from mid-April till the end of June and most parts become very hot (except in alpine zone which experience mild summer) with the average temperature ranging from 28 °C (82 °F) to 32 °C (90 °F). Winter lasts from late November till mid-March. Snowfall is common in alpine tracts (generally above 2,200 metres (7,218 ft) i.e. in the Higher and Trans-Himalayan region).

Five perennial river Sutlej, Beas, Ravi, Chenab and Yamuna flow through H.P. Out of a total of 45,000 species of plants found in the country, around 3,295 species or 7.32% are reported from Himachal Pradesh. There are six main forest types – Tropical Dry Deciduous, Sub-tropical Pine, Sub-tropical Dry Evergreen, Himalayan Moist Temperate, Himalayan Dry Temperate, and Sub-alpine and Alpine. Flora of Himachal Pradesh consists of about 180 comprising about 1038 genera and about 3400 species. The conifers consist of Chir Pine (*Pinus roxburgii*), Fir (*Abies*

*pindrows*), Spruce (*Picea smithiana*), Deodar (*Cedras deodara*), Juniperus (*Juniperus excelsa*), Taxus (*Taxua baccata*), Neora (*Pinus gerardiana*) etc. The broad-leaved varieties comprise of Kharsu (*Quercus leucotrichophora*), Khair (*Acacia catechu*), Siris (*Albizia chinensis*), Sal (*Shorea robusta*), Khirik (*Celtis austurals*), Bhoj-Patra (*Betula utilis*), Horse-chestnut (*Aesculus indica*), Poplar (*Populous ciliata*), Robinla (*Robinia seudocassia*), Walnut (*Juglans regia*), Maple (*Acer indicus*), etc. Sub-alpine scrub mainly consists of Pink Rohododendron (*Rhododendron campanulatum*). The faunal diversity of Himachal Pradesh consists of 64 Mammals, 463 Birds, 44 reptiles and 316 aquatic species. Himachal Pradesh harbours seven pheasant species namely Indian peafowl, Red Junglefowl, White-crested Khalij, Koklass, Cheer, Himalayan Monal and Western Tragopan. Of the 12 districts of Himachal Pradesh, six districts viz. Chamba, Kangra, Kullu, Mandi, Shimla and Kinnaur have suitable habitat for Western tragopan and efforts were focused to acquire data from these districts on the habitat and population status of western tragopan.

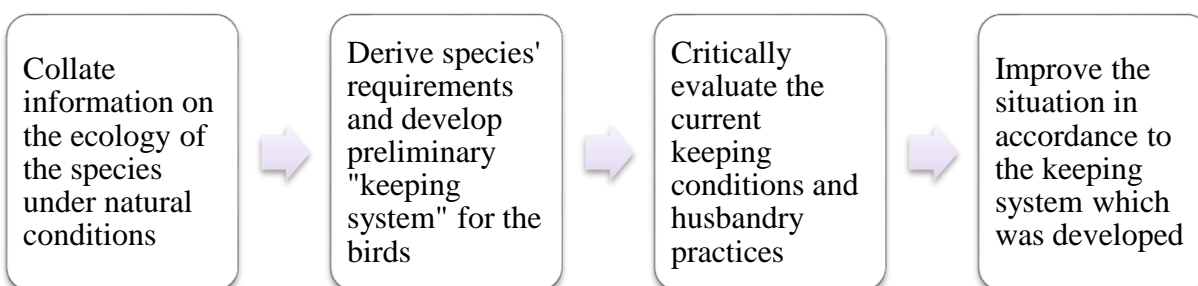


**Figure 2.2: Map of the study area**

## CAPTIVE POPULATION: EVALUATIONS AND INTERVENTIONS

**3.1. Evaluation of Keeping Conditions**

The first steps, following commencement of the project, was to critically examine the keeping conditions and husbandry regimes that were in practice for the birds and then compare them with ecological requirements of wild counterparts. The information on the species ecology and behavior under natural conditions was mostly obtained from limited information available from published works; both qualitative and quantitative in nature, and through field visits in the habitat of these birds. The information was used to develop a tentative keeping system referring to the species' requirements under human care. The approach for the science-based study involved the following steps.



The initial step towards the development of the study was to analyze the current situation, and improve it on lines of the species requirements, and simultaneously prepare the ground for intended research. The keeping conditions of the birds were critically analyzed with reference to their captive habitat, feeding regimes, reproductive management, stress factors and the development of the captive population over the years.

**3.1.1. Housing**

The ground space available for a pair of Western tragopan at Sarahan breeding centre was between a lowest of 27 m<sup>2</sup> and highest of 85 m<sup>2</sup> (only for a pair of birds). Heights of the enclosures ranged between 2 m to 2.5 m. These enclosures were placed next to each other with a common 'see-through' wire-mesh partition separating the aviaries, with fifty percent of the aviaries having neighbors on either side. Lack of such visual barriers resulted in adjacently housed individuals to pace along the fence line. Territorial behavior and conflicts hence occurred

much more frequently in comparison to the wild, which may be stressful to the birds. The contours inside the enclosures did not provide appropriate drainage and hence there was water stagnation inside the enclosures, keeping the substrate damp. Lack of vents for seepage water also added up to the building of water content in the substrate. The leaking roofs in the indoor areas led to wet ground substrate, and added to this was the improper drainage and opaque roofs due to which the drying up of the substrate was minimal. Comfort behavior such as routine dust-bathing, serves the purpose of feather maintenance and avoidance of ecto-parasite infestation in pheasants (Vestergaard et al. 1993). Damp substrate inside the enclosure deprived the birds of such an opportunity.

### **3.1.2. Roosting Opportunities**

More than 50% of the aviaries at Sarahan had a single perch in the indoor areas, placed midway, which was the only place available for roosting, leaving little opportunity for the use of the same for submissive individuals. Perches in the exhibit areas were inappropriate as they were placed at lower heights and did not provide suitable grip.

### **3.1.3. Vegetation Cover**

Most of the enclosures were deprived of vegetation, while a few enclosures were densely planted and allowed very little sunlight to reach the floor, resulting in the moisture being retained in the substrate. Undergrowth was absent in all the enclosures.

### **3.1.4. Husbandry Practices**

During 2011, the keepers confined the birds to the indoor areas ‘forcefully’ every evening to reduce the light-hours available to the birds, with an intention to reduce or inhibit breeding. The birds were housed under conditions of artificially modified day-lengths, with uniform 8-hours of light per day. Exposure of birds to such ‘unnatural environments’ for a limited period of time was expected to provide them with an opportunity to recoup from the physiological impairments resulted by it. However, the effect of chronic exposure on the bird’s physiological and reproductive processes to such conditions was unknown, but possibly had negative effects.

### **3.1.5. Diet and Feeding Strategy**

The diet offered to the Western tragopans was ‘standardized’ comprising of cereals, soybean meal, commercial preparation (vegetable meal) and calcium sources. Greens and fruits

constituted minimal components of the diet. Greens offered to the birds included locally collected clover and grasses. Tomato was the only fruit constituent of their diet. The amount of food offered and consumption was not controlled. The feed was presented in the late morning. The dietary constituents and the time of food presentation are provided in Table. 3.1.

Diet Particulars		Time
Type	Quantity (in grams)	
Wheat (soaked)	115	<u>Year round</u>
Maize (ground)	43	Feed time: 1200hrs-1300hrs
Soya Meal	30	
Vegetable Meal	4	
Lime Stone	13	
Supplivite Forte M (multivitamin supplement)	1	
	206g/bird/day	
Tomato	14	<u>Year round</u>
Carrot (not offered)	14	Feed time: 0900hrs-1000hrs
Raisins (treats)	4-5	
Grapes (not offered)	6	
Wild cut grass and greens (mostly clover)	Random quantities	<u>Year round</u> Feed time: 0900hrs-1000hrs

**Table 3.1:** Dietary constituents and food presentation times during the initiation of the project

### 3.1.5. Breeding

Western tragopans kept at the Sarahan pheasantry were housed as pairs involving unrelated individuals. All the nest sites were located in the indoor holding areas, which were designed to be permanently dark. Bamboo baskets placed on elevated platforms were used as nests. Bamboo leaves and other grasses were used as nesting material, which was rarely replaced. Previously, the eggs were removed from the nest for artificial incubation, inducing the birds to lay extra eggs. Instances of birds damaging the eggs and nest abandoning had also been recorded.

### 3.2. Hypothesis

The evaluation of housing conditions revealed that the enclosures were small in size, with less or no vegetation, roosting sites placed at lower heights with unsuitable perches and pairs were housed in visual range of each other. The diet had a low proportion of fresh food and had high proportions of seed, grains and commercial food items. The nests were low in number with inappropriate placement and nesting material. The analysis of the keeping system was hence indicative of sub-optimal housing, husbandry regimes, inappropriate diet and feeding times, and poor breeding conditions. The husbandry regime also involved artificial reduction of daylight hours available to the birds and the birds were confined to the non-illuminated indoors for the rest of the time.

Given the above observations and poor breeding history (*refer to various tables in the subsequent sections*), we hypothesized that the cumulative effects of physiological problems, nutritional deficiencies and stress factors arising due to inappropriate or sub-optimal living conditions, together may have led to the low breeding success of the population in the so many years (except for a short period when the population was boosted by artificial incubation and broody hens).

### 3.3. Niche Requirement of Western Tragopan

**Habit:** Western tragopans in their natural habitats occupy relatively large home ranges of about a km<sup>2</sup>. During the onset of breeding season, in spring, they spread-out and males probably become territorial, avoiding visual confrontations between other territorial males. It is impossible to match the enclosure size with the dimensions of their natural habitat; but enclosures have to be ‘as big as possible’ and should be positioned in a manner so that interactions between individuals of different enclosures are not present.

**Habitat:** Western tragopans are adapted to and live in temperate habitats with climatic features typified by variable conditions of day-lengths, temperature and humidity. Captive birds should hence be provided natural conditions of lighting, day-lengths, temperature and humidity. Their habitat is characterized by the presence of evergreen trees of spruce, oak etc. which provide moderate canopy cover and allow good amount of sunlight to reach the forest floor, promoting good undergrowth, which help the birds to ‘hide’ or ‘skulk’ when they feel threatened. The enclosures should thus have appropriate and diverse vegetative components, which include trees

or tree-like structures and undergrowth, possibly fruit yielding, and should also receive sufficient amount of sunlight.

**Food and Feeding:** In the wild, Western tragopans forage on varied food types, which includes vegetative components like leaves, fruits, berries etc and non-vegetative constituents like insects, grubs etc. Diet availability in the wild match the physiological requirement for various seasons such as fat-rich nuts during winter and protein-rich insects feeds during summer/monsoon coinciding breeding activities. Their altitudinal movements also reflect some degree of seasonal differences in the dietary constituents. A captive diet should ideally consist of variety of seeds, greens with a good proportion of fruits and berries and insects or other non-vegetarian components, and should be presented keeping in view the seasonal requirements and breeding patterns.

**Breeding:** Tragopans being elevated nesters, in the wild, prefer nest-sites that are located at a height of about 2-3m from the ground level. The aviary should have a designated breeding area, which is slightly higher than the rest of the enclosures. This area has to be well protected, sheltered and should be completely undisturbed. The breeding area should have multiple nest sites for the birds to choose from. This area can also function as an indoor area, and if need arises, should have an option for temporary isolation of bird(s) in this area. This part of the enclosure should be structured in a way so that the birds in this area are not visually isolated from the rest of the aviary. The size, vegetation structure and other parameters of this segment of the exhibit should match with that of the rest of the enclosure.

**Mating System:** Western tragopans have been found in groups or flocks consisting of multiple individuals during non-breeding season/winter months. An option to house birds in flocks during the non-breeding season, and subsequent separation into pairs just prior to breeding season, should be incorporated in the management regime. Such practice permits mate-choice processes, allowing the birds to pair in accordance to their natural social system.

### **3.4. Interventions**

#### **3.4.1. Enclosure Improvements**

The principle of naturalism by Anderson (1987) was used as a basis for enclosure improvements. The following requirements, put forward by Sausman (1982), were taken into account; captive data, geographic origin, habitat (including plants species), behavioral characteristics, activity

cycle, social characteristics, feeding and dietary needs, reproduction, medical needs, research and education opportunities. The above principles for enclosure design have been used in the conservation breeding of the endangered Caucasian Black Grouse (Manvelyan 2004).

We increased the area available to the birds by means of ‘*merging*’ adjacent enclosures in order to provide more space to the birds. As there were constraints with reference to the space available and flexibility to modify the enclosures, only eight enclosures could be merged and the rest were retained as it is. In the modified enclosures, the area available to the birds was doubled, and the area was compartmentalized, to facilitate isolation of individuals. The dimensions of the enclosures prior to and following modifications are given in Table 3.2. No modifications with reference to the height of the enclosures could be carried out.

In addition to the removal of the partition and increasing the area available to the birds, minor repair works were carried out to rectify faulty reinforcements and fencing problems. During the entire process, care was taken not to cause disturbance to the birds. The old substrate in the enclosures was replaced with new soil from the nearby forest.

Pair	Pre-Interention			Post-Intervention		
	Enclosure	Compartment	Ground space	Enclosure(s)	Compartment	Ground space
I	1	1	27m <sup>2</sup>	1,2 and 3	3	81 m <sup>2</sup>
II	2	1	27 m <sup>2</sup>	4 and 5	2	54 m <sup>2</sup>
III	3	1	27 m <sup>2</sup>	8 and 9	2	87 m <sup>2</sup>
IV	6	1	29 m <sup>2</sup>	15	2	63 m <sup>2</sup>
V	7	1	55 m <sup>2</sup>	6 and 7	2	84 m <sup>2</sup>
VI	12	1	42 m <sup>2</sup>	16	2	63 m <sup>2</sup>
VII	13	1	42 m <sup>2</sup>	12 and 13	2	84 m <sup>2</sup>
VIII	14	1	85 m <sup>2</sup>	14	2	85 m <sup>2</sup>

**Table 3.2:** Current housing pattern and ground space available to different pairs

New perches were installed, which were placed higher in the enclosures with a clearance of 24-30" from the roof. The wood/branches for use as perches were carefully selected, based on their rough texture and appropriate diameter ( $\geq 4-5$ "). Installation of new perches was completed in October 2011.

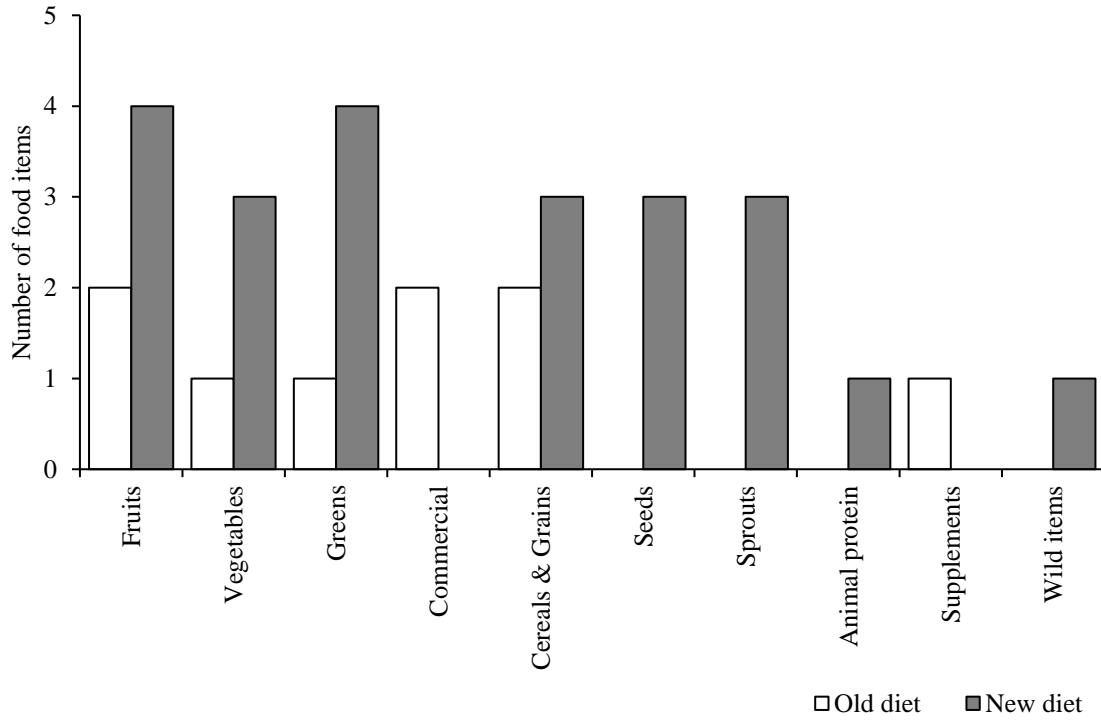
Entering the enclosures for cleaning and presentation of food is part of everyday husbandry. We observed that when the keepers entered the enclosures, the birds would move away from them into the small indoor parts present at the distal part of the enclosures. But when the keeper had to clean the indoor parts, the birds present there would be severely stressed and cornered as they did not have a proper exit route. As, most of the times, they would be resting on the perches in the indoor parts, the only escape for them was the keeper entry door where the keeper is already present. To avoid this, top exit doors measuring 50cm x 120cm were created, so that the birds had an easy escape route from the indoor parts leading to the outdoor area.

During the winter season in 2012-2013, two important measures were taken to effectively manage the birds during the strong winters. The iron perches in the newly renovated enclosures (15-18) were wrapped with jute rope to prevent frost in the birds roosting on these perches thereby reducing the chances of bumble-foot. Additionally, these perches were covered with water-proof (transparent) sheet from the top to prevent them from getting wet. The entire concrete surface in the enclosures which were frequently accessed by the birds were covered with natural materials to prevent frost during peak winters. In certain places, the concrete surfaces were covered by means of mud plastering and in others; wood was used to cover the surfaces.

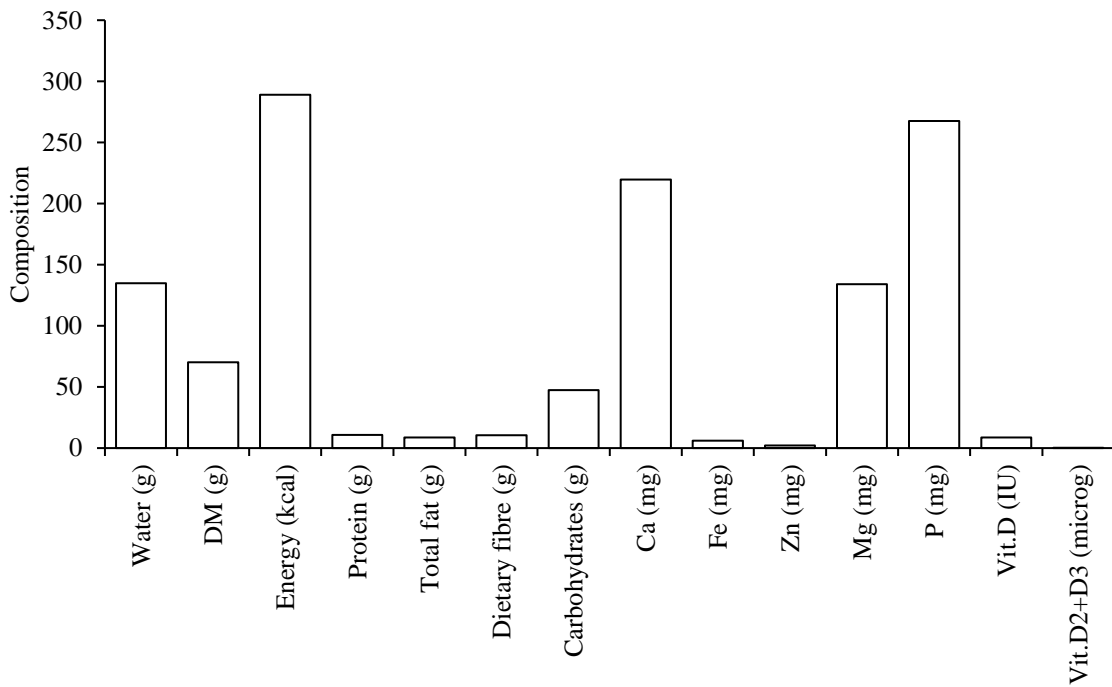
The position of the foot-baths in the existing enclosures was inconvenient for cleaning and the contents would overflow into the enclosures. This increased the possibility of birds consuming the disinfectant which could be toxic. Hence, the foot-baths were repositioned such that they were outside the enclosures and cleaning and replacement of disinfectant was also easy.

### **3.4.2. New Dietary Regime**

A new feeding regime was developed taking into account the natural feeding behaviors, digestive physiology, social needs, growth and reproductive status and basic nutritional concepts. A comprehensive document describing the need for the development of a new feeding regime was formally submitted in February 2012. The new dietary regime was started in April 2012. The new feeding regime included variety of fruits, greens and vegetables for the birds (Figure 3.3 and Figure 3.4).



**Figure 3.3:** Comparison of diversity and composition of old and new diets



**Figure 3.4:** Nutrient composition of the new diet introduced in 2012

The feeding times were also changed from the late mornings and afternoon (1000-1030/1300-1330) to early morning and late afternoon (0630-0700/1400-1500) to match with the natural feeding times of the pheasants. The birds were also offered berries, leaves and flowers collected from the wild on a more regular basis. The new diet incorporated as much as possible, natural ingredients in the form of fruits, vegetables and seeds. The new regime also intended to provide the birds with food items collected from their natural habitat. The proportion of fruits, greens, vegetables and seeds was higher in comparison to the old diet, corresponding to the wild diets of the birds. The selection of the food items was carefully done with reference to local conditions, their availability throughout the year and the feasibility involved in sourcing the items.

### **3.4.3. Reproductive Management**

Qualitative information on the breeding ecology of these birds was indicative that, like its congeners, Western tragopan nest on elevated grounds and make specific choice for suitable nests. Accordingly, multiple nest sites were offered to the birds in each enclosure. It was ensured that each breeding female had access to at least a minimum of three different nest sites. The nests were mostly cane baskets, with a diameter of about 30-40cm and a depth of about 20cm. These baskets were mounted at different locations and heights inside the enclosure, using tripods or wooden perches. Each enclosure had nests placed both in the indoor and outdoor parts. Dried moss and fern were used as the nesting material. Additionally, bundles of dry grass, twigs and bamboo leaves were placed near the nest for the female to use in nest building. The nests were camouflaged using liana and other creepers from the sides and the top.

The nests placed in outer enclosure (outdoor nests) were covered using water-proof (opaque) plastic sheets from outside, to prevent rainwater from entering the nests. Predator proofing was given high importance as far as the positioning of the nests was concerned. All the nests had perches placed near to it, to facilitate the movement from and to the nesting platforms. An inclined wooden ladder (ladder perches) was placed near all the nesting platforms with incubating females, to provide climbing options for chicks to return to their nest for roosting. Disturbance near the nesting platform was kept to minimum following the installation of the nesting platforms.

#### **3.4.4. Stress Management**

The practice of reduction in the day-light hours available to the birds, introduced earlier in 2011, was intervened to be discontinued in October 2011. The continuous administration of antibiotics and supplements was stopped in October 2011. The keepers were trained with respect to carrying out the routine husbandry regimes, such that birds go through minimal disturbance in keepers' presence. The overall level of disturbance in the aviaries was reduced significantly through the following changes in the husbandry regimes:

- Keepers were trained in the basic aspects of bird keeping regularly
- Enclosure expansion and creation of compartments to allow birds to move away from keepers
- Cleaning of enclosures on alternate days and close-up monitoring during cleaning. Careful execution of cleaning in enclosures with incubating females or chicks.

#### **3.5. Response**

Breeding history of the captive population was analyzed to examine changes in the reproductive output prior to and following interventions. The status of the captive collection has been described for the durations 2000-2011 and 2012-2013 separately. The reason is to distinctly visualize the reproductive output of the individuals following science-based interventions at the Conservation Breeding Centre at the start of 2012 breeding season.

##### **3.5.1. Pre-Intervention Period (2000-2011)**

During 2005-2011, a total of 37 individuals (17 males and 20 females) were housed at the breeding centre, comprising of 10 wild-born and 27 captive-born individuals. Five females (ID's: 006, 007, 016, 018 and 019) bred and have descendants in the living population. Five adult mortalities and eight chick mortalities (age<60 days) were recorded during this period.

The average ground space available to a breeding pair was approximately 40m<sup>2</sup>. The diet of the birds comprised of grains (wheat and maize), commercial items (soya and vegetable meal) and tomatoes. The perches were smooth and placed at low heights, and nesting sites provided to the birds were inappropriate (meaning, not in line with natural requirement of the species). The husbandry practice during 2011 also involved long-term administration of antibiotics and

reduction of day-lengths available to the birds by confining them to dark areas for up to 16 hours routinely.

A total of 280 eggs were laid during this period, of which 131 (47%) were normal and 149 (53%) were non-viable (thin-shelled, shell-less, broken and under-sized). 120 of these eggs were incubated; 97 (81%) by foster hens and 23 (19%) by tragopan hens. Only 22 (18%) incubated eggs hatched and 16 chicks fledged (survived for more than a year), with 11 being reared by foster hens and five by tragopan hens.

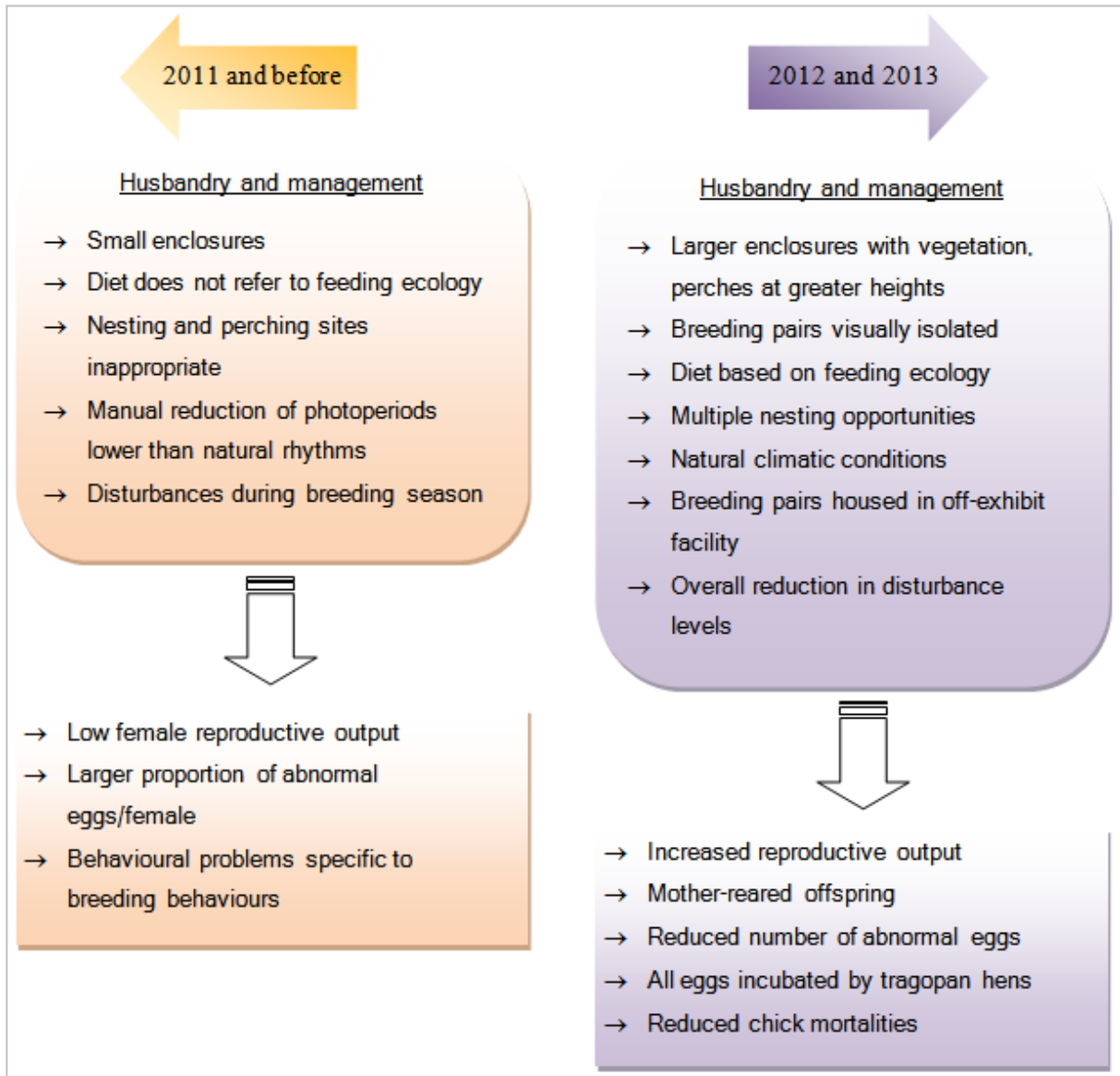
### **3.5.2. Post-Intervention Period (2012-2013)**

During 2012-2013, 29 individuals (13 males and 16 females) were housed at the breeding centre, comprising of nine wild-born and 20 captive-born individuals. Six females (ID's: 007, 009 and 019) bred and of these, two have descendants in the living population. Two adult mortalities and three chick mortalities (age<60 days) were recorded during this period.

The average ground space available to a breeding pair was approximately 75m<sup>2</sup>. The diet of the birds comprises of a major proportion of fresh food (variety of fruits, vegetables and greens), sprouts and seed mix and commercial items are discontinued. Multiples perching and nesting platforms were fixed at varying heights. The artificial reduction in light-hours was not practiced anytime.

All the adult females (9 females) laid eggs during this period and eight incubated the eggs. A total of 119 eggs were laid during this period of which 67 (56%) were normal and 52 (44%) were non-viable (thin-shelled, broken, under-sized and shell-less). 33 eggs were incubated by tragopan hens and no artificial means (foster hens or incubators) were used. 14 chicks hatched and were reared by tragopan hens, 11 of which fledged (survived for more than a year).

A summary is provided below.



### 3.6. Discussion

Kleiman et al. (2010) recommended that for managing a species in captivity, the focus should be on allowing the species to display species-specific behavioural patterns. Our approach for the captive propagation of Western tragopan took into account the spatial requirements of the species, dietary specializations, environmental needs (light cycles; humidity; temperature), specific housing requirements and medical concerns. These parameters ensured that, although not all, the critical species-specific requirements were incorporated into the management of the species in captivity.

Following the interventions, as described above concerning the keeping system of the birds, the emergence of a positive trend with respect to reproduction in the captive population was observed during the breeding season in 2012 and 2013.

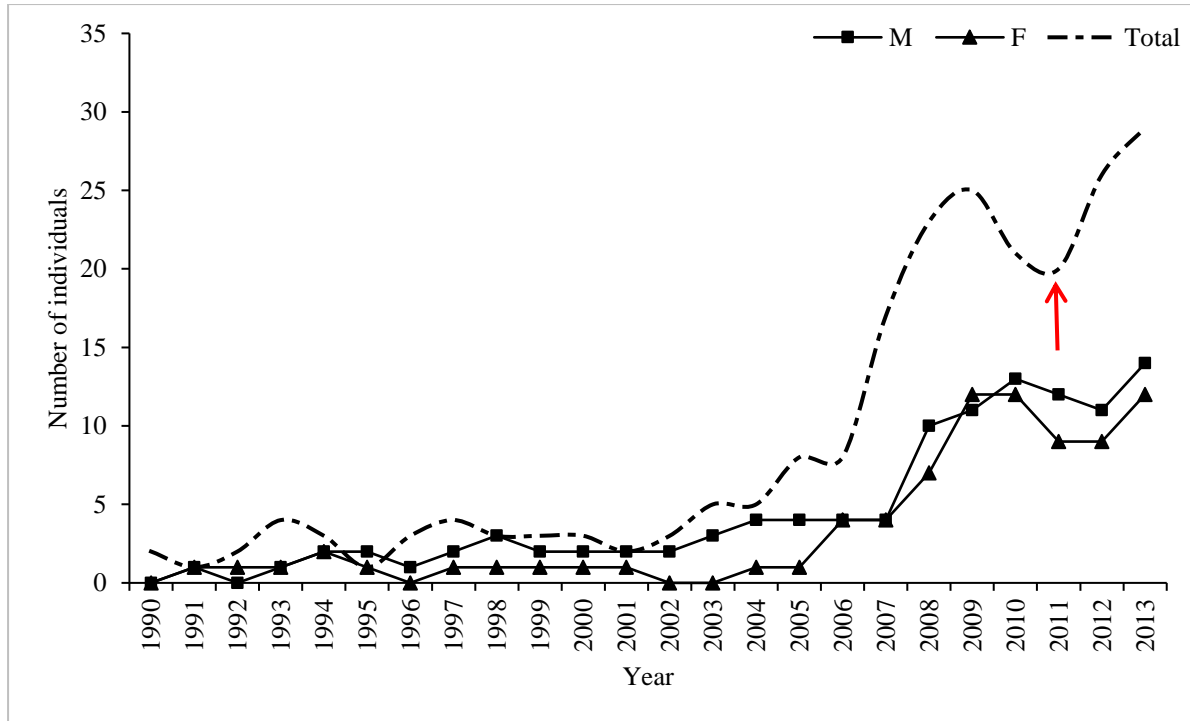
Our approach at the centre strongly adopted the principle of '*adaptive management*' (McCarthy and Possingham 2007), to plan and take robust decisions under uncertain conditions and consequently learn *via* systematic monitoring, and further applying what is learnt to optimize the decisions. The results concerning reproductive output including parent-rearing in the captive populations were indicative that the improvements allowed the birds to show their full range of adaptive behaviors, mainly concerning activities related to breeding like nesting, egg-laying, incubation and rearing of chicks. Hence, our hypothesis concerning the relationship between sub-optimal housing conditions and low reproductive outputs in the past appeared to be true. In order to document the information on the keeping system and for long-term monitoring of captive stock, a record keeping system was developed during the project period. The record keeping system formats are provided in Annexure-I.

#### **4.1. Introduction**

The captive stock of the species was initially founded by a pair of wild-born birds in 1990 at a captive facility located in Sarahan, Himachal Pradesh. The location of captive breeding centre was determined such that the species would be housed within its natural distributional range. Over the years, more wild-born birds were added to the captive stock, accompanied with the addition of captive-born individuals. The current global stock comprises of 29 individuals, of which, 27 individuals (12 males and 15 females) are housed at the breeding centre in Sarahan and two individuals (two males) are housed at Kufri Zoological Park, both facilities are in Shimla District of Himachal Pradesh. The captive population of Western tragopan is 'small' consisting of only 34 individuals, which also represent the only global captive population of the species. As a part of the project, studbook analysis was undertaken and an initial document on was produced in 2011 (Lakshminarasimha et al. 2011). The studbook has now been updated and detailed breeding analysis along with population projection has been provided. This has implications for effective management of the captive populations and provides options for *in-situ* conservation efforts based on reintroduction and restocking interventions.

#### **4.2. Census**

In the Sarahan pheasantry, a total of 48 individuals (23 males and 25 females) have been housed in captivity between 1990 and 2013. The size of the captive population of Western tragopan has evolved from 1990 to 2013 (Figure 4.1). During this period, there have been nine imports from the wild adding a total of 20 individuals to the population, of which seven individuals are part of the current population. The stock size remained at a low number ranging between 2-8 individuals until 2006, and subsequently increased in numbers until 2008, during which nine captive-born individuals and two wild-born individuals were added to the captive population. However, in 2009, the population decreased, due to four mortalities and no births until 2012. Significantly, during 2012-2014, 18 births (including 6 chicks in 2014 as of July 2014) were recorded with three mortalities, leading the current population size of 32 (+2 in Kufri) individuals in the pheasantry. This is the maximum number of captive population of this species ever recorded in the world thus far.



**Figure 4.1:** Development of the captive population of Western tragopan from 1990-2013

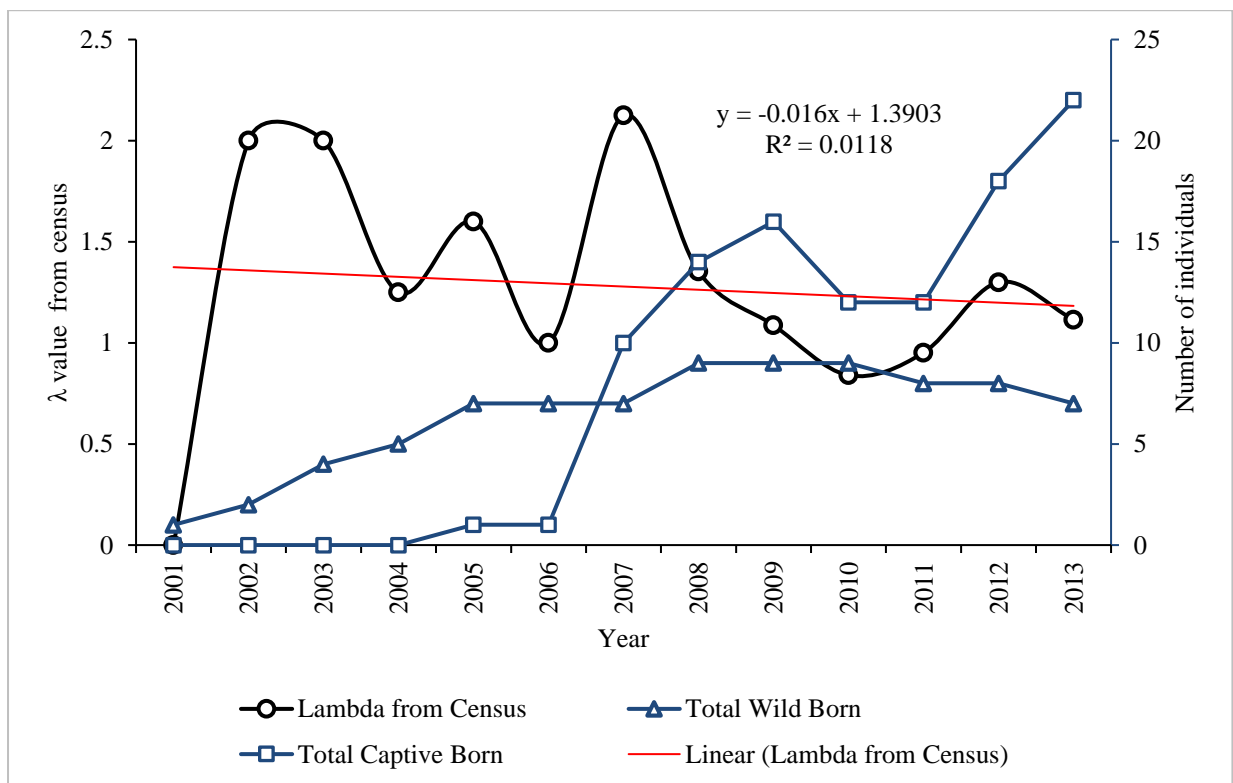
#### 4.3. Population Growth, Structure and Lineage

The population growth rates ( $\lambda$ ) (rate of change in population size expressed as a function of time), as derived from census data, is fluctuating over the years with the highest values recorded during 2007, during which nine captive births were recorded (Figure 4.2.). The growth rates decreased in the subsequent years to below zero until 2012 and 2013, during which seven and four births were recorded respectively, resulting in a growth rate of 1.16 at the end of 2013. Until 2005, the growth of the population mainly depended on the acquisition of wild-born founders, as no captive breeding was recorded. The linear trend-line indicates decreasing growth rates over the years in the captive population of Western tragopan, taking into account cumulative population size (wild-caught and captive bred), but the effective growth rate purely from captive population was recorded 2012-2013 (Figure 4.2.).

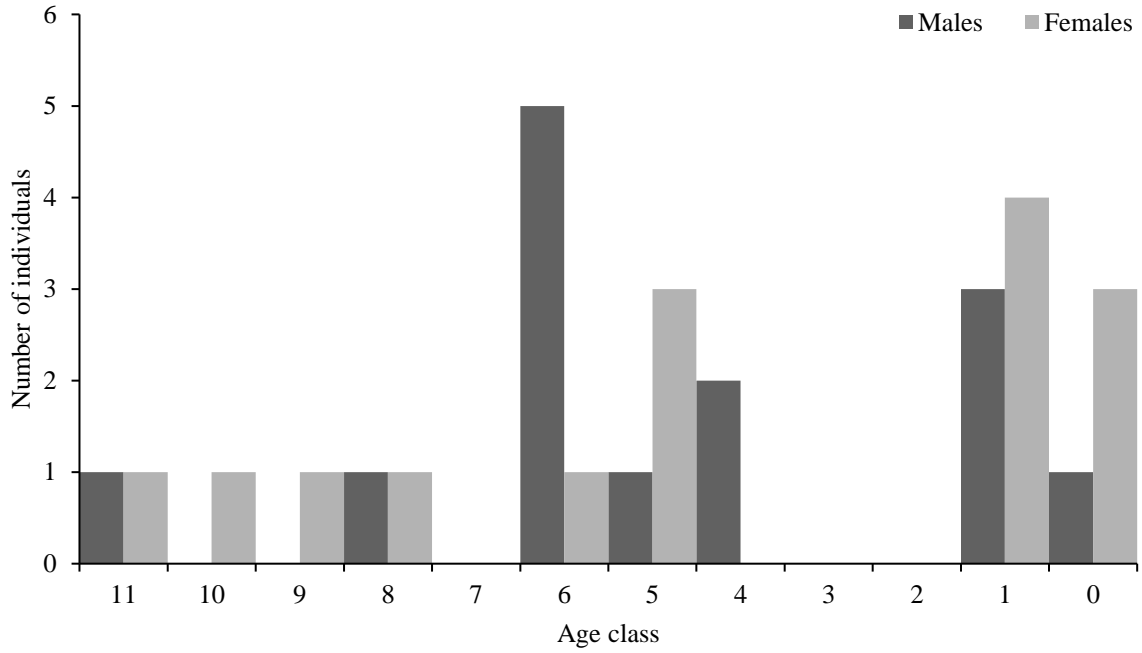
The age-sex classification of the living captive population of Western tragopan (14 males and 15 females) is presented in Figure 4.3. The two males housed at Kufri Zoological Park have unknown parentage and hence have been excluded from the breeding program. Six (21%) individuals (two males and four females) are in the post reproductive age class. The breeding age class consists of 12 individuals (8 males and 4 females). The parent-reared birds born during

2012 and 2013 are key representatives of the population comprising of 11 (37%) individuals (4 males and seven females), which are the pre-reproductive age-class. The age-sex structure is indicative of more individuals in the post-reproductive age class and skewed sex-ratios in the breeding age-class.

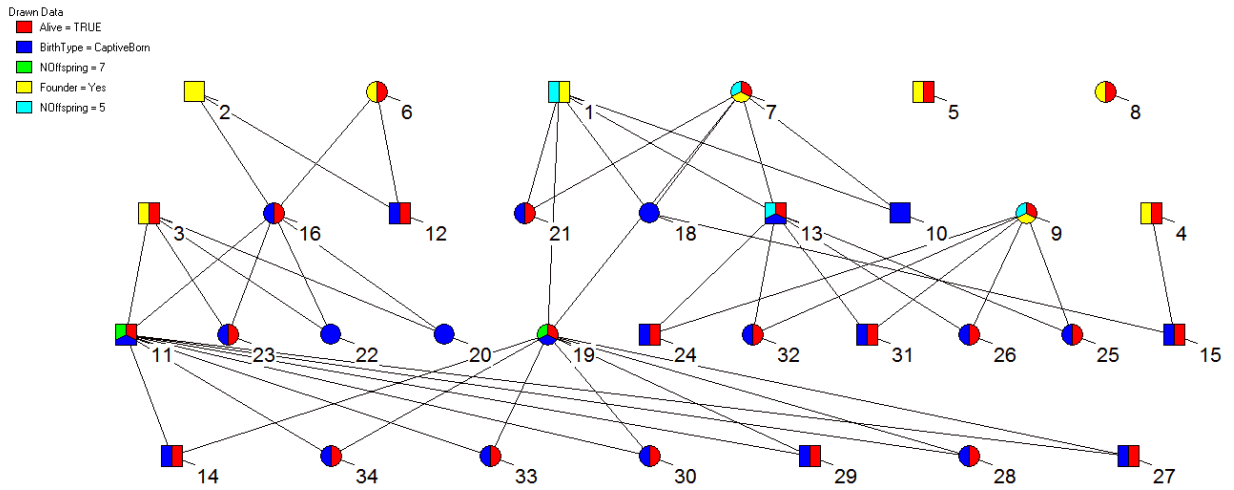
The living captive population consists of seven wild-born and twenty-two captive-born individuals. The current living population consists of five founders (003, 004, 006, 007, 009) and two potential founders (005 and 008), highlighted as yellow in Figure 4.4. The lineage diagram clearly indicates disproportionate breeding among females from F<sub>0</sub> and F<sub>1</sub> generations. The generational output of females is depicted in Table 4.1.



**Figure 4.2:** Population growth rates of Western tragopan captive population



**Figure 4.3:** Age-sex classification of captive Western tragopan from the living population



**Figure 4.4:** Parentage representation of the Western tragopan captive population

	Adult females	Reproducing females	Number of off springs	Descendants living
F <sub>0</sub>	10	4	13	10
F <sub>1</sub>	4	3	6	4
F <sub>2</sub>	4	0	0	0

**Table 4.1:** Generational details of females in Western tragopan captive population (1990-2013)

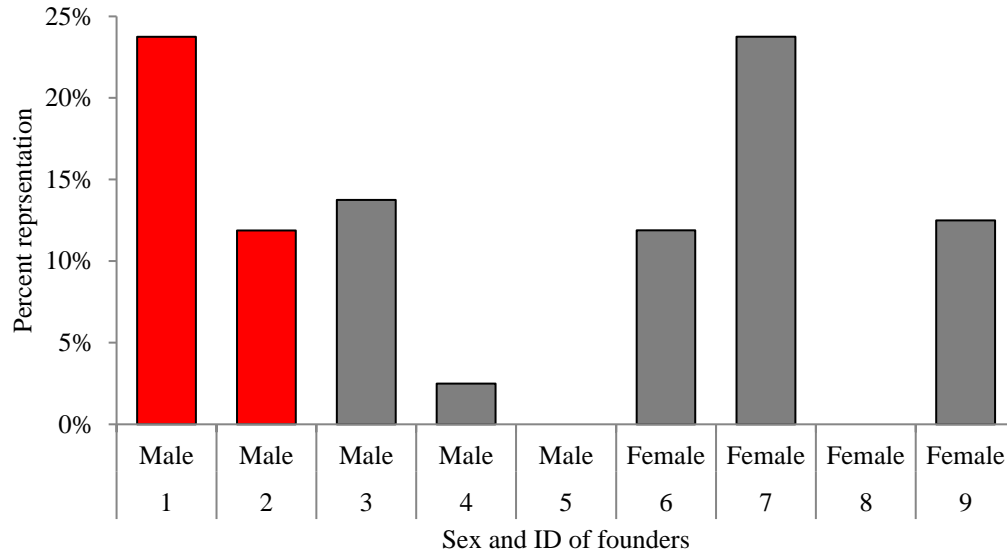
#### 4.4. Breeding History

Six (33%) of the 18 females housed in captivity during 1990-2013 have living descendants in the current population. Egg-laying records of females were available only from 2005, during which 16 females were housed. A total of 399 eggs were laid during 2005-2013, with a median 15 eggs female<sup>-1</sup> (mean  $\pm$  SD: 24.9 $\pm$ 23.3, n=16). Normal eggs constituted 47% (188 eggs) of the total eggs laid and abnormal eggs (thin-shelled, shell-less, broken and under-sized) were 53 % (211 eggs).

Of the normal eggs laid, 152 (81%) were incubated either by a foster hen or the tragopan hen and the hatching percentage was 25% (38 hatching events). Of the total number of eggs incubated, 98 (64%) were incubated by foster hen and 54 (36%) were incubated by tragopan hen. During 2005-2013, 27 births were recorded, of which 11 chicks (41%) were reared by foster hen and 16 (59%) were reared by tragopan hen. Eleven neonate deaths were recorded, which gives a fledging percentage of 71%.

#### 4.5. Founder Representation

Founder representation (i.e. contribution of each founder to the current living population) of nine individuals to the living captive population of Western tragopan (2005-2013) is represented in Figure 4.5. The non-living individuals are highlighted in red. The representation is skewed for two founders (001 and 007) with nearly 50% contribution, due to disproportionate breeding among the founders. The remaining individuals are under-represented and two founders are not represented at all.



**Figure 4.5:** Founder representation in the Western tragopan captive population

#### 4.6. Kinship

The proportional genetic diversity (as a proportion of source population) in the living population, excluding individuals with unknown pedigrees and which have not bred is 90.07%, with a mean kinship (an average degree of relatedness between individuals) value of 0.099. Inbreeding coefficient of the all the individuals are zero. The values for Mean Kinship (MK), Kinship Value (KV) and Inbreeding Co-efficient (F) are given in Table 4.2. The KV values in the table are the weighted MK values, with reference to the reproductive ages of each of the kin. The ranks indicate the priority individuals or genetically important individuals from the perspective of the breeding program. For MK ranks, the low ranked individuals are the ones with low values of MK, and for KV ranks, high ranked individuals have most kin in the reproductive age class.

ID	MK	MK Rank	KV	KV Rank	F
3	0.0688	3M	0.0695	4M	0
4	0.0125	2M	0.0189	2M	0
5	0	1M	0	1M	0
6	0.0594	2F	0.0384	2F	0
7	0.1188	6F	0.1248	6F	0

8	0	1F	0	1F	0
9	0.0625	3F	0.0852	5F	0
11	0.1438	8M	0.1355	6M	0
12	0.0719	4M	0.0421	3M	0
13	0.1625	9M	0.1711	9M	0
14	0.1719	10M	0.1809	12M	0
15	0.0813	5M	0.0954	5M	0
16	0.1063	5F	0.0732	3F	0
19	0.175	15F	0.1886	15F	0
21	0.1313	10F	0.1301	7F	0
23	0.1	4F	0.0767	4F	0
24	0.125	6M	0.1451	8M	0
25	0.125	7F	0.1457	9F	0
26	0.125	7F	0.1457	9F	0
27	0.1719	10M	0.179	10M	0
28	0.1719	11F	0.1796	13F	0
29	0.1719	10M	0.179	10M	0
30	0.1719	11F	0.1796	13F	0
31	0.125	6M	0.1447	7M	0
32	0.125	7F	0.1447	8F	0
33	0.1719	11F	0.1786	11F	0
34	0.1719	11F	0.1786	11F	0

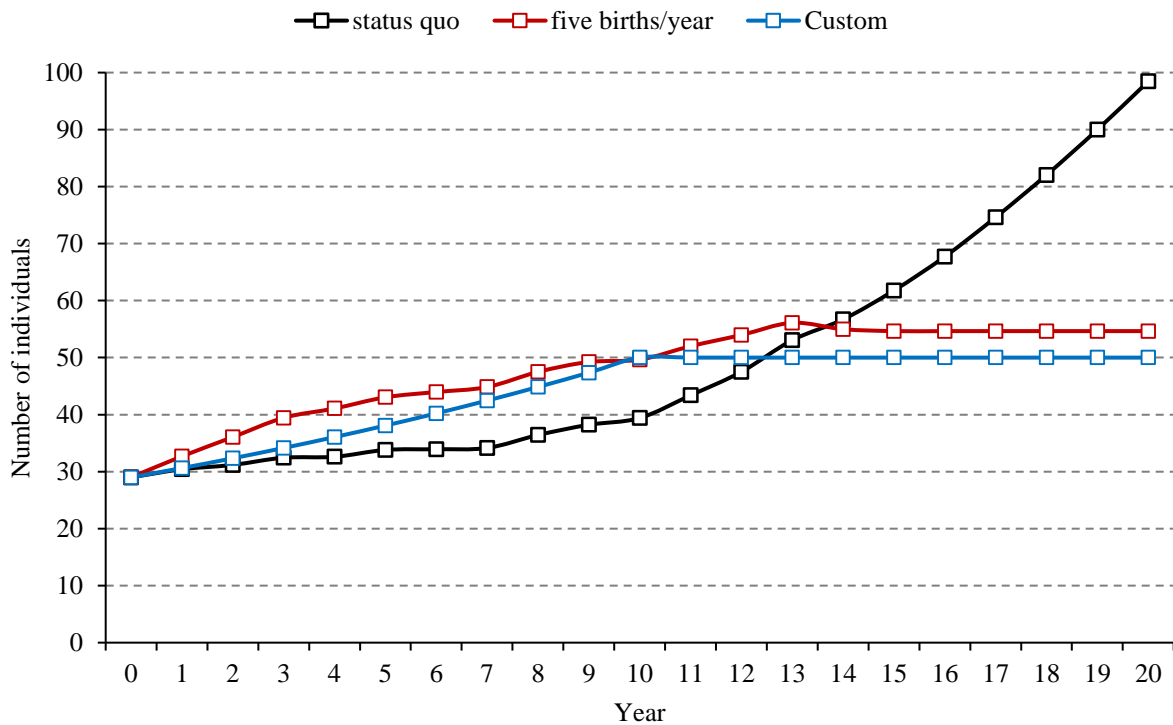
**Table 2.2:** Mean Kinship (MK), Kinship Values (KV) and Inbreeding co-efficient (F) of living individuals of captive Western tragopan. Associated ordered ranks (MK Rank and KV Rank) for each individual are indicated. The highlighted individuals with lower ranks for MK Rank and higher ranks for KV Ranks are more genetically valuable for the breeding program

#### 4.6. Population Projections

The Western tragopan captive population was visualized under three different scenarios for 20 years time scale (Figure 4.6.). The status quo projection (black line) projected the growth over

time using the demographic parameters averaged for years 2005-2013, the duration during which captive births were recorded. Considering the number the births in 2013 (n=5) and 2014 (n=6), and with an assumption that these represent the minimum number of birth per year for the foreseeable future, the growth was projected at five births per year for the next 20 years (red line). A custom scenario (blue line) was also run, with an initial population size of 29 individuals to a target population of 50 individuals to be achieved at the end of 10 years, assuming equal sex ratios at birth.

The ‘status quo scenario’ projected the  $N_{20}$  at 98 individuals; ‘birth scenario’ projected the growth to 55 individuals at the end of  $N_{14}$  and constant thereafter; while the ‘custom scenario’ required a lambda of 1.056 (i.e. 5.6% increase per year) for the target to be achieved.



**Figure 4.6:** Population projections of the Western tragopan captive population. Status quo represents the projections based on demographic parameters averaged for past eight years. Birth-based projections indicate the growth of the population with 5-births/time intervals. The custom were projected with an  $N_0 = 29$  to a target of  $N_{10-20} = 50$ , with sex ratio at birth for males at 50%.

#### 4.7. Discussion

Zoo populations of wild animals are often discussed in the context of “sustainability” and “viability”. Sustainability is the ability of the given captive population to sustain as “representatives” of their wild conspecifics, under the resources available over a predicted time scale (Gusset and Dick 2011). Viability on the other hand is the ability of the given population to long-term persistence under conditions of systemic pressures and stochastic perturbations. The stochastic events that could possibly impact populations have been classified into demographic and environmental stochasticity, natural catastrophes and genetic catastrophe (Shaffer 1981). These processes have greater effect on small populations than large populations making them less stable and more prone to extinctions Frankham (2002).

The captive population of Western tragopan has reached the highest number as of 2013 (now in 2014), since its establishment nearly two decades ago. The fluctuating growth curve indicates that the population size failed to stabilize over the years. The significant proportion of the growth of the captive population has occurred only following 2007. However until 2012, major proportion of the chicks born was raised using foster hens. The population growth rates are highly variable with a decreasing trend over the years. The breeding performance among the females in the reproductive age class is disproportionate with only one pair represented chiefly in the F1 generation. The eleven mother-reared birds added to the population in 2012, representing nearly 40% of the total population as important individuals from the perspectives of the conservation breeding program. Two founders are not represented in the living population; hence loss of alleles through genetic drift coupled with skewed founder contribution might result in the loss of founder genetic diversity. According to Ballou (2010), the genetic contribution of founders to the gene pool in populations with skewed founder contributions is less than expected. The proportion of heterozygosity retained is calculated by using the formula  $[1-(1/2N_e)]$ ,  $N_e$  being the effective population size. Frankham (2002) propose a minimum of 20-30 unrelated contributing founders in order to ease genetic management like inbreeding issues during the maintenance phase. Using the above formula, 20-30 founders would capture between 97.5-98.3% of the heterozygosity. The current Western tragopan captive population is founded by seven individuals with two potential founders in the living population. Therefore, nearly 93% of the heterozygosity is retained in the living population and in case the two potential founders breed, the proportion would increase to 95%.

The results of the breeding history analysis indicate problems associated with specific reproductive processes, possibly arising due to the given nature of the captive environment and husbandry practices. In his monograph, Beebe (1918), regards Western tragopan as a difficult species to be maintained in captivity. According to (Schales and Schales 1994), several species of pheasants, like the Tragopans, Koklass and Blood pheasants, exclusively feed on vegetative matters and are hence “difficult” to be maintained under captive conditions. Further, the authors also state that inappropriate diets could result in obesity, reduced fertility and imbalances in intestinal microflora.

Establishment of captive populations involves three phases: founding, growth and maintenance. With the given background, it is safe to assume that the captive population of Western tragopan is a “small” population in its “growth phase”. According to Frankham (2002), the priority for populations in its growing phase should be on rapid proliferation of individuals as opposed to intensive genetic management.

The principles of small population dynamics dictate that small populations are more vulnerable to extinctions in comparison to large populations Frankham (2002). As stated by the authors, one of the major factors leading to demographic vulnerability in small populations is demographic stochasticity. Random variations on an individual level with reference to reproduction, mortality rate and offspring sex ratio etc. all account to demographic stochasticity. When a population is small, these variations occurring on an individual level are magnified and further cause fluctuations in demographic structure (fecundity and mortality rates, sex ratios etc.) of the population Frankham (2002).

Caro and Laurenson (1994) emphasize the importance of genetic considerations in management of captive populations, however, the authors also indicate that the impact of problems arising from genetic factors are slower-acting than those originating from demographic and environmental factors. According to Young (1991), the extinction risks faced by small populations are more due to demographic constraints than genetic constraints and also opinions that genetic considerations are given disproportionate attention. Therefore, although genetic management and preventing the depletion of genetic diversity in a captive population is important, it should be viewed as a sub-set of a broader set of principles required for the scientific management of captive populations.

Setting a target population size is the first step towards management of a population. For a population to be managed over a century under optimal genetic conditions, an effective population size ( $N_e$ ), is calculated using the formula  $N_e=475/T$ ; T being the generation length and 475 being a constant indicating the effective population size of species with generation length of one year. The current generation length (individual of one sex to add another individual of same sex, represented as T) is 4.2 years for the Western tragopan captive population. Substituting this in the formula above, the required target population is about 113 individuals. As per the projections in Figure 6, under the status-quo situation it would require at least 20 years with current growth rates and other demographic parameters to reach a population size of around 100 individuals, slightly lower than the required target size. Once the target size is achieved, thereafter, serious considerations need to be given towards genetic management. However, during the course of 20 years, breeding between closely related individuals can be avoided, using Table 2 as reference. Another issue widely discussed in conservation breeding programs is space availability, a comprehensive account on which is provided by (Conway 1986, 1995, Conway 1980, 2011, Snyder et al. 1996). The target size, as mentioned before, of over 100 individuals to be managed is unrealistic at the moment considering the space available for housing the species in captivity. The current facility available for the species is full. However, 14 new aviaries are proposed to be built with priority, with a few being available before the breeding season in 2015. Setting the target size at 50 individual birds would hence be reasonable, with the resources available. Therefore, the population was projected with current growth rates to a target size of 50 individuals, which would approximately need 10 years to be achieved. During this process, attempts should focus on individual founders to maximize their contribution to the existing gene pool.

Various authors (Ballou et al. 2010, Foose TJ 1991, Foose Thomas J et al. 1986, Frankham Richard et al. 2002, Seal et al. 1994) discuss the framework for managing captive populations. Foose (1986) proposed two fundamental goals for captive propagation programs. The first-type is for populations under intensive genetic management and the second-type is when a species selected for captive propagation is relatively new to captivity or its husbandry poorly known.

The former goal of intensive genetic management over a set period of time having been given primary attention is criticized by various authors (Anthony and Blumstein 2000, Caro TM and Laurenson 1994, Lacy 2012, Young 1991). On the other hand, management objectives as

proposed by Frankham (1986) are distinct and provide a much clear framework of operation. The authors also present that incongruity about genetic aspects given more attention arises due to the lack of defined program goals.

Frankham (1986) categorize captive populations in four broad categories:

- 1) Common species for display
- 2) Endangered species for long-term conservation
- 3) Rare species being propagated for immediate reintroduction efforts
- 4) Rare species not yet capable of self-sustaining reproduction in captivity

The given captive population fits into Category-4. Multiple reasons underlie the failure of a species to achieve self-sustainable reproduction in captivity, possibly arising independently due to husbandry practices, stress, behavioural abnormalities, socialization problems and genetic issues or as a cumulative effect of these as problems. Frankham (1986) propose that genetic rules be relaxed for Category-4 captive populations until a situation is achieved where individuals can breed without problems. As stated by Frankham (2002), the susceptibility of small populations to extinctions is mainly due to stochastic perturbations on an individual level. According to Singh and Kaumanns (2005), one of the directions for population management should involve gaining knowhow about individuals' behaviour and life-history traits. The authors also state that individuals are "basic-units" of a population and hence, their life-history patterns greatly influence the viability of a population. There are also evidences for personality differences and variations in behaviours among individuals within a population (Wilson 1998). Therefore, the principle for management of the captive stock of Western tragopan should strongly refer to "management of individuals", and should also take into account between-individual differences in behavioural plasticity. Further, they propose that once self-sustaining reproduction is achieved, the captive population should be managed under Category-2, having had achieved the target size and consistent breeding; genetic management can then follow.

## CHAPTER-V

### BEHAVIOUR AND CAPTIVE MANAGEMENT

#### 5.1. Introduction

In the last two decades, various studies have attempted to apply knowledge of animal behaviour in species conservation. The potential benefits of applying behavioural principles in conservation have been emphasized by many authors (Caro 1998, Clemmons and Buchholz 1997b, Gosling and Sutherland 2000, Sutherland 1998). Paucity of information on the behavioural biology have often been major impediments in deciding perspectives for species conservation (Clemmons and Buchholz 1997a). Behavioural problems are also key issues in many captive propagation programs (Snyder et al. 1996, Wielebnowski 1998). Many aspects of behaviour such as foraging and reproductive behaviours are relevant in conservation context as these traits directly influence population dynamics (Anthony and Blumstein 2000, Reed 1999). The study of animal behaviour is mainly concerned with individual variations in behaviour (Caro 2007). A group of individuals constitute a population and therefore information on the life-history traits of individuals is fundamental to understanding population stability (Begon et al. 2009). Knowledge about the behaviour and life-history traits can therefore serve as baseline data in the formulation of conservation plans for managing threatened wild populations.

As evident from the available literature, many aspects of the behavioural ecology of Western tragopan have not been studied in wild, on account of habitat and behavioral complexities associated with the species. However, the captive population serves as model for understanding the behavioral aspects of the species and simultaneously helps in conservation management in captivity and wild. Accordingly, the behaviour of Western tragopan under captive conditions was studied during the project. When looked at from a conservation perspective, the *ex-situ* study should help in the understanding of how captive environments affect the behaviour of these birds and that these results are helpful in the effective captive propagation of the species and in the management of fragmented wild populations.

The primary goals for behaviour-based management were to: 1. Optimize the keeping system for Western tragopan in captivity; 2. Promote the expression of natural behaviours including parental care; and, 3. Address aspects of stereotypic behaviours and increase behavioural diversity. The

background details on the status of keeping conditions concerning housing, diet and reproductive management have already been presented in the previous chapters.

## 5.2. Methods

The behaviour of the birds were recorded through focal-animal sampling using a continuous recording regime (Martin and Bateson 1993). The behaviours of the birds were observed with reference to a pre-defined list of behaviours from the previously established ethogram and this was developed based on *ad-libitum* sampling was used. The focal animal time under all observational settings was 10-minutes and was carried out during July 2012-October 2012 and March 2013-October 2013 from 0600-1200+1300-1800h in summer and 0700-1230+1315-1700h in autumn and early winter. During focal observations, recordings of the vocalizations produced by the birds were also recorded *ad-libitum*. The breeding behaviours were recorded especially with reference to clutch size, incubation period and number of offspring produced, during the study period.

## 5.3. Results

### 5.3.1. Ethogram

A behavioural inventory of the species, often referred to as the ethogram, was established to record and describe as much as possible and precisely the behavioural characteristic of the species. This provided the basis to identify the species-typical behavioural patterns. The ethogram consists of specific names and definitions were assigned to different behavioural patterns. The behavioural patterns were then classified into categories based on their function. In all, thirty-two behavioural patterns, observed in the Western tragopan, were classified into 10 categories (Table 5.1).

Behaviour	Definition of the behavioural pattern
<b>Locomotion</b>	
<i>Walk</i>	Low-speed movement of the bird on ground or perch in which propulsive force is derived from action of legs
<i>Run</i>	High-speed movement of the bird on ground in which propulsive force is derived from action of legs
<i>Jump</i>	Low-height vertical displacement of the bird from ground in which propulsive

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	force is derived from action of legs and sometimes wings
<i>Fly</i>	Displacement of the bird between two points within an enclosure in propulsive force is derived primarily from action of wings
<b>Forage</b>	
<i>Feed</i>	Bird uses the beak (both upper and lower mandible) to pick up food items at the food bowl or strike at the food bowl
<i>Drink</i>	Bird uses the beak (both upper and lower mandible) and attempt to pick water, following which head is raised to facilitate water intake
<i>Peck ground</i>	Bird is actively involved in the process of locating food on the ground, using its beak to strike the ground at regular intervals
<i>Scratch ground</i>	Bird is actively involved in the process of locating food on the ground, using its claws to scratch the ground, often preceding/succeeding “pecking the ground”
<i>Pluck</i>	Bird uses the beak (both upper and lower mandible) to grasp or pull leaves from plant either on ground or from a perch or on the plant itself
<b>Comfort</b>	
<i>Preen</i>	Bird uses its beak (both upper and lower mandible) to grasp individual's feather, move along its entire length or comb plumage
<i>Dust-bath</i>	Bird lying on ground, usually in a shallow scrape and tossing loose soil onto its body/wings by rolling, regular ruffling of feathers and body shaking. Bird also uses the beak to loosen soil around the scrape.
<i>Wing stretch</i>	Bird stretches wings, often accompanied with stretching of tarsus on same aspect of the body
<i>Leg stretch</i>	Bird stretches tarsus, often accompanied with stretching of wing on same aspect of the body
<i>Scratch self</i>	Bird uses its claw to scratch its own body
<i>Beak Rub</i>	Bird dabs the beak against an object, usually to a perch
<i>Feather fluff</i>	Bird ruffles its feathers, often accompanied by erection of feathers
<i>Yawn</i>	Bird stretches its upper and lower mandible
<i>Lappet exercise</i>	Male bird extends the lappet and sometime horns while resting on a perch. Sometimes accompanied by vigorous shaking of head

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## Social

<i>Lateral display</i>	A form of courtship where the male is positioned close the female and presents one flank of its body to the female, with feathers and a wing lowered on that side, raised on the other, and approaches her taking side-steps.
<i>Frontal display</i>	A form of courtship where is male hides behind a object, repeatedly twitches head to expose lappets and horns accompanied by tail feather fanning, production of clicking sound and then suddenly emerges and rushes towards to female.
<i>Mating</i>	Male bird copulates with the female bird, necessarily following an elaborate or short “frontal display”
<i>Peck object</i>	Male bird uses its beak to peak at objects like wood/food bowl/wire mesh to produce sound
<i>Displacement</i>	One bird chases another bird, and forces the individuals to shift its location by more than half a feet
<i>Wing whir</i>	Bird in upright position, extends wings with intense and repeated flapping, not lasting more than 3-4 seconds accompanied by a single note vocalization and the sound of the flap itself

## Vigilance

<i>Monitor</i>	Bird is alert, taking few steps occasionally on ground or perch and watching its surroundings
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## Rest

<i>Passive</i>	No movement observed, the bird and may be in upright position on ground /perch; sitting with its breast in contact with ground/perch; with eyes may or may not be closed
<i>Roost</i>	Bird is located on the perch with its breast in contact with the perch and eyes may or may not be closed

## Time-out

<i>Out-of-sight</i>	Bird is not visible to the observer
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## Vocalize

<i>Vocalize</i>	Bird is vocalizing
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## Others

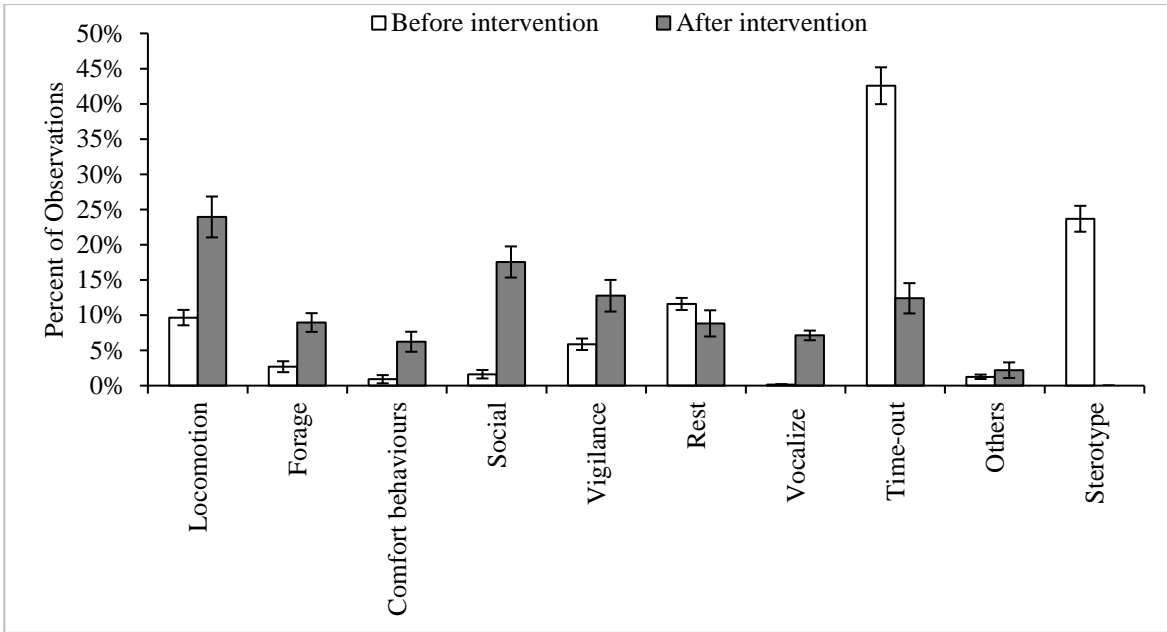
<i>Defecate</i>	Bird excrete feces
<i>Uncategorized</i>	Any behavioural pattern not following in any of the aforementioned categories
<b>Stereotype</b>	
Pace	Constant and uniform repetitive locomotory movement by an individual along the fence partition separating the aviaries. Occurs when the individuals of the adjacent pen are in the visual range.
Sources for definition and classification of behaviours: Immelmann (1989) and (Barrows 2011)	

**Table 3.1:** Behavioural categories and definitions of individual behavioural patterns

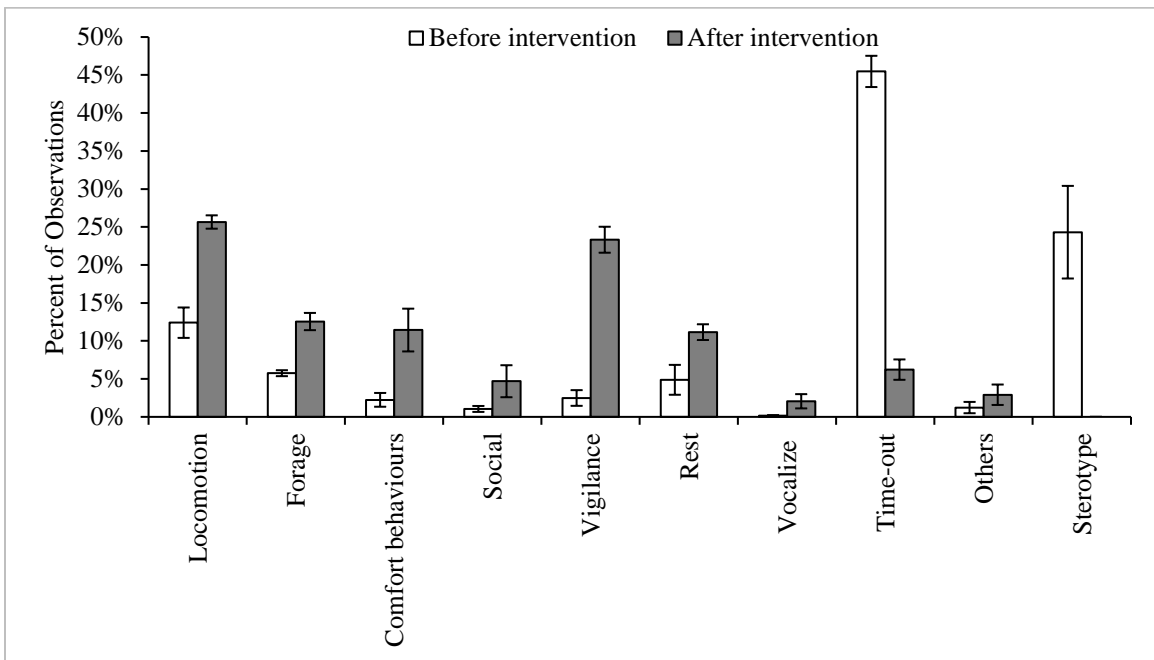
### 5.3.2. Activity Budgets

The activity budgets of male and female Western tragopan are represented in Figure 5.1 and Figure 5.2 respectively. During 2011, when the birds were housed under the previous management regime, time-out and stereotypy behaviours constituted more than 65% of the total observations in both the sexes. During 2011, the birds were confined to the indoor parts from evening till late morning (1700-0900h). The observations were carried out during the day after the birds were released to the outdoor areas. As the birds were in visual range of each other, a large proportion of the time was also spent in pacing behaviour along the separating partition of the aviaries. The results indicate that the birds still remained in the indoor parts during the day. The proportion of other behavioural categories was around 35%, with locomotion being the predominant behavioural category.

Following the implementation of new keeping system as described in Chapter-3, there were drastic changes in the proportions of various behavioral expressions. As the birds were visually isolated, stereotypic pacing was not observed. The practice of spatial confinement and reduction in light-hours was discontinued in 2012. The proportion of time spent in the indoor parts reduced to less than 50% in both the sexes. An increase in locomotion and social behaviours was observed in both males and females.



**Figure 5.1:** Comparison of activity budget of male Western tragopan (n=4) prior to (during 2011) and following interventions (during 2012-2013)



**Figure 5.2:** Comparison of activity budget of female Western tragopan (n=5) prior to (during 2011) and following interventions (during 2012-2013)

### **5.3.3. Vocalizations**

The calls of the Western tragopan along with the sonograms and the context in which they produced are given below;

#### **1. Alarm calls**

The spectrogram of the male and female alarm call is presented in Figure 5.3 and Figure 5.4. The alarm calls consists of a series of high-pitched notes uttered in quick succession. The call was often uttered when the birds was cornered in the presence of a keepers or when a predator (such as a hovering raptor or a marten) was in the vicinity. The phonetic rendition is described as a “quack” (Islam and Crawford 1996).

#### **2. Advertisement call**

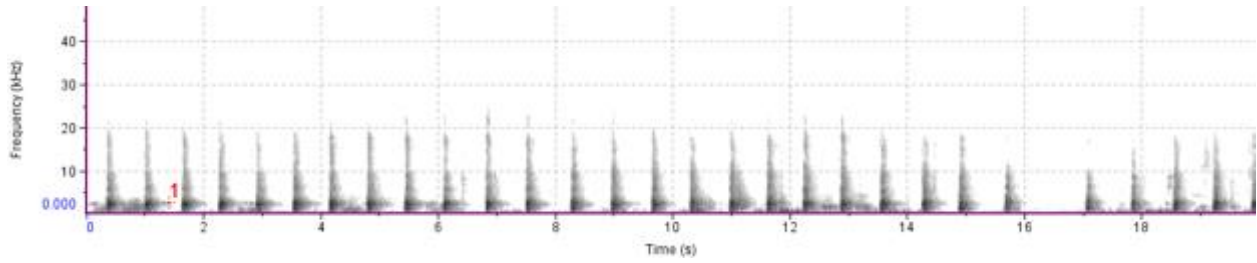
The spectrogram of the male advertisement call is presented in Figure 5.5. The advertisement call (Grimmett et al. 2008), was produced by the male only during the breeding season, specifically in the month of April and May, and scarcely in June. The call was generally uttered early in the morning, at around dawn. The call consists of loud repetitive notes, which can be heard from long distances. The phonetic rendition is described as a “kuwaah” (Islam and Crawford 1996).

#### **3. Wing-whir call**

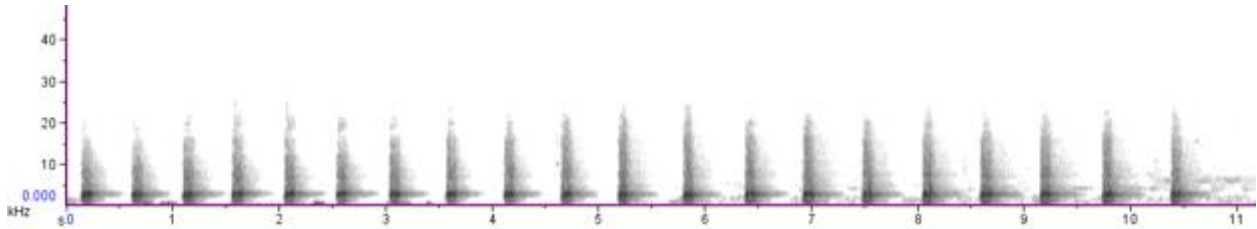
The spectrogram of the male wing-whir call is presented in Figure 5.6. The wing-whir behaviour was accompanied by a single note uttered by the male while on the ground or from atop a perch. The call was produced only during the breeding season (April-June, sometimes July) and distributed throughout the day. The phonetic rendition is described as a “waaak” (Islam and Crawford 1996).

#### **4. Female call during breeding season**

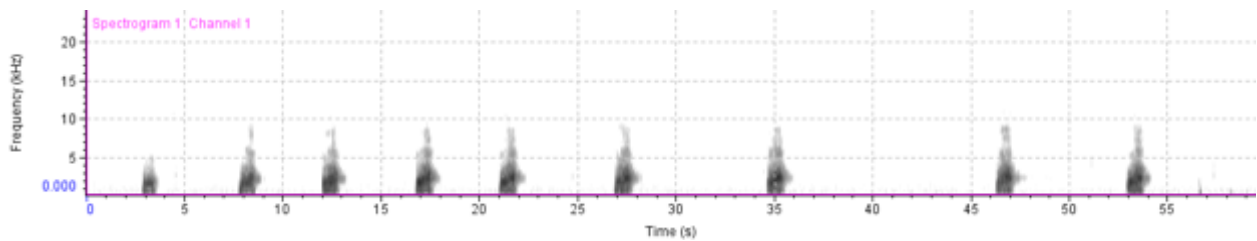
The spectrogram of female call during breeding season is presented in Figure 5.7. Only females produced this particular call during the breeding season. The frequency of calling was more in egg-laying females and increased especially prior to egg laying. The call was uttered while the individual was on the ground or atop a perch. The phonetic rendition is not described in literature, and is similar to the whig-whir call of the male Western tragopan.



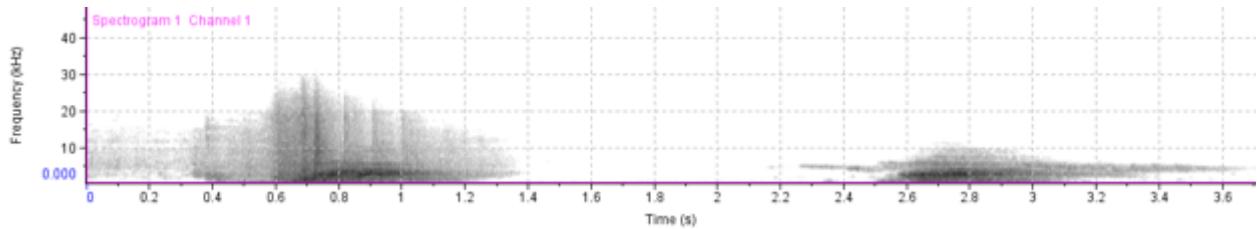
**Figure 5:** Spectrogram of alarm call of male Western tragopan



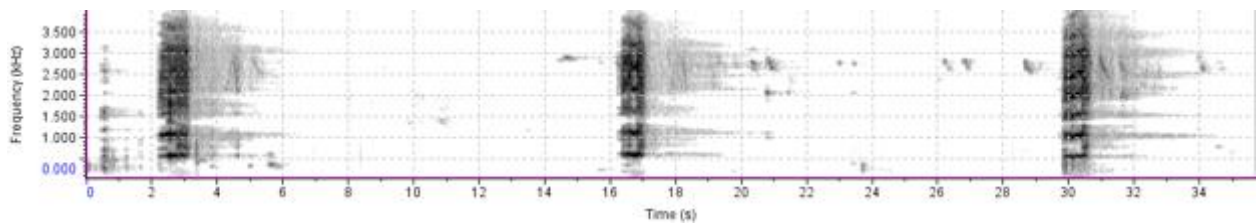
**Figure 6:** Spectrogram of alarm call of female Western tragopan



**Figure 7:** Spectrogram of advertisement call of male Western tragopan



**Figure 8:** Spectrogram of wing-whir call (territorial call) of male Western tragopan



**Figure 9:** Spectrogram of call of female Western tragopan during breeding season

### 5.3.4. Breeding Behaviour

During the study period, various life history parameters of Western tragopan were studied. A comparative account of the breeding history has already been described in Chapter-III. The parameters presented here are only for the duration 2012-2013, during which the birds were housed under naturalistic keeping conditions.

**Chronology of Breeding:** The annual chronology of breeding activities is presented in the table 5.2 below.

<b>Month</b>	<b>Activity Onset</b>
<b>March</b>	<i>Third-fourth week:</i> Feather pigmentation in males: The plumage color in males darkens and become more bright and shiny.
<b>April</b>	<i>First week:</i> Occasional wing-whir and advertisement calls by males <i>Second-third week:</i> Increased frequency of advertisement calls by males; Courtship and display; Mating <i>Fourth week:</i> Onset of egg laying by females
<b>May</b>	<i>First week:</i> Advertisement and wing-whir calls continue; Courtship and display; Mating; Egg-laying in females <i>Second-fourth week:</i> Commencement of incubation by females
<b>June</b>	<i>First week:</i> Advertisement and wing-whir calls reduced; Courtship and display; Mating; Egg-laying in females; Incubation by females almost complete <i>Second-third week:</i> Commencement of hatching of chicks <i>Fourth:</i> Egg laying almost complete
<b>July</b>	<i>First-third week:</i> Completion of egg-laying, incubation and hatching of chicks by all the females; Advertisement calls, courtship and display cease
<b>August</b>	<i>First week:</i> Commencement of molting

**Table 5.2:** Chronology of breeding activities

**Clutch Size:** During 2012-2013, 13 females laid a total of 119 eggs. Of these, 60 (50%) were non-viable (thin-shelled, under-sized and shell-less eggs). The overall clutch size was  $5.4_{\text{Mean}} \pm 2.94_{\text{SD}}$  (n=22). The number of normal eggs produced by each female was  $2.7_{\text{Mean}} \pm 1.8_{\text{SD}}$  (n=22).

**Incubation Period:** During 2012-2013, a total of 15 females incubated eggs naturally. The incubation period was  $29.9_{\text{Mean}} \pm 0.74_{\text{SD}}$  (n=15).

**Offspring, Rearing and Life-span:** The captive-born birds at Sarahan had low life-expectancy ( $40.7_{\text{Mean}} \pm 36.07_{\text{SD}}$  months, n=22) as compared to rescued wild-born birds ( $113.8_{\text{Mean}} \pm 25.99_{\text{SD}}$  months, n=9). A total of 14 offspring were born during this period (9 in 2012 and 5 in 2013). Three chick mortalities were observed. Tragopan hens reared all the offspring naturally.

#### **5.4. Discussion**

One of the possible reasons explained by Cabib (2006) for the development of stereotypic behaviour in adults animals is stressful environmental changes. The “neuro-behavioural adaptations” to such sub-optimal environments can lead to stereotypes. As described earlier, the keeping conditions did not refer to the ecological requirements of species due to which a high proportion of stereotypic pacing behaviour was observed in the birds. Subsequently, the principle of behaviour-based management implemented during the project allowed the evaluation of abnormal behavioural traits and through optimization of the keeping conditions, the reduction in stereotypies could be achieved. Anthony and Blumstein (2000) point out that behaviour of individuals can affect the viability of populations. Therefore emphasis on the integration of behaviour into management of individuals is necessary.

The project was initiated to address issues faced by the captive population and develop science-based methods for the management of this species in captivity. The approach of the study was to interlink basic behavioral research and practicalities associated with the functioning of the centre. The behaviour – based management is complemented by behavioural studies and vice-versa. Optimization of the keeping system involved expansion of the aviaries to provide more enclosure space to the birds, a diet developed based on the feeding ecology of the birds and intensive reproductive management to address issues related to production of thin-shelled eggs and non-expression of reproductive behaviours like incubation and chick-rearing.

### HABITAT SUITABILITY AND REINTRODUCTION

#### 6.1. Introduction

How many individuals are there in an area? Is the population stable, increasing or decreasing? These are among the basic and crucial questions that concern most wildlife managers and conservationists. The number of individuals of a species in an area is generally assumed to be strongly associated with the size of the geographical range of the species, availability of suitable habitat and the mean density achieved by the species (Newton 1998). There are various tools that facilitate modeling and mapping habitats of the species, as surrogate for understanding population status in the wild. Remote Sensing (RS) and Geographic Information System (GIS) are important tools for such purposes and there are several examples across the world for such integration of technology in conservation biology. Habitat suitability models have been used successfully to predict potential distribution of target species (Bakkenes et al. 2002, Peterson 2001) and for identification of reintroduction sites.

Western Tragopan is generally known to be habitat specific (Fuller and Garson 2000) pheasant showing strong correlation with inter-related physical factors such as vegetation, elevation, aspect, slope and other local ecological factors (Johnsgard 1986, Gaston et al. 1983a, Islam and Crawford 1987, Ramesh 2003). Given the logistic constraints and difficult terrain, efforts were focused on habitat specific nature of the bird in GIS domain and to remotely model its distribution probability across the geographical range in Himachal Pradesh.

Amongst several competing models, Rule-based Model and Maximum Entropy (MaxEnt) model are frequently used for landscape level mapping of wildlife habitats and distribution. Rule-based model allows characterization of broad distribution range and a rough habitat suitability model of the bird in the wild (Ramesh 2003). MaxEnt model enables species-habitat relationship analysis and predicts probability of occurrence. Numerous studies have suggested that this maximum entropy modeling framework consistently outperform other methods (Elith et al. 2011, Tsoar et al. 2007, Williams et al. 2009) exhibiting a good trade-off between model performance and data characteristics (Phillips et al. 2006, Torres et al. 2010). Once the habitat mapping was achieved, sample estimates of population size could be integrated to obtain a reasonable estimate

of population size of the species such as Western tragopan, which is otherwise difficult to be counted reliably in the field.

## 6.2. Methods

### 6.2.1. Spatial Database

A detailed spatial-database on various thematic layers was created involving intensive efforts that included processing of satellite data, digitization and verification of various thematic layers. The thematic layers represented both raster and vector formats, obtained and procured from various institutes and organizations (Table 6.1). Image processing and other GIS based analysis were carried out using specialized software such as Erdas Imagine and ArcGIS (Wilson et al. 2011).

Data Set	Source	Resolution	Operation	Output
<b>Raster Layers</b>				
Maximum, minimum and mean temperature and precipitation	Worldclim ( <a href="http://www.worldclim.org/current">http://www.worldclim.org/current</a> )	Spatial Resolution: 1000m Temporal Resolution: Monthly	Band collection analysis	Environmental information on seasonal basis
Night light data for the year 2012	NOVA's defence meteorological research satellites ( <a href="http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html">http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html</a> )	Spatial Resolution: 1000m Temporal Resolution: Monthly	Euclidian distance	Distance from night-light
Human disturbance	SeDac ( <a href="http://sedac.ciesin.columbia.edu/data/sets/browse">http://sedac.ciesin.columbia.edu/data/sets/browse</a> )	Spatial Resolution: 1000m		Human footprint
NDVI for the year 2012-13	MODIS; using the earth explored platform ( <a href="http://earthexplorer.usgs.gov/">http://earthexplorer.usgs.gov/</a> )	Spatial Resolution: 250m Temporal Resolution: 16-day	Cell statistics	NDVI range, standard deviation and mean

Elevation in the form of DEM	USGS earth explorer ( <a href="http://earthexplorer.usgs.gov/">http://earthexplorer.usgs.gov/</a> )	Spatial Resolution: 30m	Hydrology analysis	Aspect, slope and DEM
Vector layers				
Road network	Wildlife Institute of India database	1:50,000	Euclidian distance	Distance form road
River or major streams				Distance form water bodies
Town location				Distance form town
State and district boundaries			Extraction by mask or clip	Extracted raster layer for study area only
Note: All the raster layers were re-sampled to 1000 m resolution for WGS84 Longitude-Latitude projection and clipped for Himachal Pradesh				

**Table 6.1:** List of various spatial data developed for the project

### 6.2.2. Rule-based Model

The rule based model works on the basis of Boolean logic, which relies on well-established available knowledge and prescribes the area to be either suitable (1) or unsuitable (0) without any other middle level (Lenton et al. 2000). Landscape variables such as elevation and forest cover were subjected to niche requirement of the species and accordingly, the preferred elevation zone of Western tragopan for summer (2200-3400m) and winter (1800-2300m) was mapped using raster query in Arc GIS 9.3. This layer was multiplied by moderately dense and dense vegetation classes to map the potential habitat of the species in the state.

### 6.2.3. MaxEnt Model

MaxEnt model characterizes probability distributions based on the principle of maximum entropy (Phillips et al. 2006. Loiselle et. al. 2008). Although there are several models available for evaluating habitat distribution of many species (Guisan and Thuiller 2005), these are often constrained by false absence data that can decrease the reliability of predictive models (Elith et al. 2011). The advantage of MaxEnt is its ability to perform model building based on presence-only data and uses background environment of the study area as reference. It is a machine-

learning method for making predictions from incomplete information from presence only data (Phillips et al. 2006). MaxEnt is a process of adjusting the vector of feature weight, by sequential or parallel updating until convergence, through a maximum likelihood estimation method. It is also advantageous since it uses both continuous and categorical variables and the output is a continuous prediction. The output of MaxEnt is a probability map interpreted as a habitat suitability index (HSI), whose values range from 0 (unsuitable) to 1 (perfectly suitable).

In the present case of model building for Western tragopan habitat, a total of 22 variables representing four geographic (DEM, aspect, slope and hill shade), nine environmental (distance from road, river, town, night light, human foot print, NDVI mean, NDVI-SD, NDVI range, and NDVI minimum) and nine climatic (seasonal temperature and precipitation) were subjected to distribution modeling involving primary and secondary location data of species occurrence (Appendix III). All these datasets were clipped and rescaled according to the specific requirement of MaxEnt model as input dataset (Table 6.2). Different environmental and spatial raster layers of study area collected from different sources as described above were analyzed in MaxEnt to generate habitat suitability model for Western tragopan. All spatial layers used in the modeling were of the same extent, projection and in ASCII format (Pearson et al. 2007) and the analysis was performed in the customized MaxEnt software.

Sl. No.	Thematic Layers	Data Type
1.	Presence data	Vector
2.	DEM	Raster (Continuous)
3.	Aspect	Raster (Continuous)
4.	Slope	Raster (Continuous)
5.	Alternate Stream	Raster (Continuous)
6.	Distance to Road	Raster (Continuous)
7.	Distance to town	Raster (Continuous)
8.	Distance to Water	Raster (Continuous)
9.	Human Footprint	Raster (Continuous)
10.	Distance from night light	Raster (Continuous)
11.	NDVI	Raster (Continuous)
12.	Environ-Climatic layers	Raster (Continuous)

**Table 6.2:** Database and their suitable format used for MaxEnt modeling

In MaxEnt software program, 80 out of 99 (80% i.e. manually fixed) of locations were selected randomly for model building and remaining locations (20%) were used for model revalidation (Fouquet et al. 2010). Model validation and predictive performance were evaluated using the area under the curve (AUC) of receiver operating characteristics (Fielding and Bell 1997). AUC values are threshold-independent measures of model accuracy that illustrate the model's discrimination ability (Fielding and Bell 1997), where an AUC value of 0 indicates a model with no better discrimination than chance and an AUC value of 1 indicates perfect discrimination. MaxEnt develops response curves and based on this, a weight index was generated for each variable, which was then used for mapping the potential habitat of the species. The final result was in the form of response plots and suitability maps. The suitability map was then classified as summer and winter habitat based on the elevation gradient. Elevation ranging between 2800-3800m and 1800-2800m were respectively classified as summer and winter distribution ranges (Gaston et al. 1981) .

#### **6.2.4. Identification of Reintroduction Sites**

Development and implementation of a population supplementation and restoration plan for any endangered species should involve an understanding of the species' habitat requirements prior to the release of any captive bred individuals (Wilson et. al. 2010). In species restoration program, release of species required a greater understanding of the landscape and habitat niche (Seddon et. al., 2007), which requires characterization of landscape. For characterization and identification of reintroduction sites, areas under high and very high suitability classes were further analyzed. The spatial variability and Geo-spatial characteristics of the modeled layers as obtained from suitability maps across winter and summer habitat were assessed (Hirzel, 2004). For this purpose, entire study area was divided into 1 Km grid along the longitudinal axis. The raster values of all spatial layers for these grids (mean or majority of all cells under grid) were extracted using zonal statistics in ArcGIS for both summer and winter habitats separately, from which seasonal variability in the habitats were assessed. Variability assessment of geo-spatial characteristics across summer and winter habitat for each variable under high and very high class of potential habitat obtained from MaxEnt modeling was used in the identification of potential release sites. Grid wise comparative assessment of spatial variability across the habitat offered the identification of the potential reintroduction sites. This assessment was done by plotting simple line graph of spatial characteristic of each habitat for each grid. The basic concept

underlying the comparative analysis across the seasonal habitat was that the area having similar characteristics in both summer and winter habitat offers better suitability, than the area without sufficient winter or summer habitat availability. Accordingly, the areas representing high suitability for any one season but not for other season were discounted as suitable for long-term viability of the species.

Review of literature and field surveys in selected sites during the project period revealed that there have been local extirpations of the species populations in the last two decades. These sites were identified and further details were gathered for experimental reintroduction and restocking efforts.

#### **6.2.5. Population Estimation**

A robust estimate of population size is important for establishing effective management and monitoring strategy for the species. Efforts were made to conduct statewide survey for population estimation of Western tragopan involving the forest staff from all the areas, which represent distribution range of the Western tragopan. However, there were gaps in the participation of the staff from several sites on account of administrative and financial reasons. Therefore, sample surveys were carried out by project team in select localities during summers of 2012 and 2013 based on trail walk and call counts. The sites sampled include Rupi Bhaba WLS, Dharanghati WLS, Manali WLS etc. and few territorial forest divisions including Sara in Chamba district. Final estimate was obtained integrating the probability estimate by MaxEnt, detection probability during trail walk estimated in DISTANCE 6.0 software and probability of bird presence in a beat based on the sample survey efforts. The probabilities were introduced in each step of calculation and were corrected for small sample size. This was the best possible procedure by which a conservative estimate of population size for the species could be obtained; unless large numbers of trained people carry out intensive surveys and camera trapping methods involved, which would involve long-term efforts and substantial investments.

Prior to initiating field studies, preliminary questionnaire surveys involving forest guards were carried out in areas with historical presence. Based on this information, field surveys were conducted in potential habitats located in the districts of Chamba, Kinnaur, Shimla and Kullu districts. Workshops were held to train forest guards in basic aspects of bird census, data

collection, use of GPS and recording protocols over a span of 14 days during (17 to 30 April 2012). The details of the training workshops conducted are provided in the table 6.3.

S. No.	Venue	Date	Number of Attendees
1	Chopal	17.04.2012	18
2	Sarahan	19.04.2012	11
3	Sarahan	20.04.2012	15
4	Kangra	22.04.2012	21
5	Chamba	24.04.2012	30
6	Chaurah	25.04.2012	17
7	Mandi	28.04.2012	9
8	GHNP	30.04.2012	40

**Table 6.3:** Details of Workshops held for Capacity Building of Forest Guards

During the field-sampling period, trails walks in combination with call stations were the principal methods used for counting. Breeding calls of males were counted from fixed and variable radius circular plots laid at 500m intervals along the trail. Call playbacks were also used to ascertain bird presence. Pre-fixed trails of lengths varying from 1-2 km were established in potential habitats and surveyed in morning hours (4 am to 6 am) during breeding season (April to May).

## 6.3. Results

### 6.3.1. Vector Database

A vector dataset was generated to maintain the shape files (point, line and polygon) for the physical features like state boundary, district boundary, road network, rivers & stream and towns etc. in the study area. The shape files were used for visualization, mapping and geoprocessing analysis of the raster as well as other vector dataset.

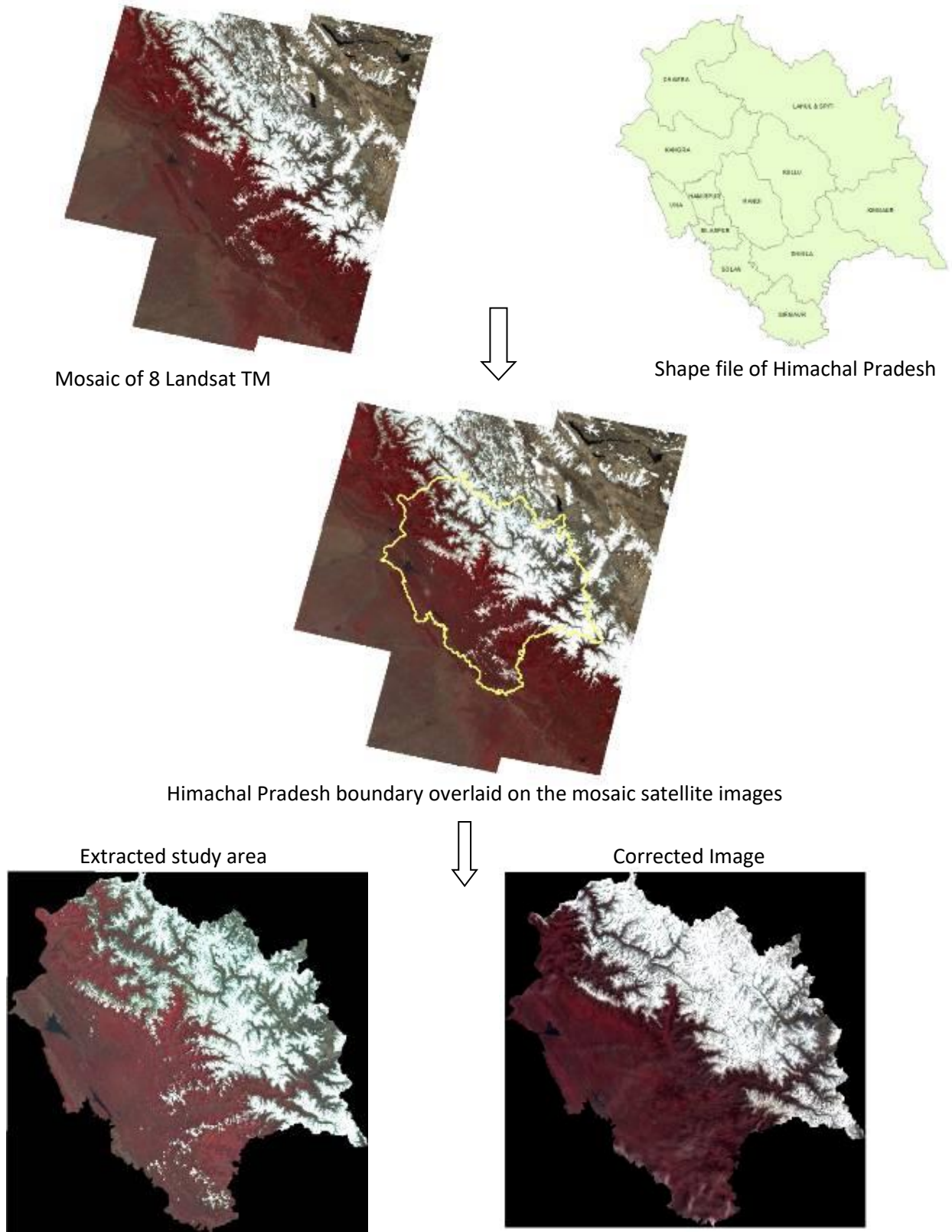
### 6.3.2. Raster Database

Landsat TM satellite Images, with spatial resolution 30m and spectral resolution of seven bands, were downloaded for the years of 2010 from Earth Explorer. Two season images i.e. June (pre-monsoon) and September (post-monsoon), with less than 10% cloud cover, for the year 2010 were processed. Aster DEM of 30m resolution was also downloaded (ASTER DEM is a product

of METI and NASA). The downloaded files were unzipped to obtain multiple geotiff images; one image for each spectral band. These multispectral images were subsetted to remove the noise at the border of the images and then subsequently mosaiced in ERDAS Imagine 9.2 using histogram matching and feathering. The shape file of Himachal Pradesh was overlaid on the mosaiced image and the image was subsetted with the image boundary as the area of interest (AOI) and the extracted thereafter. Dehaze was applied the raster image of Himachal Pradesh to remove the haze from the image and bring out the natural reflectance of the ground cover in false colour composite (Figure 6.1).

Variables such as aspect, slope and hillshade are known to influence the presence of Western tragopan. Aspect is the compass direction that a topographic slope faces, usually measured in degrees from north. Aspect can be generated from continuous elevation surfaces. Slope is a measure of incline, or steepness, of a surface. Slope can be measured in degrees from horizontal (0–90), or percent slope. A slope of 45 degrees equals 100 percent slope. As slope angle approaches vertical (90 degrees), the percent slope approaches infinity. Hillshade analysis obtains the hypothetical illumination of a surface by determining illumination values for each cell in raster. It is used for illumination but also incorporated in running the model to map the probability distribution of the birds to find the effect of illumination of each cell at different times of the day with the probability of presence of the bird. All these variables were generated using DEM in Arc GIS (extension spatial analyst).

Eighteen bioclimatic layers were downloaded from Worldclim web resource. The bioclimatic variables represent annual trends (e.g., mean annual temperature, annual precipitation), seasonality (e.g., annual range in temperature and precipitation) and extreme or limiting environmental factors (e.g., temperature of the coldest and warmest month, and precipitation of the wet and dry quarters). Values for each of the variables were summarized and presented in Table. 6.4. Maps of the aforesaid layers and environmental parameters are given in Appendix-III.



**Figure 6.1:** Thematic flow-chart of the image analyses process

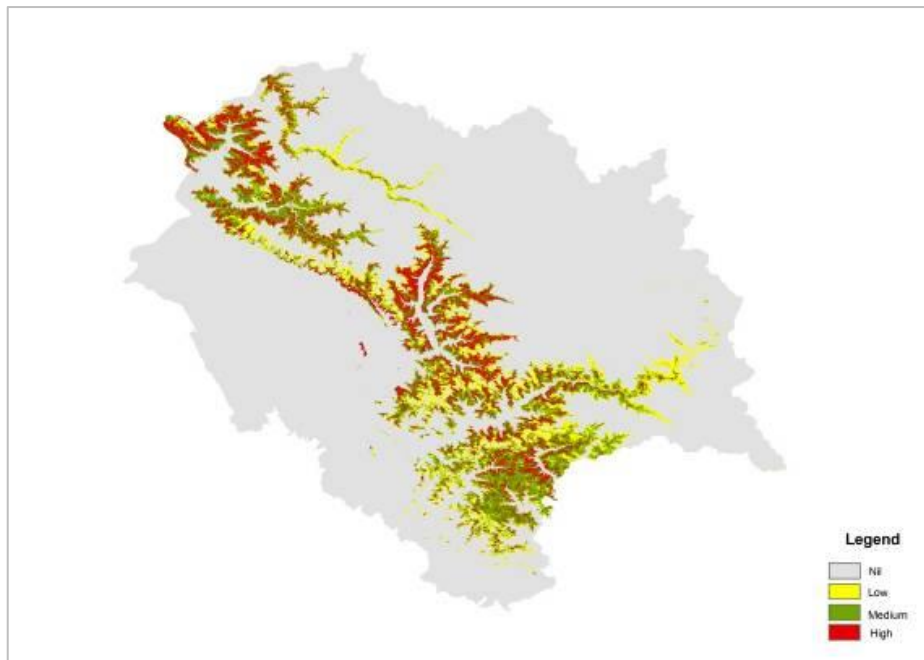
	MIN	MAX	MEAN	STD	MIN	MAX	MEAN	STD
Distance From Road in km					Distance From River in km			
Complete State	0	17.4	2.8	2.3	0	43.9	7.2	6.5
Potential habitat	0	11.2	2.5	2.0	0	29.2	5.5	5.1
Winter Habitat	0	11.2	2.2	2.2	0	24.1	5.4	5.0
Summer Habitat	0	8.6	2.1	1.7	0	24.6	5.5	4.9
Distance From Town in km					Distance From Night Light in km			
Complete State	0	81.1	18.8	13.7	0	123.2	31.6	25.5
Potential habitat	0	52.7	14.3	8.1	0	83.9	24.3	15.7
Winter Habitat	0	36.8	11.1	5.8	0	70.6	19.6	11.9
Summer Habitat	0	49.0	17.4	8.4	0	83.2	28.4	17.2
Human Foot Print in %					NDVI STD (-1 to +1)			
Entire State	0	85	28	12	0.01	0.41	0.13	0.07
Potential Habitat	10	84	29	8	0.02	0.41	0.20	0.06
Winter Habitat	15	84	31.05	8.93	0.02	0.37	0.18	0.05
Summer Habitat	11	62	28.45	6.75	0.02	0.39	0.23	0.06
NDVI Max (-1 to +1)					NDVI Min (-1 to +1)			
Entire State	-0.14	1.00	0.51	0.35	-0.20	0.74	0.09	0.21
Potential Habitat	0.00	1.00	0.73	0.19	-0.20	0.72	0.07	0.13
Winter Habitat	0.04	1.00	0.79	0.09	0.20	0.72	0.15	0.14
Summer Habitat	0.00	1.00	0.68	0.23	-0.20	0.59	0.00	0.07
Winter Rainfall in cm					Pre Monsoon Rain in cm			
Entire State	52	449	189	78	62	644	242	106
Potential Habitat	115	449	261	57	147	644	356	68
Winter Habitat	167	449	271	68	229	644	385	60
Summer Habitat	109	408	257	41	144	588	331	65
Monsoon Rainfall in cm					Post Monsoon Rain in cm			
Entire State	85	2184	619	473	19	128	57	21
Potential Habitat	119	1729	609	323	31	128	75	15
Winter Habitat	119	1867	257	257	42	128	82	12
Summer Habitat	119	1339	369	175	29	116	69	15
Winter Min Temp in °C					Winter Max Temp in °C			
Entire State	-29	7.00	-7.00	11.00	-10	28.00	10.00	10.00
Potential Habitat	-19	5.00	-4.00	5.00	-1.00	20.00	12.00	4.00
Winter Habitat	13	5.20	0.22	2.57	4.60	21.20	14.98	2.25
Summer Habitat	-17	-2.90	-7.00	3.28	0.40	18.00	9.19	2.53

Summer Temp Min in °C					Summer Temp Max in °C			
Entire State	-18	19.00	4.00	11.00	2.00	41.00	22.00	11.00
Potential Habitat	-7.6	15.00	6.40	4.20	10.0	31.00	22.00	3.00
Winter Habitat	15.8	33.20	24.96	2.32	1.50	15.40	9.99	2.41
Summer Habitat	-6.0	12.90	3.28	2.91	11.8	28.50	19.80	2.35
Monsoon Temp Max in °C					Monsoon Temp Min in °C			
Entire State	5.00	35.00	20.00	8.00	-10	24.0	9.0	10.00
Potential Habitat	12.0	27.00	21.00	2.00	-1.0	18.0	11.0	3.00
Winter Habitat	16.6	28.90	22.23	1.71	4.5	18.9	13.47	2.00
Summer Habitat	13.7	25.20	19.30	1.69	0.2	16.2	8.14	2.37

**Table 6.4:** Summary of different climatic and environmental variables used in habitat suitability modeling and analysis

### 6.3.4. Potential Habitat

Potential habitat defined by the rule-based model revealed that most part of the upper temperate region contains potential habitat for the species (Figure 6.2). Further categorization of the potential habitat predicted by the model indicated specific pattern in the relative suitability of the species habitat and this appear to correspond with available knowledge on the species distribution and abundance in the state.

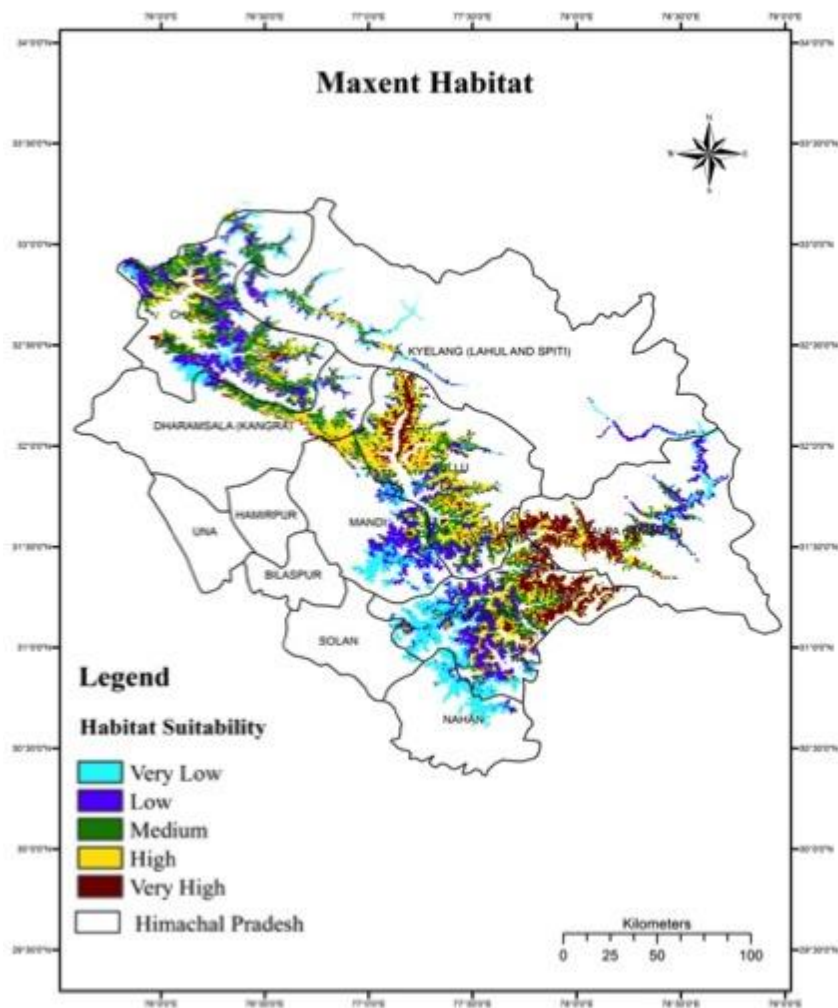


**Figure 6.2:** Potential habitat of Western tragopan as defined by rule-based model

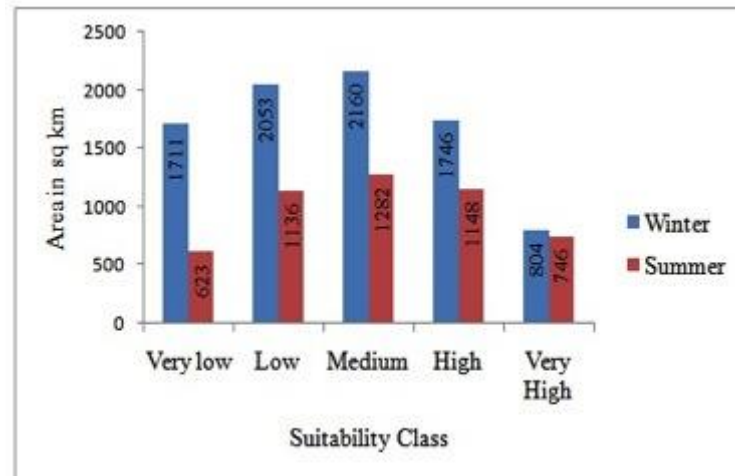
### 6.3.5. Predicted Distribution and Habitat Suitability

MaxEnt used 80 out of 99 input locations for training and 19 locations for testing/validation and 10080 background points for the model building. With 500 iterations, AUC of training and test datasets were 0.91 and 0.82 respectively. The maps generated using MaxEnt was classified the areas in the elevation range of 1800-3800m asl in the entire state based on different levels of suitability. The suitability was characterized as a range from very low suitability to very high suitability (Figure 6.3). The potential areas were then classified as summer and winter (Figure 6.4) habitats based on the elevation range of the species occurrence. The output of the model was finally used to classified the state into five classes of suitability, i.e. very low suitability, low suitability, medium suitability, high suitability and very high suitability (Figure 6.5). MaxEnt model calculated contribution of each variable (Table 6.5) in suitability prediction and also plotted response curves for all the variables (Appendix-V). The DEM showed a highest contribution of 31.7% and lowest contribution of monsoon temperature of 0.02%. Three other variables showed contribution more than 10% viz. NDVI SD (17.8%), Winter Precipitation (16.6%), and NDVI Range (11.3%).

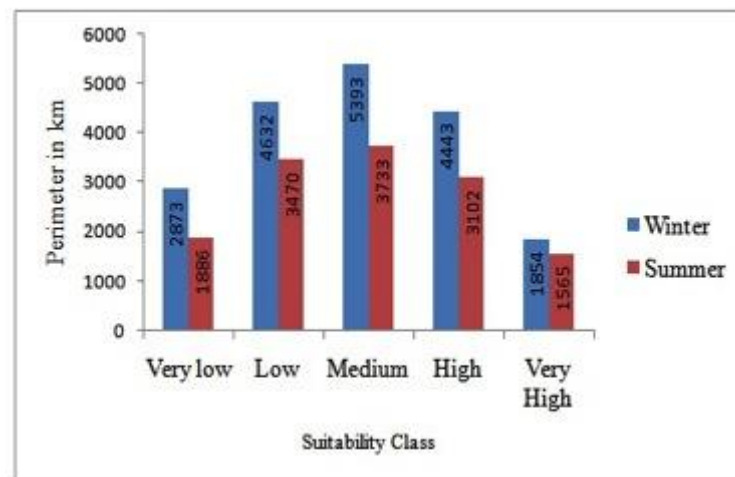
Areas and perimeter under different classes of suitability were calculated. The details of the area, perimeter and width of the potential habitat under various suitability categories are provided in Table 6.6. Interestingly, three parameters of the potential habitat did not significantly differ across seasons (area:  $U=3.000$ ,  $N1=5$ ,  $N2=5$ ,  $p$  (exact) = 0.056; perimeter:  $U=7.000$ ,  $N1=5$ ,  $N2=5$ ,  $p$  (exact) = 0.310; width:  $U= 3.000$ ,  $N1=5$ ,  $N2=5$ ,  $p$  (exact) = 0.056). Final suitability map revealed existence of available habitat for Western tragopan in the districts of Shimla, Kinnaur, Mandi, Kullu, Dharamsala, Chamba and Lahul & Spiti. Area and percentage of total area in different districts under high and very high suitability class was also calculated. Kullu, Shimla and Kinnaur districts were found to have substantial summer and winter habitats. Chamba and Dharamsala were predicted to have substantial winter habitats, while Lahul Spiti to have summer (Table 6.7). However, former districts showed less summer habitats and the latter showed less winter habitats. The obtained patterns appear to relate to the field conditions as to why substantial populations of Western tragopan population in areas around Beas and Sutlej in Himachal Pradesh. Also, it was possible to detect that the habitats are fragmented and proportion of summer habitat is lower than the winter habitat, thus the typical areas required for the species are restricted.



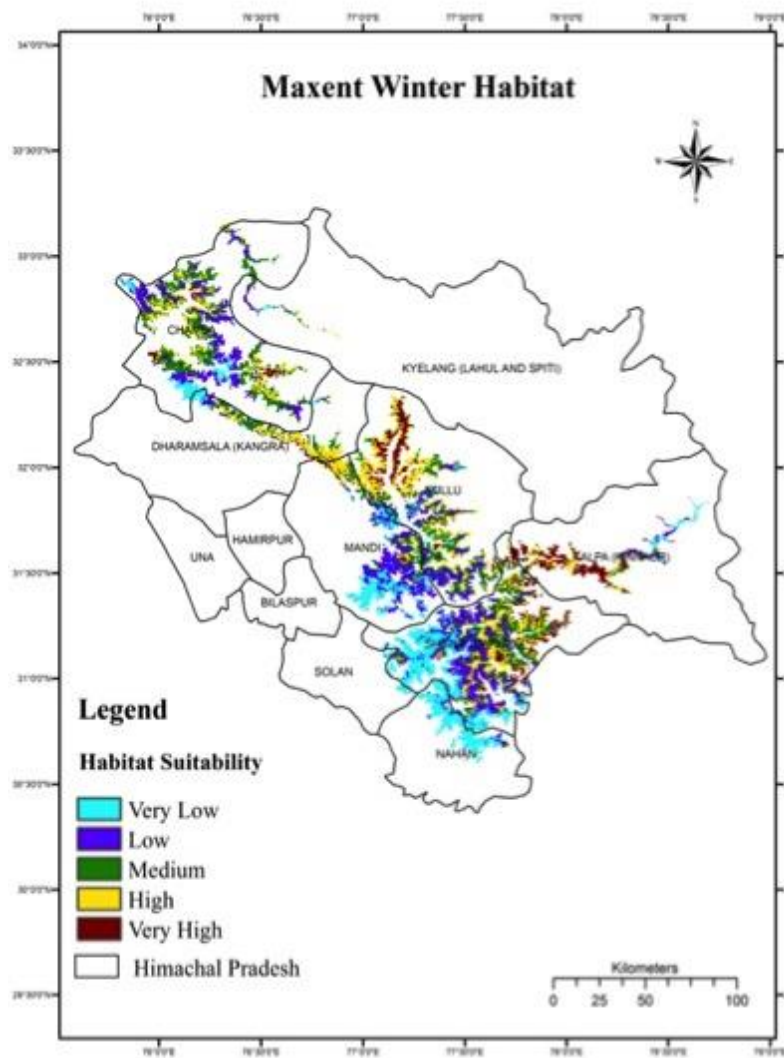
(a)



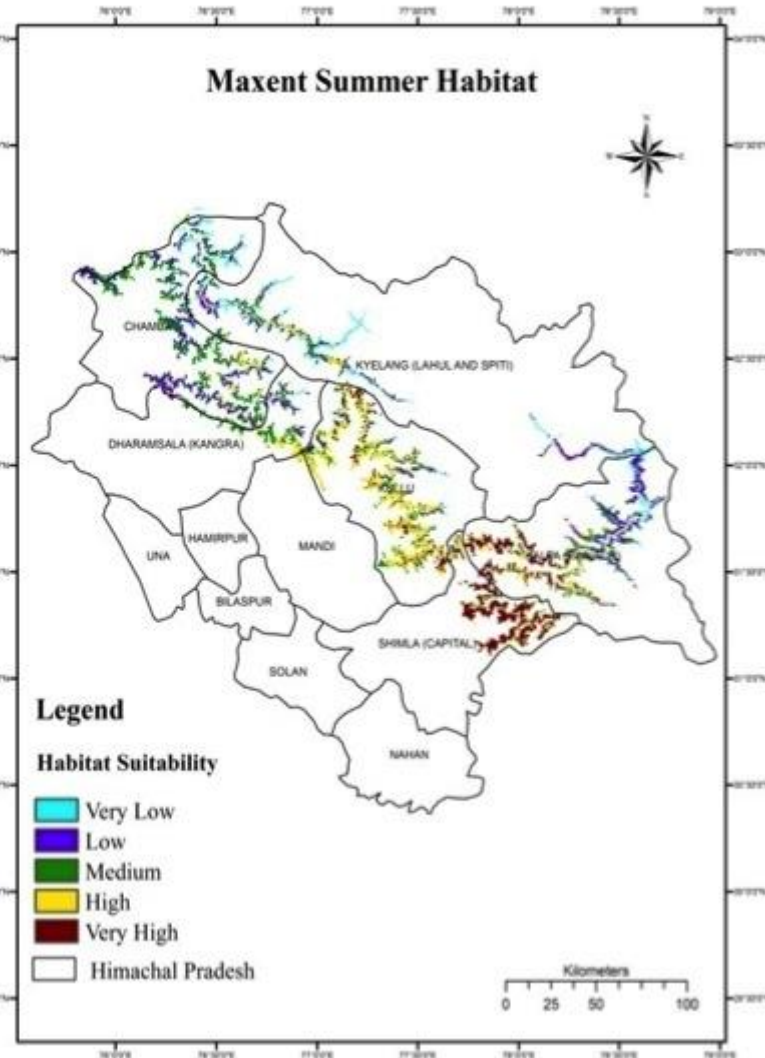
(b)



**Figure 6.3:** a. MaxEnt habitat suitability map for Western tragopan in Himachal Pradesh; b. Graphical representation of area and perimeter under different suitability classes

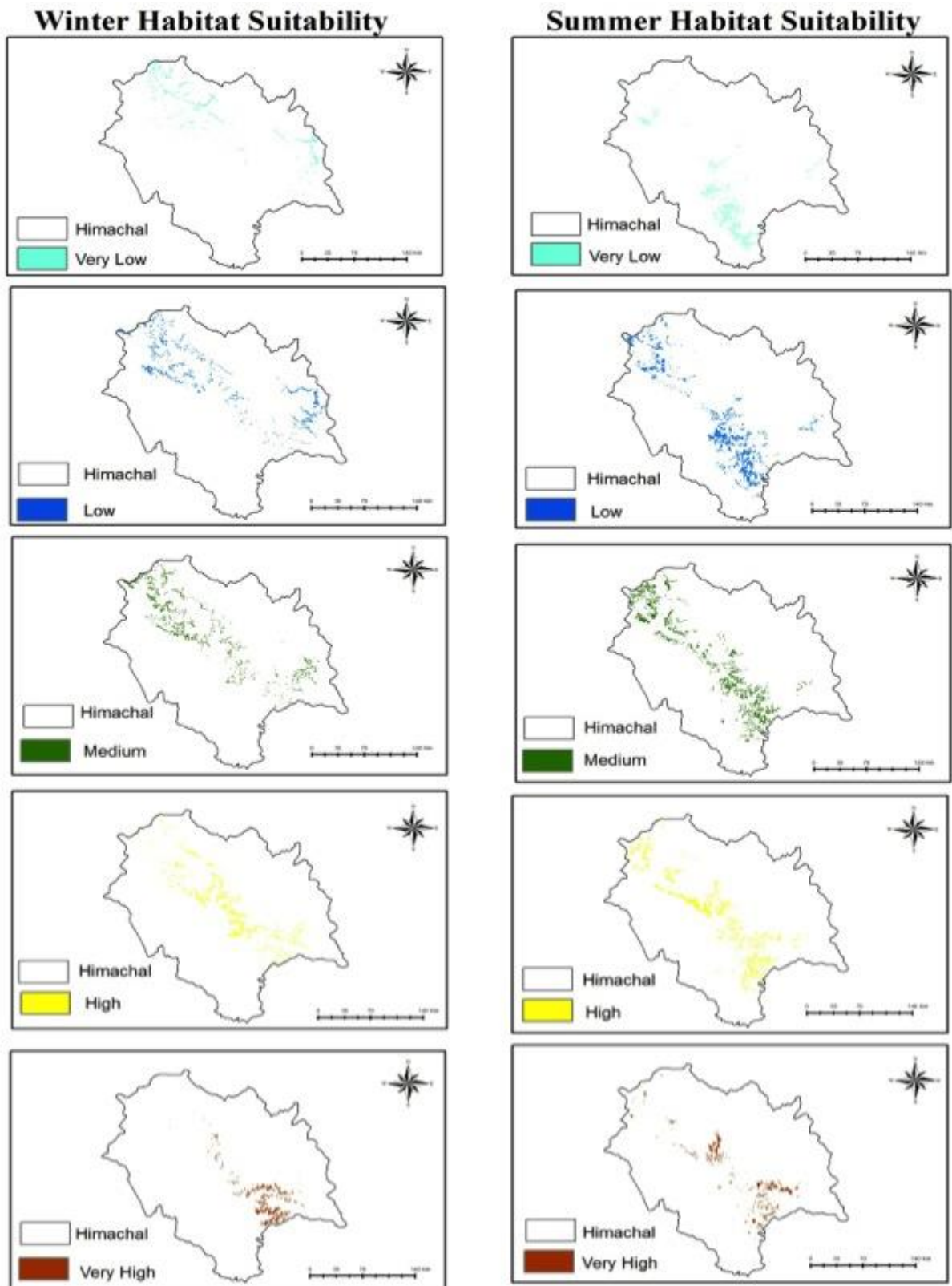


(a)



(b)

**Figure 6.4:** a. MaxEnt suitability map for Summer Habitat; b. MaxEnt suitability map for Winter Habitat



**Figure 6.5:** Comparative representation of summer (right panel) and winter (left panel) habitat suitability obtained from MaxEnt Analysis

Suitability Class	Area in Sq.km		Perimeter in km		Thickness in km	
	Winter	Summer	Winter	Summer	Winter	Summer
Very low	1711	623	2873	1886	2.72	1.31
Low	2053	1136	4632	3470	1.85	1.31
Medium	2160	1282	5393	3733	1.85	1.31
High	1746	1148	4443	3102	1.49	1.49
Very High	804	746	1854	1565	1.85	1.85

**Table 6.5:** Geometry of different suitability class in summer habitat and winter habitat

District Name	Number of Cells (0.76 sq km/cell)		Predicted Habitat Area in KM		
	Summer habitat	Winter habitat	Summer habitat	Winter habitat	Total
Kullu	711	869	539(8.8 %)	660(10.8%)	6113
Shimla	609	672	461(8.3%)	510(9.1%)	5579
Kinnaur	480	406	364(7.3%)	308(6.2%)	4983
Lahul and Spiti	65	5	49(0.9%)	4(0.1%)	5513
Chamba	20	323	15(0.4%)	245(6.3%)	3881
Kangra	19	189	14(0.1%)	143(1.0%)	14456
Mandi	12	126	9(0.1%)	96(1.4%)	6885

**Table 6.6:** District wise area under summer and winter habitat in high and very high suitability class

Background Parameters	Contribution	Permutation Importance
DEM	31.7 %	27.7 %
NDVI SD	17.8 %	15.6 %
Winter Precipitation	16.6 %	1.9 %
NDVI Range	11.3 %	0.5 %
Winter Maximum Temperature	4.6 %	1.7 %
Winter Minimum Temperature	4.2 %	10 %
Post Monson Precipitation	2.7 %	4.3 %

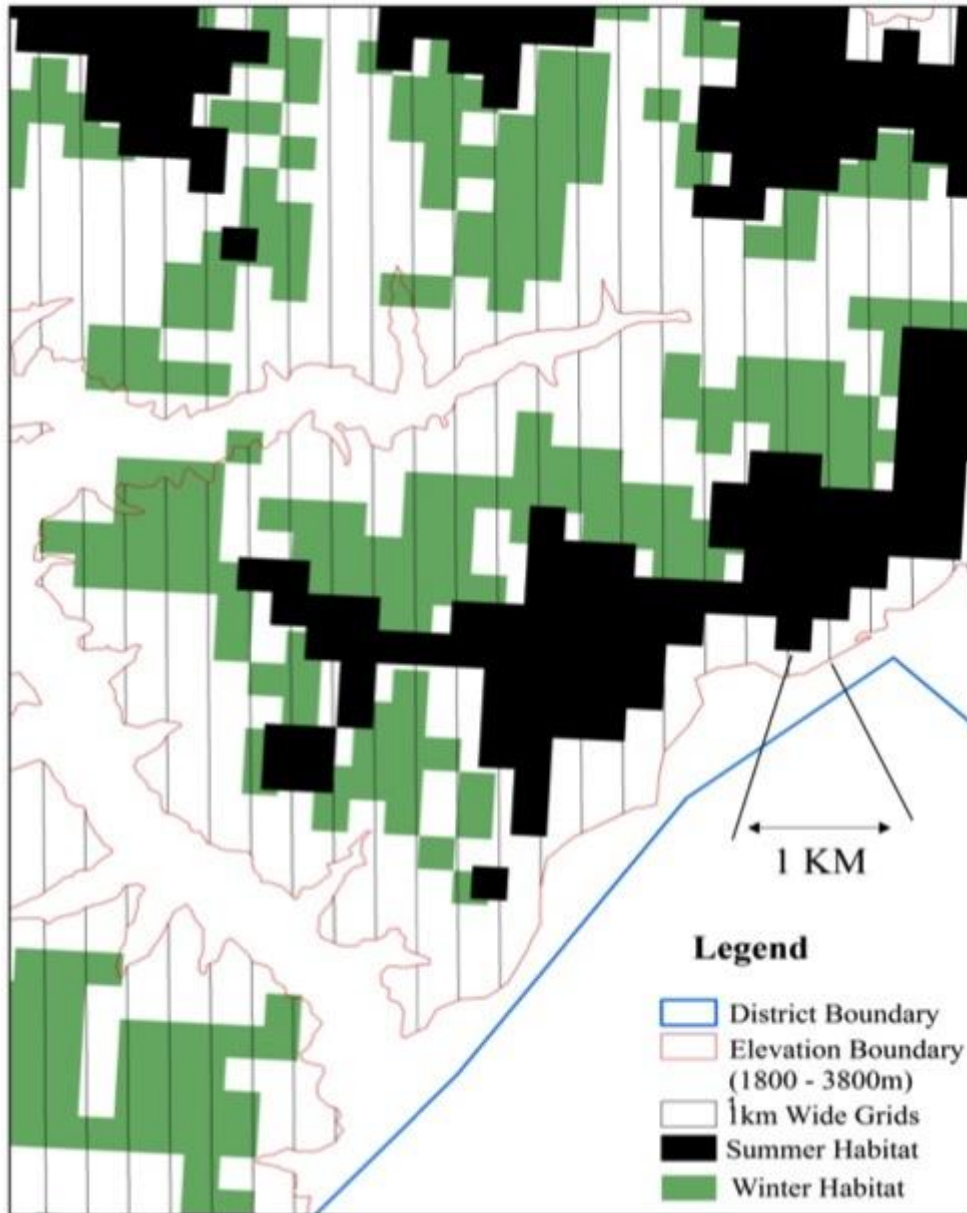
NDVI Maximum	1.9 %	6.1 %
Distance from Town	1.7 %	3.9 %
Monsoon Precipitation	1.4 %	6.4 %
NDVI Mean	1.3 %	2.3 %
Distance from town	1.2 %	13 %
Human foot print	1.1 %	1.2 %
Summer Maximum Temperature	0.9 %	0.8 %
Aspect	0.8 %	0.9 %
NDVI Minimum	0.3 %	0.5 %
Monsoon Maximum Temperature	0.1 %	0.1 %
Distance from river	0.1 %	0.6 %
Summer Minimum Temperature	0.1 %	0.2 %
Hill shade	0.03 %	0.3 %
Distance from night light	0.04 %	0.05 %
Monsoon Minimum Temperature	0.02 %	1.1 %

**Table 6.7:** Contribution and permutation importance of each variable in suitability prediction (MaxEnt)

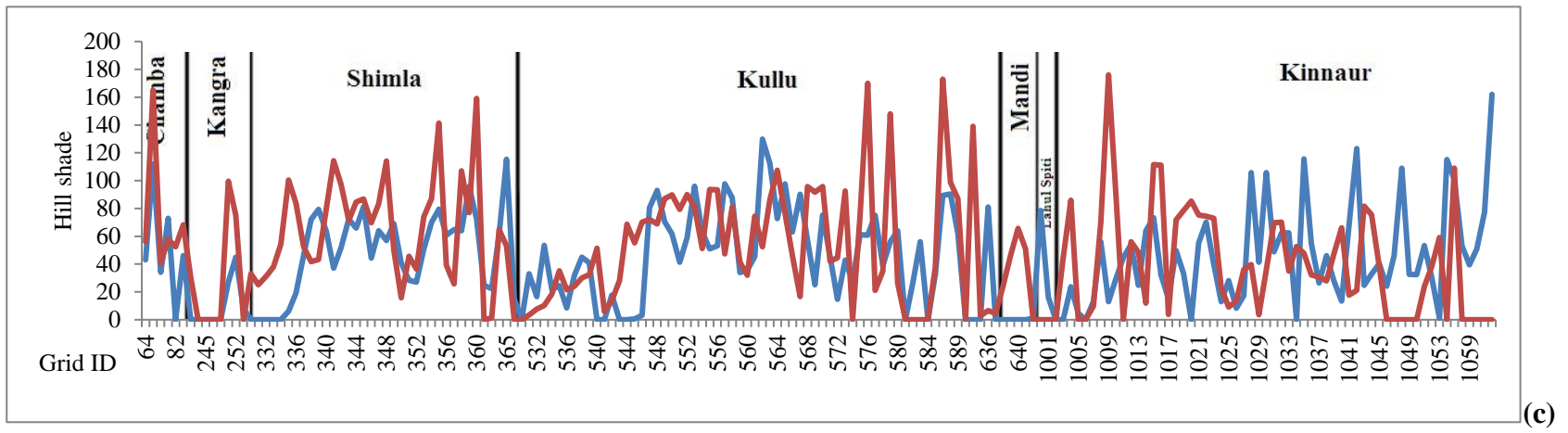
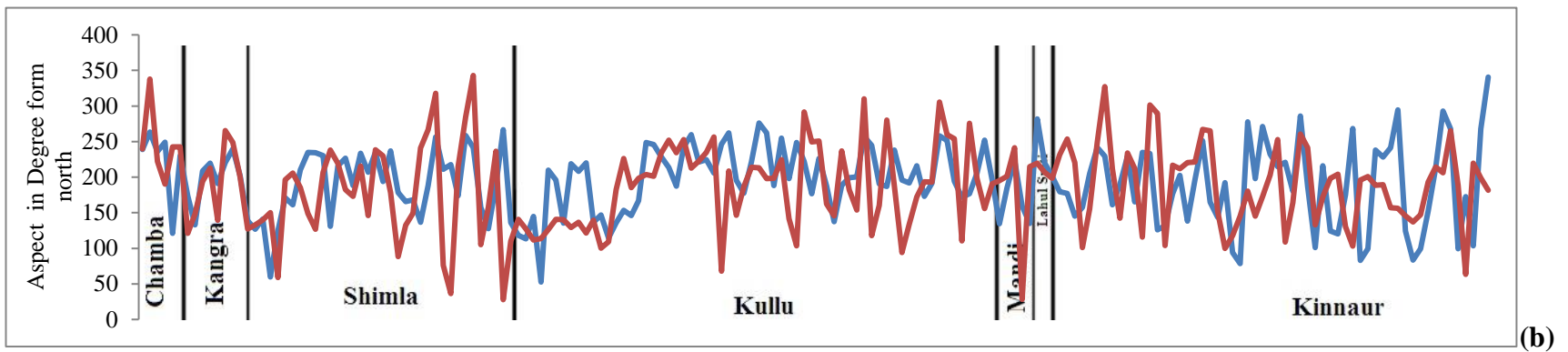
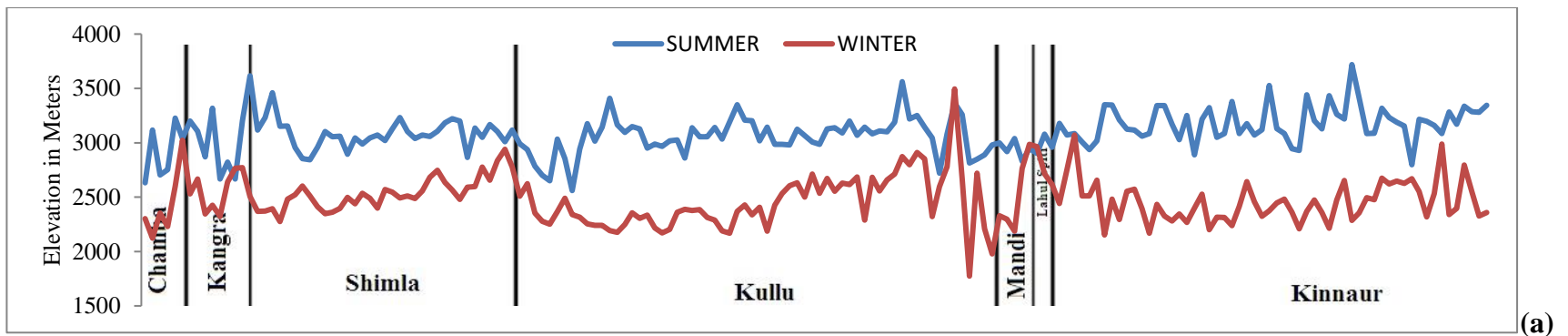
### 6.3.6. Potential Reintroduction/Reinforcement Sites

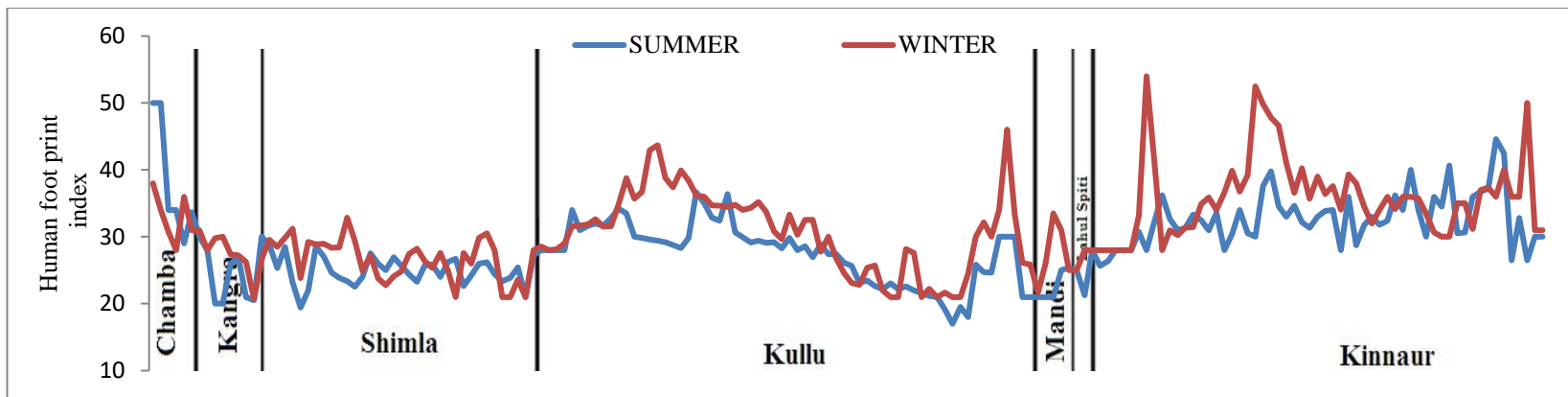
In order to identify potential reintroduction sites, areas under high and very high suitability were categorized into grids with 1 km width along the longitudinal axis for each district separately (Figure 6.6). It was apparent that the species showed consistence preference for habitat features across seasons and as expected, there were variations only in the altitude and temperature between the seasons (Figure 6.7). Such pattern is similar across the spatial units as reflected by the estimates for various districts where Western tragopan occupies. Of the 1101 grids representing high and very high potential habitat, 179 grids contained both summer and winter habitat together and thus, provided a first list of sites for reintroduction/reinforcement to be considered. However, many of these grids support good population of Western tragopan currently, while some sites such as Manali WLS and Churdhar WLS have lost Western tragopan in the recent years, while parts of Rupi Bhaba WLS have reduced population status. These sites

are initially proposed for reintroduction and reinforcement purposes. Further to identification of these sites, details for most promising sites were obtained so that the candidate populations of Western tragopan, either from captivity or wild, could be considered for reintroduction and reinforcement in these sites. The details of the grids and their corresponding location within the state are provided in Appendix-IV.

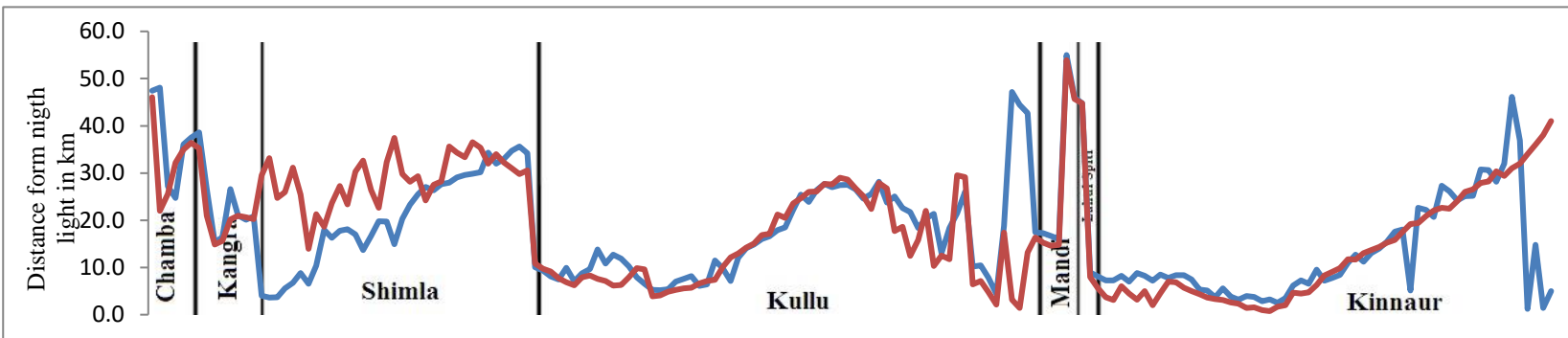


**Figure 6.6:** Map indication placement of grids within the suitable habitats

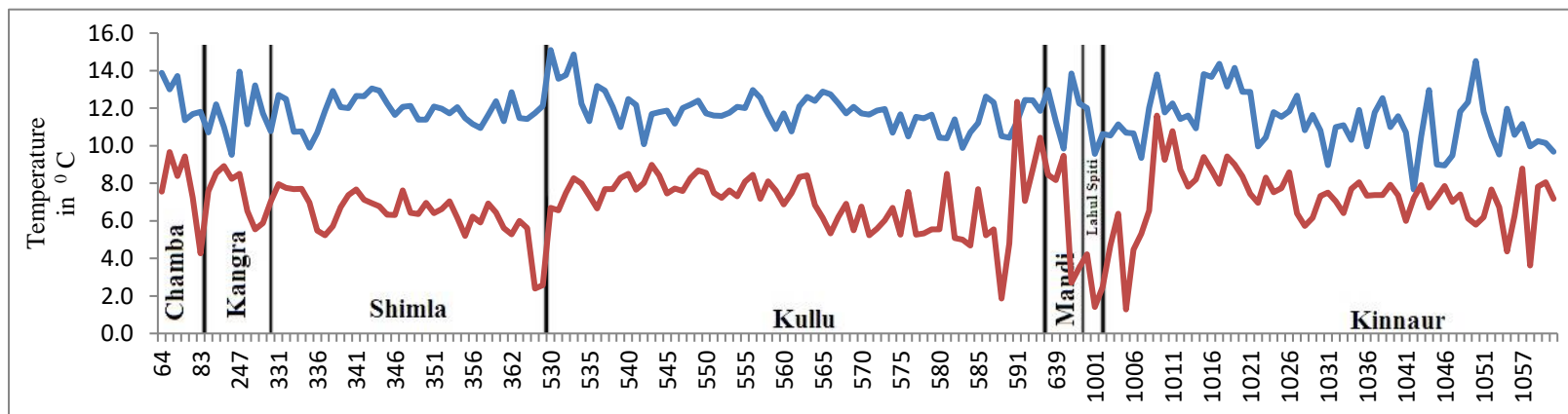




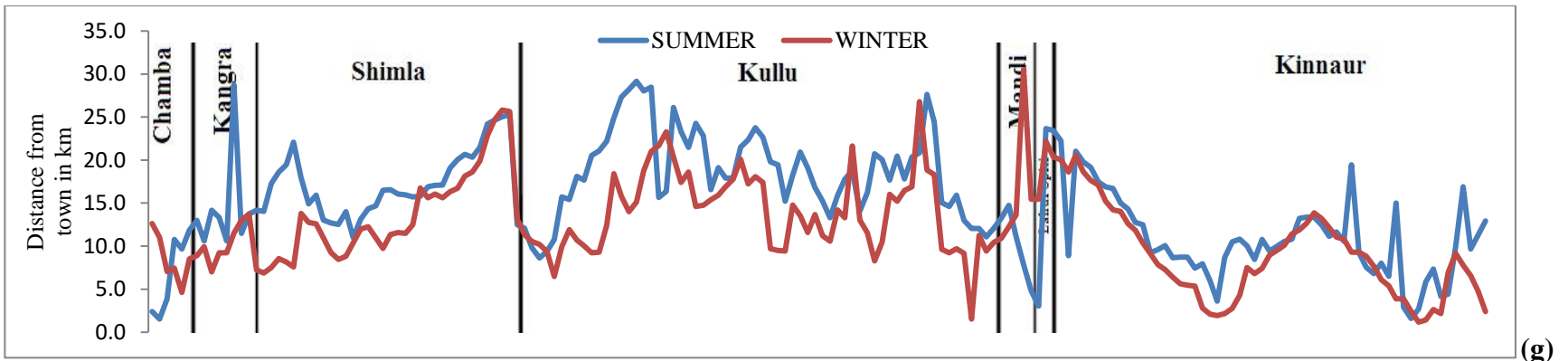
(d)



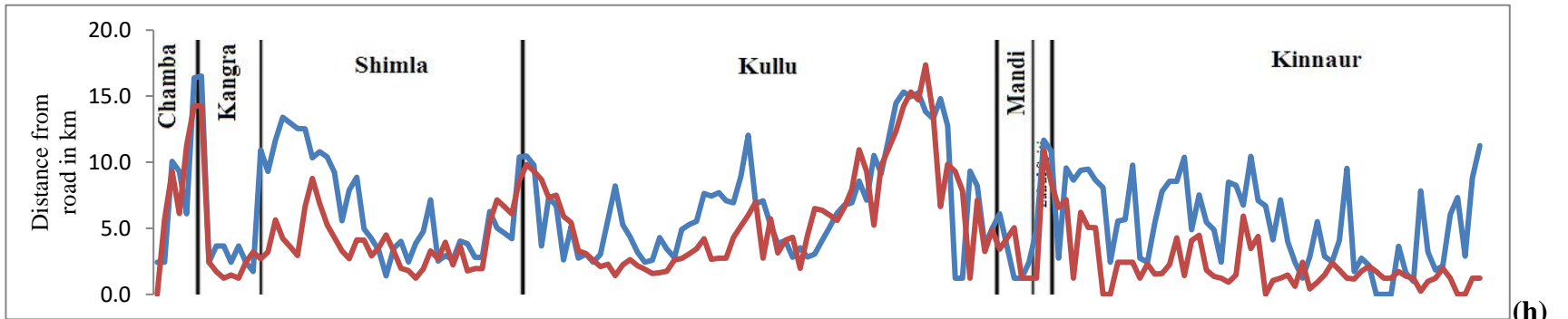
(e)



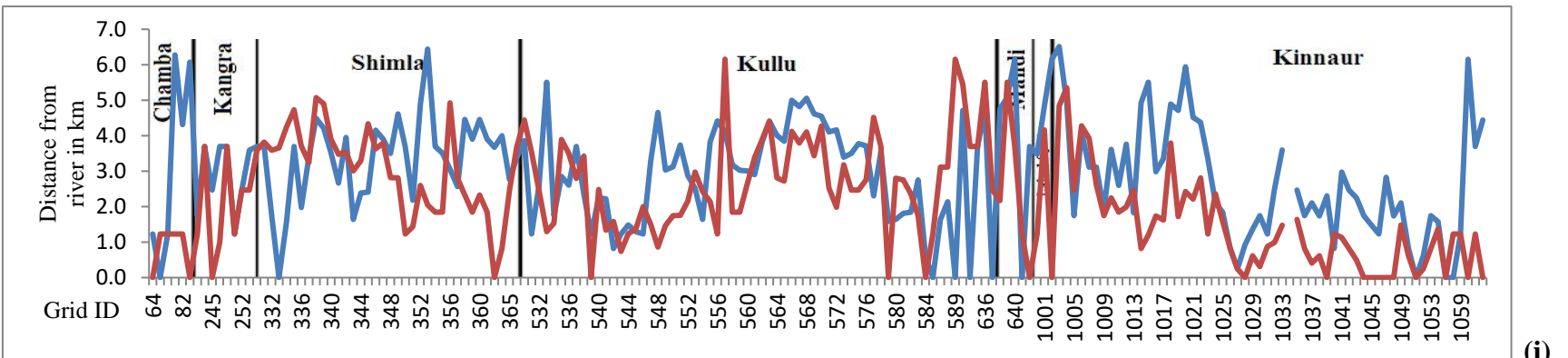
(f)



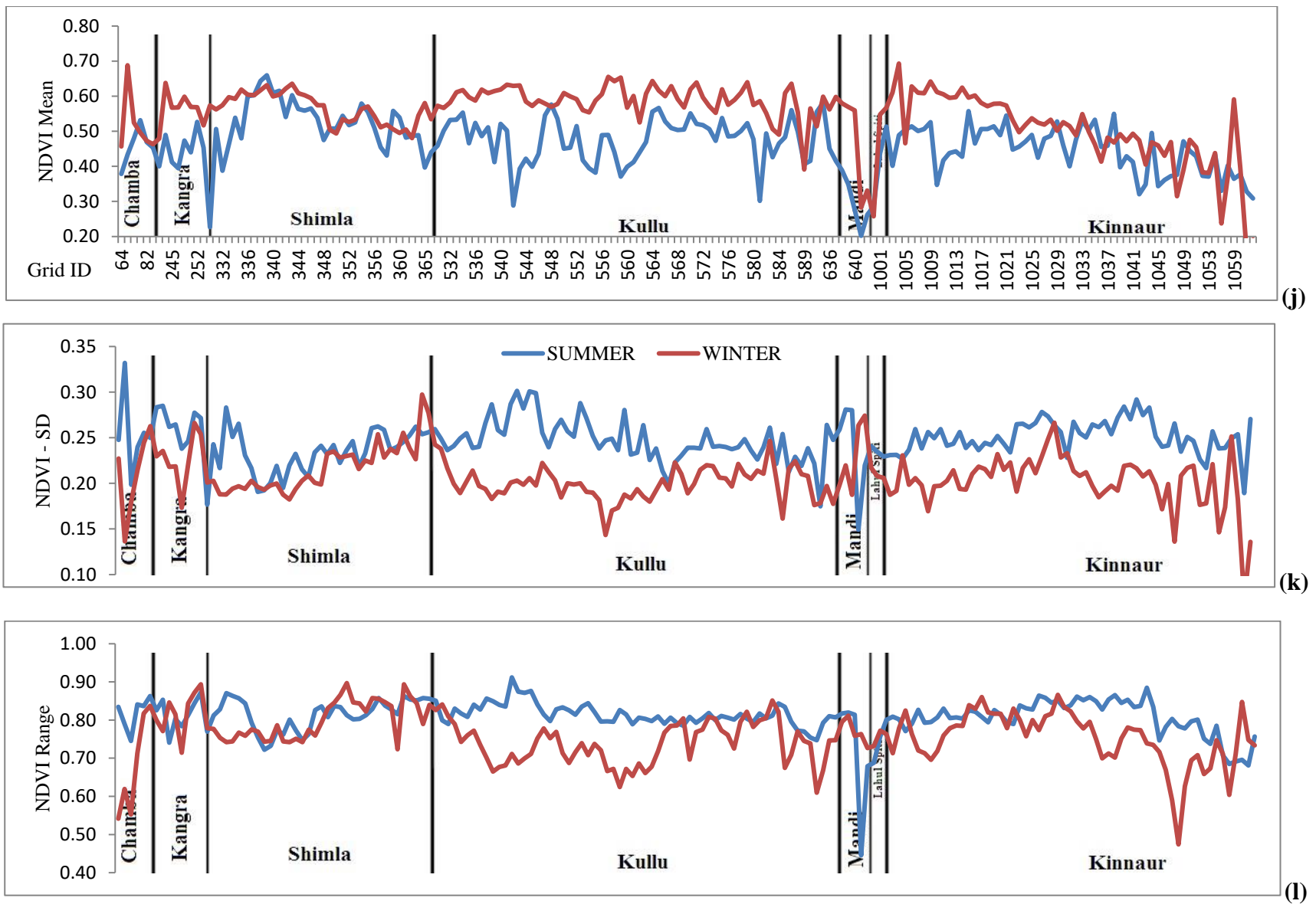
(g)



(h)



(i)



**Figure 6.7:** Grid wise variability in habitat parameters across summer and winter in different districts

### **(1) Manali Wildlife Sanctuary**

Manali Wildlife Sanctuary was declared as a sanctuary on 26 February 1954, under the Punjab Birds and Wild Animals Protection Act of 1933. The area of the Sanctuary is about 31.8 sq. km. and comprises of two Beats: Manalgarh (18.47 sq. km.) and Bangdwari (13.28 sq. km.) separated by Manalsu, a tributary to River Beas. The sanctuary starts about two kilometer from the Manali and is surrounded by the territorial beats of Manali, Goshal and Shalin. After the field survey was done, a secondary questionnaire survey was carried out in the villages adjoining the territorial beats adjacent to the Manali Wildlife Sanctuary. Information was gathered from forest department about number of household from each village going to the forest regularly.

Of the total number household depending on the forest fully or partially for their livelihood, 10% was surveyed. A total was 27 respondents were asked about the sighting details for Western tragopan. Majority of 18 person confirmed of not seeing Western tragopan in wild and seven of them confirmed sighting of Western tragopan in Manali Sanctuary as well as in adjacent territorial beats. Most of them reported sighting the bird 35-40 years back while two people confirmed the presence of the bird as recent as 25 years back in the territorial beat. However, a recent sighting of bird around 12 - 15 years back was also reported but the respondent was not certain about identification. There has been no confirmed record of Western tragopan ever since.

The survey as well as the secondary survey results confirmed the absence of Western tragopan from the area, although the species inhabited the area. The habitat of the Bangdwari, the beat surveyed, was found to be very suitable for the bird in terms of terrain condition, vegetation type, minimal disturbance and water sources and this may be considered for reintroduction, in addition to other sites Manali. It emerged that Manali WLS would be an ideal site in terms of logistics and the ecological requirements and therefore, it may be placed on priority list for reintroduction/reinforcement purpose. The interior of the sanctuary, though undisturbed, shows increasing sign of disturbance nearer to the boundary. Ecotourism is also allowed inside the sanctuary. So, if the area is considered as one of the reintroduction sites for the captive bred birds, management needs to take strict measures regarding mitigating the human pressure to minimize the disturbance inside the protected area.

### **(2) Churdhar Wildlife Sanctuary**

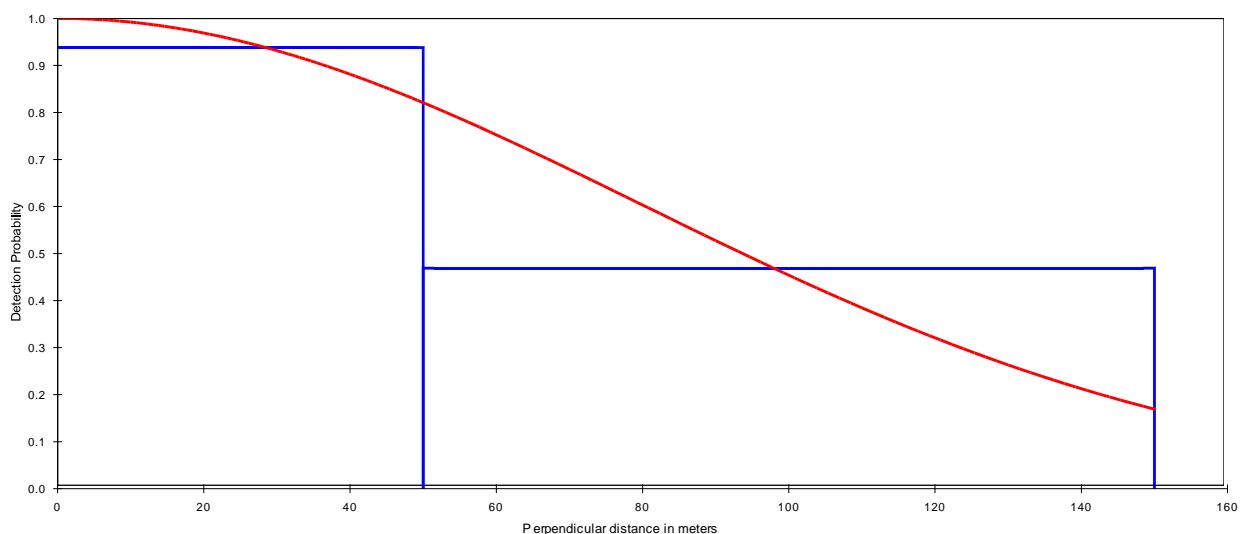
Churdhar Wildlife Sanctuary is named after Churdhar peak, the highest peak in the outer Himalayas. It was declared as a sanctuary on 1985. The area of the sanctuary is about 66 sq km. The altitude of the area ranges from 2000 to 3650m and cover Mixed Coniferous, Oak and Deodar forest and alpine pastures covering the higher altitudes. Churdhar Wildlife Sanctuary was selected to be a survey site based on the historical presence records. Though rule based model showed a considerable percent area of the sanctuary to be suitable as for Western tragopan, the MaxEnt model gave a very low probability (30-50%) of Western tragopan in the sanctuary. The reason for low probability predicted by MaxEnt is due to the proximity to localities and increased human disturbance in the area. However, a survey conducted by WWF in April 2010 based on early morning call count method confirmed absence of tragopans from the area which was validated by the forest guards during interaction session during training program.

### (3) Rupi Beat (Rupi Bhaba WLS)

Rupi Bhaba Wildlife sanctuary lies on the left bank of River Satluj in the Kinnaur district of Himachal Pradesh. Covering an area of an estimated 354.14 sq. km., it was declared a sanctuary in June 1982. It consists of ten beats viz. Rupi, Bara Khamba, Chhota Khamba, Dubbling under Rupi Wildlife Range, and Salaring, Nathpa, Kandhar, Katgaon, Yangpa and Sangko under Katgaon Wildlife Sanctuary. The Rupi beat under Rupi range is the outermost beat of the Rupi Bhaba WLS. With an estimated area of 39.21 sq km., Rupi had hosted a good population of Western tragopan in recent past. The model run also showed a good probability of presence of Western tragopan in the beat. However, growing number of human settlements inside the protected area boundary and their increasing dependence on forest resources for their livelihood has caused a drastic decline in the population of birds in this area. A survey in 2010 by Ramesh and Jayapal (2010) failed to record any evidence of the bird in wild, although it was recorded to be present in the past. Though sighting of a single male bird had been recorded last year, interaction with locals and forest guard hints at absence or a vestigial remnant of a once good population of the birds in this area. Therefore, this site may also be candidate for reintroduction/reinforcement of Western tragopan.

#### 6.3.7. Population Estimate

Of the surveyed beats, 67% of the wildlife beats and 33% of the territorial beats registered species presence, with MaxEnt model predicting over 50% probability of birds' presence in these beats. Data from six wildlife beats which recorded presence of the birds were taken into account while calculating the density as we had both trail walk as well as call count data from these beats. A binomial model was run in DISTANCE 6.0 with a detection range of 0-150 m keeping the cut-point at 50m as the detection probability was observed to decrease after 50m (Figure 6.8), given the shrub density in the preferred habitats. The density of the birds was calculated individually from trail walks (DISTANCE 6.0) using a Half- Cosine model and Call stations with 500 m as the radius using the formula  $(3.14 * 0.5^2 / n)$ ; where n is the number of calling birds recorded from a calling station).



**Figure 6.8:** Detection probability for the count based on binomial model

The density obtained from call stations were doubled as only male calling birds were taken into account to calculate the density but the density obtained by trail walk was kept constant as both

male and female sightings were incorporated to get the density (Table 6.8). The averaged density was then multiplied with the area available (in sq. km) in territorial and wildlife divisions as predicted by MaxEnt and the product was further multiplied by 0.67 and 0.33 for Wildlife beats and territorial beats respectively to account for variation in the occupancy pattern (Table 6.9). Based on these calculations, the total population of Western tragopan was estimated to be  $1418 \pm 831.3$  at a confidence interval of 95%, with an upper limit of around 2250 birds in the wild in Himachal Pradesh. In terms of population distribution in the six districts, ca. 520 birds appear to be in Kullu district, followed by ca. 380 birds in Chamba, ca. 180 birds in Shimla and ca. 100 birds in Kangra and Kinnaur. Kullu followed by Chamba and Shimla. Mandi is poorly represented with around 50 birds. The territorial beats of Kullu and Chamba showed to host a large population of Western tragopan, suggesting that significant population of Western tragopan still inhabit outside Protected Area network.

Strata	Male Density	Actual Density (Male Density*2 )	CV	Density (Trail Walk)	Density (AVG)	CV	Pooled CV	SE
High	0.99	1.98	0.05	1.67	1.83	0.58	0.58	1.06
Medium	0.42	0.85	0.50	0.00	0.42	0.00	0.50	0.21

**Table 6.8:** Estimated density of Western tragopan

	Wildlife Beat (High Suitability)	Territorial Beat (High Suitability)	Wildlife Beat (Medium Suitability)	Territorial Beat (Medium Suitability)	Overall Estimate for the State
Area Available (km <sup>2</sup> )	240	935	584	2816	1418
Occupancy Probability	0.67	0.33	0.67	0.33	
Estimated Area Occupied	161	309	391	929	
Density	1.8	1.8	0.4	0.4	
Estimated Number of Birds	293.6	563.4	166.1	394.6	

**Table 6.9:** Estimated population of Western tragopan in Himachal Pradesh

#### 6.4. Discussion

Predicting the ecological niche and potential habitat distribution of a given organism is one of the central domains of ecological and biogeographical research (Qiao et al., 2012). MaxEnt is a recently introduced modeling technique, achieving high predictive accuracy and enjoying several additional attractive properties (Phillips et al. 2006). This study used presence only locations is supported by some of the published discussion, which suggests presence only data in some sense release us from the problems of unreliable absence records (Jiménez-Valverde et al., 2008). As described in “A statistical explanation of MaxEnt for Ecologists”, species

distribution models estimate the relationship between species records at sites and the environmental and/or spatial characteristics of those sites (Cordellier and Pfenninger 2009, Franklin 2010, Hu et al. 2010, Peterson et al. 2006). The selection of variables at two spatial scales (a) landscape parameters and (b) habitat parameters (Wilson et al. 2011) including climatic, environmental and geographic that influence species directly or indirectly were used for distribution mapping as base environmental layers (Pearson et al. 2007). Variables such as elevation, aspect, vegetation (NDVI mean, NDVI SD, and NDVI range), distance from water sources, human foot print and other human disturbance indicators (distance from road, town and night light) were considered as habitat variables that influence the specie presence directly (Saqib et al. 2013). Although the landscape variables (temperature and precipitation) do not influence the species presence directly, these play a very important role in influencing the local variables such as vegetation cover.

In the model output, similar to (Lu et al. 2012), the AUC of 0.91 for training and AUC of 0.73 for test datasets with low standard deviation of 0.05 suggest that model performed well. Accordingly, the maps obtained from MaxEnt showed the availability of ca. 4000-km<sup>2</sup> suitable habitat in the state. The visual interpretations of each suitability class separately give some qualitative evidence of fragmented habitat and restricted summer habitats. Response curves obtained from the MaxEnt modeling for variables such as elevation, aspect, hillshed, human foot prints, and distance from road and monsoon and winter precipitation were found to be very crucial for presence of species. As indicated by Saqib et. al. (2013), human population had both positive and negative impact on the land-cover (Saqib et al. 2013), which was also evident from the response curves obtained in this study. DEM (one of geographic variable) was found to have the highest gain (contribution of DEM) when used in isolation as found in other studies (Moreno et al. 2011), clearly suggesting that elevation contains the most useful information by itself. Next to the DEM, NDVI-SD (Standard Deviation of NDVI) showed higher contribution and this was greater than NDVI-Mean, suggesting that Western tragopan prefers consistent ground cover and mosaic habitats regardless of seasons. Winter precipitation (i.e. snow fall at higher altitudes) also showed high contribution, perhaps relating to that the species responds to snow cover quickly and tend to prefer low snow cover as found by field studies on the species (Ramesh 2003).

As a part of the strategies to counter the risks of biodiversity loss, reintroduction schemes are becoming more and more common world-wide (Carroll et al. 2003, Sarrazin and Barbault 1996). Reintroduction programs will only be effective if the ecological requirements of a species or local population are well understood (Breitenmoser 1998). The output of models indicated probabilities of presence ranging from 0 and 1 (Moreno et al. 2011) which was further classified in to five suitability classes; very low to very high suitability classes. From this, the areas under high (0.6 to 0.8) and very high (0.8 to 1) classes of suitability was characterized for identification of potential reintroduction sites. This idea of characterization of habitat for identifying the reintroduction sites was driven from study of “ecological requirements of reintroduced species and the implications for release policy: the case of the bearded vulture” (Hirzel et al. 2004), where analysis of relationships between two GIS data sets: the distribution of vulture sightings and a set of environmental descriptors was performed.

The development and implementation of a population supplementation and restoration plan for any endangered species should involve an understanding of the species' habitat requirements prior to the release of any captive bred individuals (Wilson et al. 2011). In species restoration program, release of species required a greater understanding of the landscape and habitat niche (Seddon et. al., 2007), which requires characterization of landscape. For the characterization of entire landscape, a grid-wise assessment of spatial variability across the seasonal habitat provides the information about availability or non-availability of both summer and winter habitat together. The availability of both habitats together in same grid considered as suitable site for potential release of birds. The overlapping trends of most of variables were indicating the availability of summer and winter habitat together in same grid, which is frequently found in Shimla, Kinnaur and Kullu district but rarely found in Chamba, Mandi, Kalpa and Lahul Spiti districts. While these maps and grids offered the way forward for identification of sites reintroduction, the project outcome clearly established three priority sites for reintroduction on the basis of field surveys, species-habitat models and questionnaire survey and these are, Manali WLS, Churdhar and Rupi. Regardless of availability of captive populations, these sites should be considered for reintroduction / reinforcement even from other wild populations that are found in the territorial forest divisions. However, in order to take the logical next step of the conservation-breeding program of Western tragopan, it will be ideal to begin with few founder individuals from the captive facility for experimental release and reintroduction in Manali Wildlife Sanctuary.

In terms of population status, studies and reports have indicated that constant monitoring of Western tragopan and reduced disturbance during their breeding season can increase the density of bird significantly just in a decade (Miller et. al. 2008). Recently the census conducted in GHNP ascertained the bird density to be around 6.5 birds / sq. km., which is a significant increase from 1.5-2 birds/ sq. km. in 2003 (Ramesh, 2003). Thus, with an area of at least 4000 km<sup>2</sup> spread across the territorial and wildlife divisions and with effective management inputs including regular monitoring, the state has the potential to hold over 4000 birds in wild and will remain key to recovery of the species population in the world. Enhanced conservation inputs in their natural habitats and successful conservation-breeding program yielding consistent recruitments with natural behavior patterns will significantly facilitate such futuristic option.

### 7.1. Introduction

Re-introduction of captive-bred individuals from the captive population of Western tragopan is foreseen as one of the future species conservation strategies. The current stock at Sarahan is small consisting of around 30 individuals. Once the population attains the target size as proposed in the conservation-breeding plan (Appendix-II), experimental reintroductions and restocking efforts can be planned.

So far, no information on reintroduction efforts for Galliformes in India is available. However, the broad concepts are outlined in the guidelines prepared by the IUCN (2009). As a general strategy, reintroductions are generally carried out at sites where the species was historically present. In addition to this, detailed field studies to ascertain the status of the species in the wild and the need for reintroduction, identification of release sites and the assessment of the reasons for their extinction at the proposed sites and their mitigation have to be integrated into the reintroduction plan. One of the preliminary decisions to be made, as part of a re-introduction effort is the initial number of individuals required to be released. This is further dependent on the size of the captive stock and the number of individuals available for harvest/release.

In order to assist the decision concerning the initial population size to be released, a population viability analysis was performed. Population Viability Analysis (PVA) is often employed to estimate future population sizes and predict risk of extinctions. A PVA model uses actual life-history parameters to project the population characteristics over a specified time scale using stochastic computer simulations (Lacy 1993). PVA allows modeling of populations' persistence under various scenarios (described in the later sections), thus allowing to comparatively exploring and evaluating the effectiveness of different management options.

The accuracy of predictions obtained through PVA is questioned by various authors (Beissinger and Westphal 1998, Ellner et al. 2002). The authors emphasize on the importance of high-quality input data and its influence on the ability of the computer simulation to accurately predict future vital rates. Brook et. al. (2000) point out two important assumptions of PVA; (1) high quality data and sufficient sample sizes to ensure that estimates of mean and variance are accurate, and (2) the mean and deviation of the vital rates as obtained from the historical data either remains stationary in future or can be accurately predicted. As no information on the population-level parameters of Western tragopan under natural conditions is available, life-history information obtained through analysis of breeding records and population trends of the captive population of Western tragopan were used. In order to predict the survival probability of a reintroduced population of Western tragopan, and to understand the factors influencing their long-term persistence, a population viability analysis was carried out.

### 7.2. Vortex Model

The program VORTEX version 10.0.7.1 was used to conduct the analysis and project the probability of reintroduced populations' persistence over 50 years. A series of simulations on the viability of the population under different scenarios were carried out. The different scenarios

varied with reference to the initial population sizes and subsequent supplementations. Five hundred iterations were performed for each of the scenarios (Table 7.1). The extinction was defined at the point when individuals of only one sex remained. All the input parameter values for the analysis were obtained from the captive population of the species through analysis of breeding records during 2005-2013. Population data was available for years 1990-2013. The input parameters for the analysis are indicated in Table 7.2.

Scenario	Description
<b>Pop-12</b>	Initial population size of 12 individuals
<b>Pop-12_supplement</b>	Initial population size of 12 individuals with supplementation 1♂: 1♀/2 years for the first 20 years
<b>Pop-20</b>	Initial population size of 20 individuals without any supplementation
<b>Pop-20_supplement</b>	Initial population size of 20 individuals, supplementation of 1♂: 1♀/2 years for the first 20 years
<b>Pop-12_supplement_all years</b>	Initial population size of 12 individuals with supplementation 1♂: 1♀/2 years for the first 20 years

**Table 7.1:** Details of scenarios

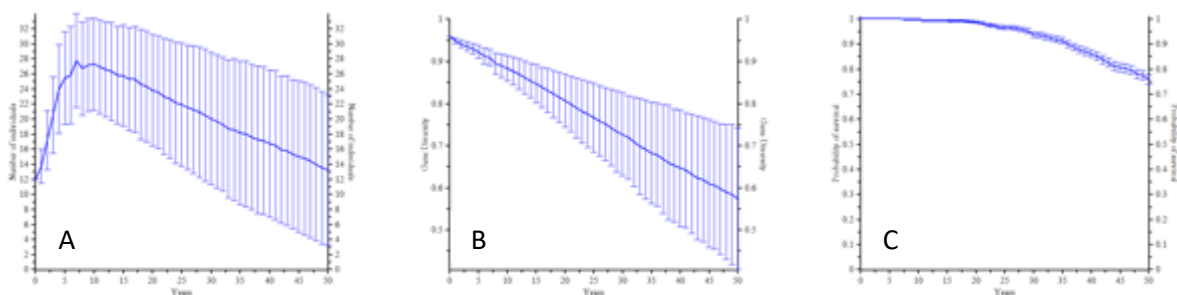
Parameter	Value
<b>Mating system</b>	Long-term polygyny
<b>Age at first reproduction (females)</b>	2 years
<b>Age at first reproduction (males)</b>	2 years
<b>Lifespan</b>	8 years
<b>Maximum number of broods per year</b>	1
<b>Maximum number of offspring per brood</b>	3
<b>Sex ratio at birth</b>	1♂: 1♀
<b>Maximum age of female reproduction</b>	8 years
<b>Maximum age of male reproduction</b>	8 years
<b>Density dependent reproduction</b>	Yes
a. % breeding at low density P(0)	a. 50
b. % breeding at carrying capacity P(K)	b. 25
c. Allee parameter, A	c. 1
d. Steepness parameter, B	d. 2
<b>SD in % breeding females due to EV</b>	10
<b>Number of offspring per females per brood</b>	2.5 (standard deviation=1)
<b>Mortality rates (♂ and ♀)</b>	
a. Age 0-1	a. 30% (SD due to EV= 5)
b. Age 1-2	b. 5% (SD due to EV= 3)
c. Adults	c. 5% (SD due to EV=3)
<b>Catastrophes (Number of catastrophes)</b>	2
<b>Disease [Catastrophe 1]</b>	Local
- Frequency	- 0.25
- Severity	- Fecundity reduced by 30% and survival reduced by 15%
<b>Natural calamity [Catastrophe 2]</b>	Local
- Frequency	- 0.01
- Severity	- Frequency reduced by 20% and survival by 20%

**Table 7.2:** Summary of input parameters for the population viability analysis of the Western tragopan

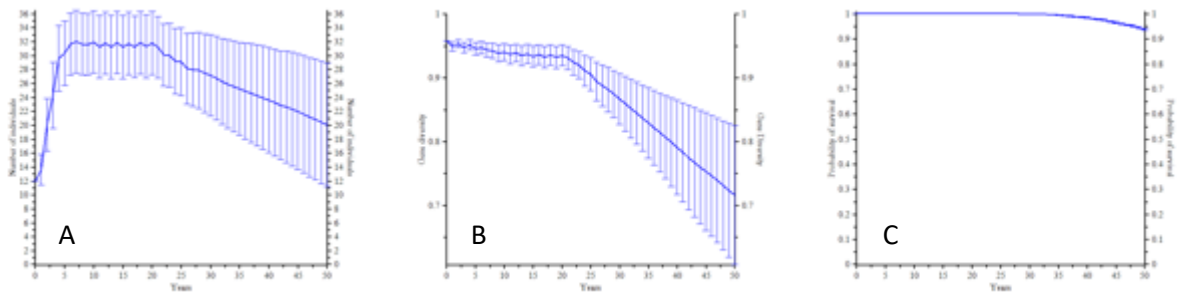
### 7.3. Selection of Scenarios

The number individuals in scenarios were selected based the nature of the social groups which is usually considered for reintroduction purposes. Anecdotal evidence from literature suggests that Western tragopan have been observed as family groups during post-breeding season and winter until the onset of the following breeding season. As per the IUCN guidelines and specific case of the Grey partridge reintroduction by Buner (2008), releasing birds as family groups is generally recommended for Galliformes. This is specifically known to be effective through empirical validations (Buner Francis and Schaub 2008, Buner Francis D et al. 2011). In this context, PVA modeling was performed with an initial population of 12 individuals (3 family groups, with each group consisting of one adult male and female and two offspring) and 20 individuals (5 family groups, with each group consisting of one adult male and female and two offspring). The results indicated that reintroduced populations without any supplementations were at a higher risk of extinction than those, which were supplemented regularly. The population size, gene diversity and probability of survival of reintroduced populations under various scenarios described above are represented in Figure 7.1 – 7.5.

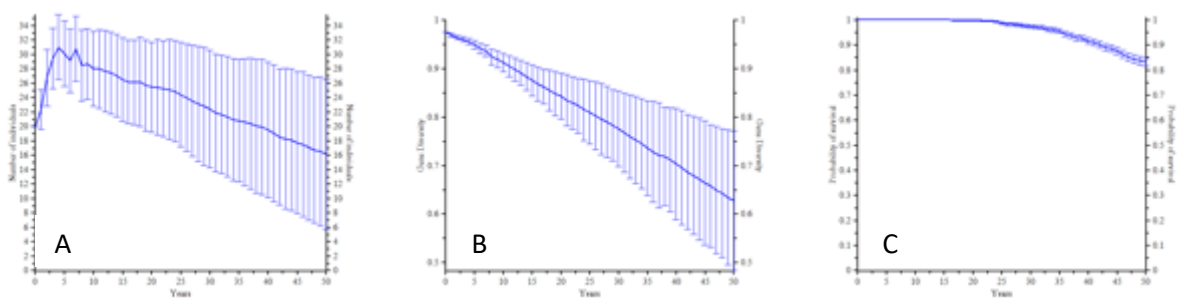
The extinction probability for reintroduced population with 20 and 12 individuals was 20% and 30% respectively at the end of 50 years. Without supplementation, the populations showed a decline in the size after an initial growth phase, with the final population size ranging between 12-15 individuals. The gene diversity also decreased over time in both the cases. With supplementation of new individuals for the first 20 years, the extinction probabilities of populations reduced to 5% (initial size=12 individuals) and 8% (initial size=20 individuals) and with its size slightly higher or maintained at the initial population size at the end of 50 years. However, the gene diversity levels remained low in both the cases at around 70%. The scenario with regular supplementation of individuals, i.e. Scenario-V, resulted in a population size of around 30 individuals and a gene diversity of higher than 85%. The extinction probability in this case was zero.



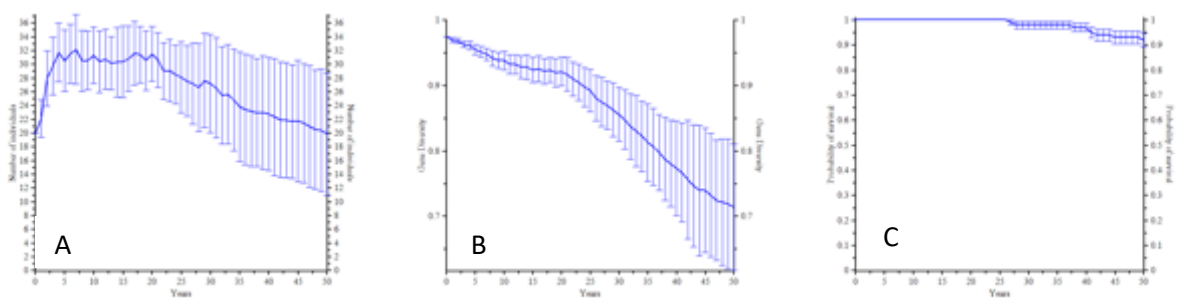
**Figure 7.1:** Scenario-I – Initial population=12; K=35 (EV=5). A. Number of individuals over the years (0 – 35 scale). B. Gene diversity over the years (0 – 1 scale). C. Probability of survival over the years (0 – 1 scale). Error bars indicate SD. X-axis is years: 0 – 50 scale.



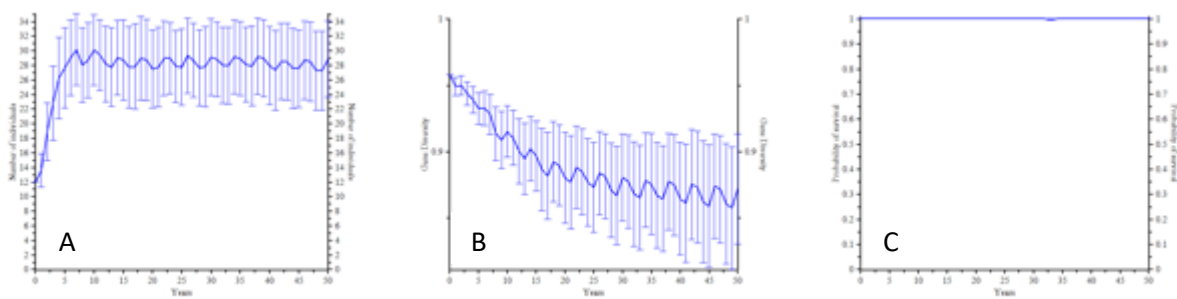
**Figure 7.2:** Scenario-II – Initial population=12; K=35 (EV=5); supplement (T<sub>2-20</sub>): 1♂: 1♀/2 years. A. Number of individuals over the years (0 – 35 scale). B. Gene diversity over the years (0 – 1 scale). C. Probability of survival over the years (0 – 1 scale). Error bars indicate SD. X-axis is years: 0 – 50 scale.



**Figure 7.3:** Scenario-III – Initial population=20; K=35 (EV=5). A. Number of individuals over the years (0 – 35 scale). B. Gene diversity over the years (0 – 1 scale). C. Probability of survival over the years (0 – 1 scale). Error bars indicate SD. X-axis is years: 0 – 50 scale.



**Figure 7.4:** Scenario-IV – Initial population=20; K=35 (EV=5); supplement (T<sub>2-20</sub>): 1♂: 1♀/2 years. A. Number of individuals over the years (0 – 35 scale). B. Gene diversity over the years (0 – 1 scale). C. Probability of survival over the years (0 – 1 scale). Error bars indicate SD. X-axis is years: 0 – 50 scale.



**Figure 7.5:** Scenario-V – Initial population=12; K=35 (EV=5); supplement (T<sub>2-50</sub>): 1♂: 1♀/4 years. A. Number of individuals over the years (0 – 35 scale). B. Gene diversity over the years (0

– 1 scale). C. Probability of survival over the years (0 – 1 scale). Error bars indicate SD. X-axis is years: 0 – 50 scale.

#### 7.4. Perspectives for Reintroduction

The captive population is small and is in the growing phase as concluded from the data analysis (Chapter-4). On the other hand, increased habitat disturbances are rapidly affecting wild populations of Western tragopan causing their decline across their distributional range. Supplementation of wild populations or re-establishment of locally extinct populations might a necessary strategy for species conservation following amelioration of the factors originally causing decline or extinctions. Although *ex-situ* conservation is expensive and less preferred means of achieving recovery of threatened species, several species that were extinct in the wild like California condor (*Gymnogyps californianus*), Spix's macaw (*Cyanopsitta spixii*) and Przewalski's horse (*Equus ferus przewalskii*) were re-established exclusively by the use of individuals propagated in captivity.

In the case of Western tragopan, there is a lack of empirical validation for the need of reintroduction, at least as urgent requirement, except in cases where local extinction needs to be addressed. However, there is always a necessity to maintain captive populations with focus on establishing technical know-how and facilities for conservation breeding, so that it can serve as a reserve and model population for meeting *in-situ* requirements in the future as and when emerges. In this specific case, knowhow on the management of captive population targeted at eventual release into the wild has been generated and with the growth of the captive population, experimental reintroduction in certain areas can be attempted. The population viability analysis carried out with reference to options available for reintroduction can be applied during such exercises and flexibility may be considered if other wild population in less secure environment (territorial forest divisions with high anthropogenic disturbances) can be sourced. The key points obtained through population viability analysis are:

(a) The population is a growing phase as described in Chapter 4 and hence reintroduction efforts have to be planned much carefully than an ideal situation. As achieving maximal growth in a short span of time is the priority, reintroduction should be planned after the population size in captivity reached the target size.

(b) If reintroductions are to be carried out, key aspects to be given consideration are:

(i) A reintroduction plan needs to be developed based on the results of the PVA and the priority sites that could be considered as outlined in Chapter 6.

(ii) If an experimental reintroduction is planned, a relatively large number of individuals have to be released, as low numbers are prone to extinctions at a faster rate (Buner Francis and Schaub 2008), except if it can be supplemented either from captivity or from other source populations in the wild. However, it may be possible to consider adaptive strategy if the captive breeding of Western tragopan could be achieved successfully with higher recruitments over the years with natural behavior as was accomplished in the last three breeding seasons. It is also suggested that some of the territorial forests where the species

population may be under anthropogenic pressure may be considered for sourcing populations for reintroduction.

(iii) The birds to be selected for release, at least in the initial phases, should be those descending from the most prolific lineages in captivity, exhibiting viable natural behaviours.

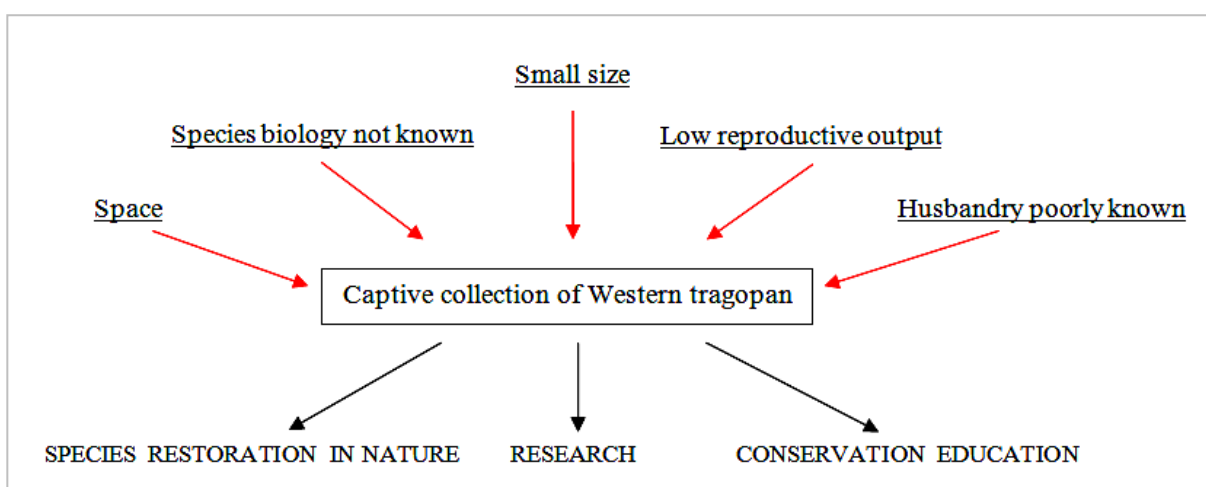
(iv) Post-release supplementation is necessary given the high level of disturbances in the habitat and therefore, release plan should have an integrated approach than release of just one founder population.

SYNTHESIS AND RECOMMENDATIONS

8.1. Synthesis

The integrated approach employed in this project attempted to establish linkage between *ex-situ* and *in-situ* conservation. The captive population is small and ever since the implementation of the science-based management regimes in 2011 as part of the collaborative project, significant growth has been achieved as seen from the conservation outcome in terms of population growth and display of natural behaviors. The science-based management regime introduced in the last three years has yielded exceptional results such that the population of 17 birds in 2011 has been almost doubled to 32 in 2014 in Sarahan pheasantry, with 20% annual average growth rate, against the decreasing growth rate registered during the preceding periods. Percentage of normal eggs during 2005-2011 was 47 (which is 131 of 280 eggs) and this increased to 58% (which is 117 of 201 eggs) following interventions. Significantly, the proportion of normal eggs versus abnormal eggs was consistently lower every year during previous regime, while the trend was reversed to higher number of normal eggs every year in 2012-2014. Also, no mortality of birds (adult or chicks) due to disease was recorded during the project period. During 2005-2011 (seven years), a total of 16 chicks were born, of which only five were mother-reared, while during 2012-2014 (three of this project period), 20 chicks were born, of which 18 are living and all area mother-reared. In the history of captive management of this species or its congener, considerable breeding success has been achieved without involvement of broody hens or incubators and this has significant implication for cost-effective management, enhanced suitability for maintaining the population as a reserve or model and for release in the wild. Therefore, the keeping system should be kept constant and improved as per requirement in order to expect similar trend. The requirements on the level of human resources are described in detail in Appendix-II.

Further, based on the results of the project, a detailed master plan specific to the Sarahan conservation-breeding centre is provided in Appendix-II. As part of the master plan, a short-term strategy is proposed to allow the population to attain a size corresponding to the existing zoo capacity (14 breeding pairs). Once the target size is achieved, the possibility of experimental reintroductions and/or splitting of the population into smaller sub-populations can be considered. The potential concerns and role of the captive population of Western tragopan is diagrammatically represented below;



As part of the ongoing project, most of these concerns were addressed and the outcomes of the project as outline in the original proposal are presented below, along with the necessary future inputs;

<b>Outcomes as envisioned in the original project proposal</b>	<b>Status of Accomplishment</b>	<b>Remarks</b>
A list of possible pre-release sites, reintroduction sites and potential new reintroduction sites	Completion (Chapter-7; Appendix IV)	<ul style="list-style-type: none"> <li>→ Pre-release sites are not viable; instead birds will be released in the wild directly.</li> <li>→ Three sites are readily available for release.</li> <li>→ List of sites, as grids have been provided.</li> </ul>
User-friendly data management protocol for record-keeping of captive birds	Completion (Chapter-3; Appendix-I)	<ul style="list-style-type: none"> <li>→ Studbook has been updated twice and needs to be updated regularly in the years to come.</li> <li>→ Behaviour monitoring should be considered as part of the record keeping system.</li> </ul>
Genetic and demographic profile of individuals birds	Partial Completion (Chapter-4)	<ul style="list-style-type: none"> <li>→ Demographic profile of the birds has been done. Additionally, life history traits and population trajectory have been analyzed and presented.</li> <li>→ Genetic profiling needs to be carried out. Blood sample could not be obtained.</li> </ul>
Identification of candidate birds for future conservation breeding and reintroduction.	Completion (Chapter 4; Appendix-II)	<ul style="list-style-type: none"> <li>→ Candidate birds have been identified and pairing options have also been worked out.</li> <li>→ Reintroduction plan including post-release monitoring strategy should be developed before release in the wild.</li> </ul>
Veterinary care, stress management and nutrition regime	Completion (Chapter-3 and 5)	<ul style="list-style-type: none"> <li>→ Basic health monitoring was done.</li> <li>→ Improved sanitation and hygiene practices. Suitable preventive and responsive measures were taken as and when required.</li> <li>→ Non-invasive monitoring of stress</li> </ul>

		and reproductive status needs to be initiated.
A detailed activity budget, vocalizations and breeding chronology	Completed (Chapter-5)	→ Further study should be commissioned to integrate individual profile with behavioral responses.
Population Viability Analysis for determining the size and composition of founder population, in captivity and wild	Completed (Chapter-8)	→ PVA should be undertaken at periodical interval to have realistic projection, since the demography is dynamic. → Once the meta-population has been identified in the field, spatially explicit PVA should be done to provide specific management inputs in the field.
Distribution and population assessment of wild populations of Western tragopan in selected localities (potential areas for reintroduction)	Completion (Chapter-6)	→ Distribution maps, along with various level of suitability has been done. → Population estimation has been done based on sample surveys in selected localities and integration of detection probability and habitat availability at various classes. → A detailed population estimation and monitoring strategy involving camera-traps and other sophisticated tools are required for local scale population estimation.
Increased breeding success and establishing required number of founder population for reintroduction or supplementation in the wild if need be	Completion (Chapter-3 and 4)	→ Management should strongly refer to the proposed keeping system in order to enhance population growth to enable reintroduction efforts.
Work towards development of Sarahan pheasantry as “Centre of Excellence” for conservation breeding of Western tragopan and training opportunities for biologists and managers	Partial Completion (Chapter-3; Appendix-II)	→ Technical know-how, capacity building and successful breeding plan have been accomplished. → Further infrastructure should be developed for housing the birds with large spaces for improving the knowledge base.

		→ There is a need for establishing training center with advance level of logistics and support system either at Sarahan, Shimla or Manali for creating opportunity for others to learn from the conservation-breeding program.
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The current population size is the highest recorded since its establishment nearly two decades ago. The reproductive output of the population has significantly increased with reduction in problems like mortality during egg laying and production of thin-shelled eggs. As mentioned above, the key achievement has been the expression of natural breeding behaviours and all the chicks born during the project period being naturally reared by tragopan hens. Considerable knowledge about the species biology and husbandry has been generated.

The in-situ component of the project focused on sample surveys for population estimation and Remote-sensing and GIS-based approaches to model species-habitat relationship. These efforts have placed the population estimate of the species to be around 1400 individuals in the state, with an upper limit of 2200 individuals. The results also revealed that substantial population of this species occur in areas outside the protected area network. The result has provide the best possible estimate of the population size and habitat status of Western tragopan in Himachal Pradesh based on the sampling framework, than the previously available estimates based on educated guess. The GIS database generated as part of the study has immense value in the habitat management of the species and for developing or updating management plans for various protected area in the state. The spatial modeling carried out using geographic data and habitat correlates of the sighting locations has yielded a list of possible sites, which could be considered for experimental reintroduction or population reinforcement. However, robust field surveys to evaluate the habitat parameters should be carried out prior to decision of reintroduction sites, specifically in line with the IUCN guidelines for reintroduction of Galliformes.

## 8.2. Recommendations

The project outcome clearly emphasizes the following points for successful conservation breeding and management of the Western tragopan in the state of Himachal Pradesh:

- a. Incorporation of science-based management guidelines/strict scientific supervision. It is required to establish a high-level of local competence at the breeding centre in order to ensure scientific management on a regular basis.
- b. Management of species referring to species ecology/behavior and husbandry design should be based on species-specific life history traits, as demonstrated during the project.
- c. There is a critical need to develop a comprehensive health monitoring and management plan to deal with immediate and long-term health issues and to ensure welfare and to enhance desirable reproductive outputs in the pheasantry.

- d. Target oriented inputs and measurable success indicators at short-term and long-term. Priority should be accorded to preparation of comprehensive reintroduction and post-release monitoring plan with a clear road map and accordingly, the future strategy should be followed.
- e. Experiment should be considered for housing groups of birds in larger enclosure during winter season to allow for mate-choices by themselves, as it is still unclear on the mating system of the species. There is a need to bring the pheasantry under remote surveillance and monitoring (e.g. CCTV) system for regular monitoring of the birds and related factors.
- f. Individual profiling of the population should be undertaken so as to develop a baseline for physiological stress and genetic linkages, as it will serve significant basis for maintaining right set of candidate animals in captivity and for release in the wild. It is also prudent to consider conservation genetic of the species population in the wild, so that founder improvement in the pheasantry could be sourced from appropriate populations to offset inbreeding and allele issues.
- g. Institutional mechanism needs to be developed to undertake population estimation based on occupancy and capture-recapture framework involving camera traps and monitoring should be planned every three years at state level, and every year at wildlife divisions. This would allow integration of *in-situ* and *ex-situ* management inputs and outputs.
- h. There is still gap in the species biology in the wild and with availability of modern technology including Wireless Sensor Networks, GPS telemetry and un-manned aerial vehicle (Drone), representative populations of this species needs to be studied intensively alongside the released population. In this context, release of birds in Manali WLS and wild population in Great Himalayan National Park provides ideal option in terms of the requirement, logistics and long-term viability of the conservation actions.
- i. Western tragopan is the State Bird of Himachal Pradesh. If the flagship value of the species has to be utilized for conservation goals, there is a need for facilitating Citizen Science and Community Participation by the local people, with potential for larger conservation outcomes and local ownership.

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## Appendix-I: Record Keeping System

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### INTRODUCTION

Record keeping must be an integral part of all zoological husbandry programs. Zoos and especially conservation breeding centres, like the one established for Western tragopan at Sarahan, require that a record of all the activities are maintained in a centralized database, which is easily accessible. The records which are maintained over the years can serve as an indispensable material and help in the planning of effective management regimes and for various purposes, like breeding of specific individuals, transfer of individuals to other facilities, effective health care and management of the species and also during reintroduction procedures. Therefore, record keeping forms an important baseline activity for the conservation breeding centre in Sarahan.

At Sarahan pheasantry, currently there is no centralized database existing to record the activities of the conservation breeding centre. As of now, the only record maintained consists of a live-stock inventory to record the total number of individuals at the pheasantry. No accurate records of health care management, general upkeep of the birds and individual animal history records exist. Hence, it is of utmost importance that a system is established soon which addresses this aspect of captive animal management. As a part of this collaborative research project, a studbook was recently published describing the population of Western tragopan and its demographics at the captive breeding centre in Sarahan. However, the need is a system where data is recorded on a routine and regular basis and consolidated regularly and finally, there is data flow between the institution managers for effective planning and management of the ongoing program. Western tragopan is currently kept under captive conditions only in two facilities worldwide viz. Sarahan pheasantry and Kufri Zoological Park, Shimla and this being such a critical conservation measure for saving the state bird, establishing a record keeping system is evident.

There are multiple levels of record keeping that are integral part of the captive management:

- a. **Inventory:** It is a listing all the animals currently being housed at the centre, acquisitions of new animals, births, deaths, and transfers of animals to other institutions. The inventory will also have the record of individual animal identity in terms of the local name and the tag number, which in this case would be the number on the leg-band of the

bird and the national studbook number. This is currently being maintained at Sarahan pheasantry.

- b. ***Animal history sheet***: This is a record of each individual animal/bird and the critical data related to the animal/bird like specimen identification, sex, parentage, age, source and provenance, disposition and other related data.
- c. ***Studbook***: A record of the population as a whole and the demographic structure of the population which is currently established and maintained by the Wildlife Institute of India.
- d. ***Daily observation report***: A record maintained through routine observations on specific details of individual animal/bird and consolidated at a later stage. This is the most valuable piece of information collected regularly which documents daily observations by the keepers and the managers and can be of great help in devising better management practices.
- e. ***Medical records***: A database to record regularly the healthcare practices followed at the breeding centre. It records all the information concerning the medications and supplements offered to individual birds.
- f. ***Diet chart***: A chart for reference at the centre for the routine preparation of diet the birds/animal.

Here, we present the first draft of documents and formats required for developing a basic record keeping regime at Sarahan pheasantry. Following are the instructions to fill the documents and how the information should flow between the officials involved in the management of the centre.

### **Instructions for filling Animal History Sheet, Medical Record and De-worming record**

1. An animal history sheet exists for each individual animal/bird. The animal history sheet of each individual animal/bird should be maintained in a separate file and should be updated regularly.
2. Established on: Date on which the animal history sheet was created for an individual.  
Enter month and year. **Example**: November 2012
3. Local ID: Local identity of the individual. **Example**: Moti, Sanju etc.
4. Sex: Sex of the individual
5. Studbook number: National studbook number (if any)

6. Identification
  - a. Type: Type of identification on the individual. **Example:** Metal leg ring
  - b. Number: Number on the tag. **Example:** 2256Q
  - c. Date: Date on which the band was applied on the individual
7. Date of acquisition: Date on which the animal was bought from wild or was born or was acquired from other zoo. Enter date, month and year.
8. Birth origin: Hatching origin. Wild-born or Captive-bred
9. Date of birth: Date on which hatching occurred. Write UNKNOWN for wild rescued birds. Enter date, month and year.
10. Pedigree
  - a. Sire: Enter Local ID and Identification number of the male parent
  - b. Dam: Enter Local ID and Identification number of the female parent
11. Breeding history: Enter an Yes or No
12. Death
  - a. Date: Date of death. Enter day, month and year
  - b. Mode of disposal: Details on how was carcass disposed. Bury/Incinerated etc.
13. Transaction
  - a. Date: Date on which animal was transferred to other zoo/facility
  - b. Location: Place to which the animal was transferred. Enter zoo name and location
14. Other notes and updates: The information mentioned below is to be entered here:
  - a. Breeding data: Egg laying, hatching, chicks etc.
  - b. Transfer: Transfer from one enclosure to another
  - c. Capture of birds for any reason
  - d. Interventions in terms of enrichment, changes in enclosures, pairing, etc
  - e. Other miscellaneous notes.
15. Treatment/Medical record
  - a. Date: Date on which the event occurred
  - b. Symptoms and diagnosis: The symptoms observed the keeper/guard/veterinarian which attracted attention and demanded treatment. Can be disease/injury/any other health condition

- c. Treatment: The medication administered to treat the bird as prescribed. Enter name of the drug administered and dosage administered.
- d. Notes: Other information related to the recovery of the animal, stop of treatment or any other related information.

#### 16. Supplementation and de-worming record

- a. Date: Date on which the fecal samples were collected and sent for examination
- b. Report and findings: Whether the report was positive or negative and, if positive, what were the endo-parasites reported
- c. Treatment regime: The de-worming medication used and dosage administered per bird
- d. Remarks: Information on the activity of the bird following the administration of the medication like diarrhea/limited activity or other observed information.

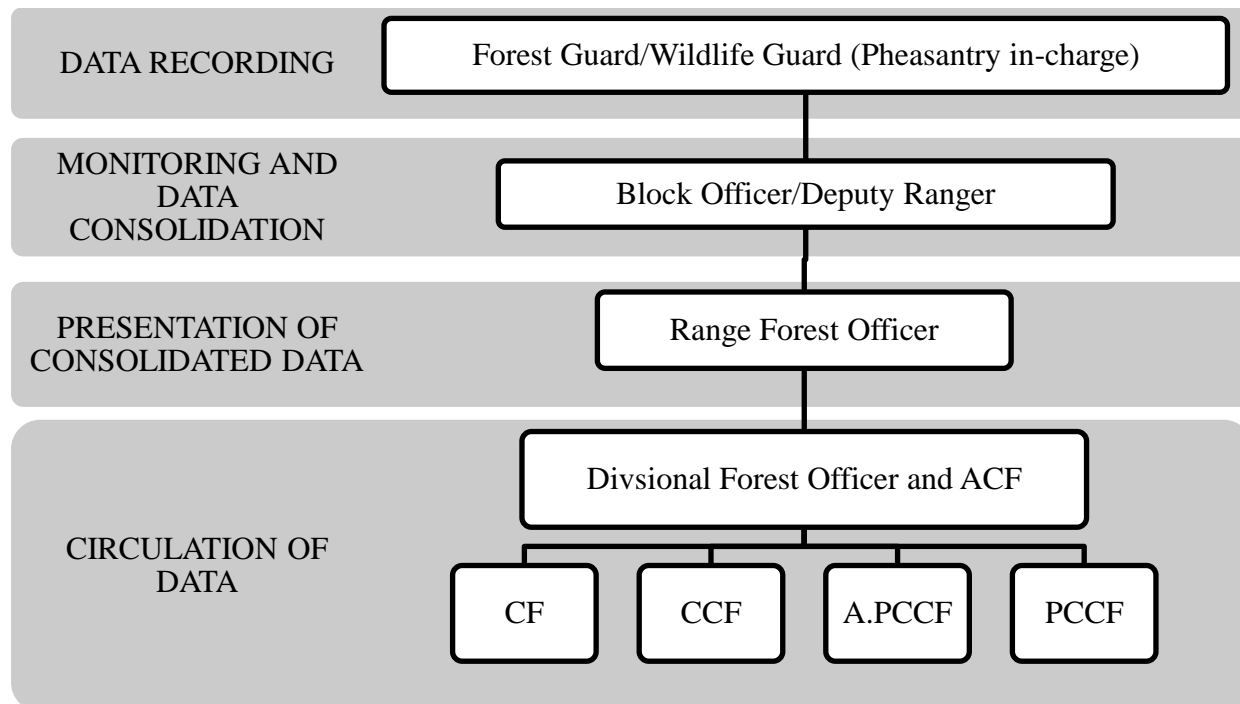
#### **Instructions for filling Daily Observation Report**

The daily report is self explanatory. The report is prepared everyday for each enclosure and filed. The birds are watched with reference to the observations indicated in the report and the appropriate boxes are checked. Additional information can be noted under the 'Notes'.

#### **Instructions for filling the Record of Breeding Activities**

This activities pertaining to breeding is recorded only during the breeding season, specifically for the months April-August. Recording information in this report is initiated when the first breeding calls from the males are observed and recorded in the daily observation report, and henceforth is maintained on everyday basis. The form is more or less self explanatory. The pairs are observed for the behaviours mentioned in the report and the appropriate boxes are checked. Numbers of eggs laid and hatched are filled manually. The breeding activity record is maintained for each pair and a separate file is maintained for each pair.

## Data recording, consolidation and flow of information



There are two primary goals to be achieved with the system of establishment of record keeping. One is to ensure that accurate records are maintained for the animals housed at the breeding centre and second is to ensure that there is flow of information along the system to ensure that the top-level are managers updated on a regular basis about ground-level situation. The pictographic representation above shows the organization of data collection, consolidation and dissemination across the system to prevent communication gaps.

A brief description of the functioning of the record keeping system is described below:

1. **DATA COLLECTION BY FOREST/WILDLIFE GUARD:** The collection of data and maintenance of the records is done by the ground-level staff deputed at the pheasantry, which in this case is the Forest/Wildlife Guard. He will be responsible for creating, maintaining and regular updating of the Animal History Record. The forest guard will also observe the bird's everyday and fill in the Daily Observation Report and file it. During the breeding season, the record concerning the breeding activities are also recorded by him/her on daily basis as described before and maintained. Printed booklets

of the formats can be issued to the forest guard, which he can use by him to record the required information.

2. **MONITORING AND DATA CONSOLIDATION BY DEPUTY RANGER:** The process of data collection and record keeping by Forest Guard is regularly monitored by the Deputy Ranger and if any discrepancies are found, he can direct the concerned as per requirement. At the end of every fortnight (15 days), the Block Officer should refer to the daily reports, animal history records and breeding activity record and prepare a consolidated report highlighting the important events. A draft format for fortnightly report indicating the important points to be highlighted is also enclosed.
3. **PRESENTATION OF CONSOLIDATED DATA BY THE RANGE FOREST OFFICER:** The consolidated data presented by the Deputy Ranger is cross-referenced by the Range Forest Officer and then presented to the higher officials (DFO and ACF) for further dissemination.
4. **CIRCULATION OF DATA:** The data is circulated among the top officials of the Forest Department by the DFO or the ACF in electronic format for quick reference. The higher officials can further issue directions to the concerned based on the report.

**FORMAT-I: ANIMAL HISTORY RECORD**

**SARAHANPHEASANTRY**

**ANIMAL HISTORY REPORT**

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**Established on:**

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**Common Name:** **Western tragopan**

**Scientific Name:** *Tragopan melanocephalus*

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**Local ID:** ..... **Sex:** ..... **Studbook number:** .....

**Identification** | **Type:** ..... **Number:** ..... **Date:** .....

**Acquisition** | **Date:** ..... **Location:** .....

**Birth origin:** ..... **Date of birth:** .....

**Pedigree** | **Sire (with ID):** ..... **Dam (with ID):** .....

**Breeding history** | **Has the animal previously bred or not:** .....

**Death** | **Date:** ..... **Cause:** ..... **Mode of disposal:** .....

**Transaction** | **Date of transfer:** ..... **Transferred to:** .....

**OTHER NOTES AND UPDATES**

<b>Date</b>	<b>Notes</b>

<b>Date</b>	<b>Notes</b>

## TREATMENT/MEDICAL RECORD

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<b>Date</b>	<b>Symptoms and Diagnosis</b>	<b>Treatment</b>	<b>Notes</b>

**SUPPLEMENTATION AND DEWORMING RECORD**

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<b>Date</b>	<b>Report and Findings</b>	<b>Treatment Regime</b>	<b>Remarks</b>

**FORMAT-II: DAILY OBSERVATION REPORT**

**SARAHAN PHEASANTRY**  
**DAILY OBSERVATION REPORT**

---

Species: ..... Enclosure: ..... Date:

.....

Name of the animal attendant (s):.....

No	OBSERVATION	REPORT		
		Yes	No	
1.	Are the birds showing any sign of weakness/limited movement/ drooping wings/fluffed feathers?	<input type="checkbox"/>	<input type="checkbox"/>	
2.	Was any bird observed to be roosting on the ground the previous night?	<input type="checkbox"/>	<input type="checkbox"/>	
3.	Do the birds show any sign of injury on the rump/head/eyes?	<input type="checkbox"/>	<input type="checkbox"/>	
4.	What is the physical appearance of the feces:	Solid <input type="checkbox"/>	Liquid/Frothy <input type="checkbox"/>	Blood stained <input type="checkbox"/>
5.	Do the claws of the bird appear damaged or curled causing difficulty in locomotion?	<input type="checkbox"/>	<input type="checkbox"/>	
6.	Are the individuals showing any sign of aggression towards each other? Was pecking of one individual by other seen?	<input type="checkbox"/>	<input type="checkbox"/>	
7.	Were the leftovers of the food removed from the enclosures and the food bowls washed?	<input type="checkbox"/>	<input type="checkbox"/>	
8.	Was the enclosure cleaned and excrements removed?	<input type="checkbox"/>	<input type="checkbox"/>	
9.	Was the foot-bath cleaned and fresh disinfectant filled in the baths?	<input type="checkbox"/>	<input type="checkbox"/>	
10.	Was the food offered to the bird at the time prescribed in the diet chart?	<input type="checkbox"/>	<input type="checkbox"/>	
11.	Were the individual birds observed consuming food?	<input type="checkbox"/>	<input type="checkbox"/>	
12.	Are the birds loosing feathers (moulting)?	<input type="checkbox"/>	<input type="checkbox"/>	
13.	Were the birds captured for medical examination or for transferring to other enclosures?	<input type="checkbox"/>	<input type="checkbox"/>	
14.	Is there any immediate requirement of repairs in the enclosures? Mention under remarks.	<input type="checkbox"/>	<input type="checkbox"/>	
15.	Was any health issue related to illness or injury in the bird reported to higher officials/veterinarian?	<input type="checkbox"/>	<input type="checkbox"/>	
16.	Were the birds administered any form of medication for treatment of injury of disease? Mention details in	<input type="checkbox"/>	<input type="checkbox"/>	

	remarks.		
17.	Was the injured or diseased bird observed consuming the medication offered?	Yes <input type="checkbox"/>	No <input type="checkbox"/>
18.	Are the birds under any form of supplementation? Mention details in remarks.	Yes <input type="checkbox"/>	No <input type="checkbox"/>
19.	Is the leg-band (ring) of the bird intact?	Yes <input type="checkbox"/>	No <input type="checkbox"/>
20.	Are the males vocalizing and giving out breeding calls?	Yes <input type="checkbox"/>	No <input type="checkbox"/>

Notes (Forest guard/Deputy ranger/Range officer/ACF/DFO):

Signature of pheasantry in-charge:

### FORMAT-III: BREEDING RECORD

#### SARAHAN PHEASANTRY RECORD OF BREEDING ACTIVITIES

Block: ..... Enclosure: ..... [Pair]: Male: ..... ; Female: .....

Date	Vocalization by male	Courtship and display	Mating observed	Egg laying	Number of eggs laid	Disturbance of female by the male at the nest	Isolation of male	Commencement of incubation	Number hatched
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**FORMAT-IV: CONSOLIDATION REPORT**

**SARAHAN PHEASATRY  
FORTNIGHTLY REPORT**

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Date: ..... To .....

Report prepared by:

1. Acquisition of new birds:
2. Egg laying events:
3. Commencement of incubation by the females:
4. Birth or hatching events:
5. Death of birds:
6. Capture/Shifting of birds/Re-shuffling of pairs:
7. Diseases reported, treatment regime and recovery:
8. Fecal samples sent for endo-parasite examination and its report:
9. Requirement of repair works or modification at the pheasantry:
10. Other relevant information:

Signature of the Official

## Appendix-II: Western tragopan Conservation Breeding Plan

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The captive stock of Western tragopan was established in 1990's with a pair of wild-born founders. The stock reached the current size through subsequent addition of wild-born individuals and captive breeding. A research project to study the behavioural ecology of the species in captivity was initiated in June 2011. In addition to this, the project also intended to address issues such as poor health of the captive birds, low reproductive output and to develop science-based methods for the management of this species in captivity. The analysis of the breeding records indicated that the keeping conditions during the initial phases of project were inappropriate, which was assumed to be the cause of the low breeding success. Fundamental improvements in the keeping conditions with strong emphasis to the ecological and behavioural requirements of the species were carried out. This was implemented with specific reference to housing conditions, dietary regime, reproductive management and stress reduction, which was achieved by lowering the level of overall disturbance. Following the implementation of the new keeping conditions, the breeding success improved along with reduction in the proportion of abnormal eggs and expression of natural incubation and off spring rearing behaviour.

The aim of this document is to provide management options for the further steps in the establishment of a reserve population of the species and to support recovery efforts *in situ* through species restoration. The conservation-breeding plan proposed here identifies the priorities and actions required.

### **Status of the captive collection at Sarahan (as of July 2014)**

The collection at Sarahan consists of only 32 individuals (12 males, 15 females and 06 juveniles); of which 16 individuals (eight males and eight females) constitute the breeding pairs. It comprises of seven wild-born founders (three males and four females) and 20 captive-born individuals (9 males and 11 females). The age structure of the collection is indicated in Figure 1. Three distinct age-class groups are identifiable, the aged individuals (>8 years or older) consisting mainly of wild-born founders, the reproductive age class consisting mainly of captive born individuals with low reproductive success so far and the group with the younger individuals born in 2012 and 2013, which are still to be paired.

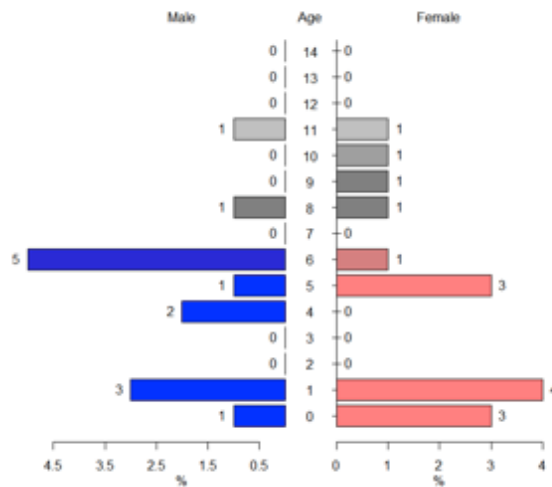


Figure 10: Age structure of the Western tragopan captive collection (living), 2013

12 of the 19 founders from the historical population failed to breed. The analysis of the breeding records during 2005-2013, during which a mean 7 adult pairs/year were recorded, revealed that only six of the 18 females housed during this period bred producing 20 living descendants. A median of two surviving offspring

The captive stock is facing problems such as low number of breeding founders, production of thin-shelled eggs and high degree of relatedness between the descendants.

was born annually during this period. All the pairs were established prior to 2011. As depicted in Figure 2, all these descendants are derived from two prolifically breeding wild-born pairs (002 x 006 and 001 x 007). During this period, founders also were paired with the F<sub>1</sub> individuals, resulting in the descendants sharing common ancestry with multiple founders. Further, pairing of individuals 11 and 19 (in 2008) resulted in mixing up of the lineages resulting in a large proportion of related siblings. The reproductive output of the tragopan females at Sarahan so far was low. The reasons of the low breeding success are the production of non-viable eggs (thin-shelled, under-sized, and shell-less eggs) and low hatching success. Non-viable eggs comprise of more than 50% of eggs laid during this period. Mortality patterns indicate that the captive-born birds at Sarahan had low life-expectancy (40.7<sub>Mean</sub>±36.07<sub>SD</sub> months, n=22) as compared to rescued wild-born birds (113.8<sub>Mean</sub>±25.99<sub>SD</sub> months, n=9).

All the breeding aviaries at Sarahan are currently used and no spare enclosures are available. The existing infrastructure including off- and on-exhibit enclosures can accommodate 14 pairs (28

individuals). The use of exhibit enclosures, which is necessary, would require significant modifications, relocation of a pair each of Himalayan Monal and Kalij pheasant and closure of their facility to public visitation. The personnel working at the centre comprise of four zookeepers and a forest-guard (local supervisor). The activity of the zookeepers and the forest-guard is supervised by Deputy Ranger, Range Officer and Assistant Conservator of Forests and Division Forest Officer (local Head). The personnel working at the centre are not trained in the basic aspects of the bird biology and husbandry. The breeding program is currently not scientifically supervised by a zoo biologist, which is mandate as per the Central Zoo Authority regulations. However, this gap (at functional level) was taken care of by the researcher of the Wildlife Institute of India working in the collaborative research project during 2011-2014.

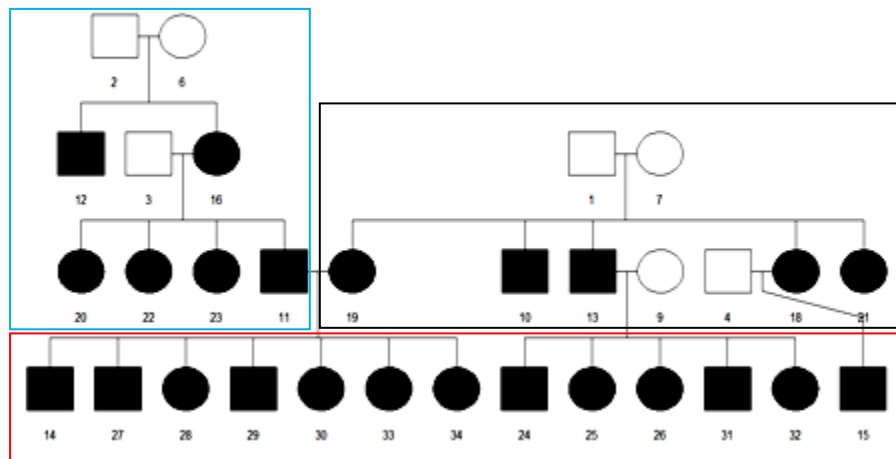


Figure 11: Pedigree chart of the Western tragopan captive collection. Males are represented as squares and females as circles. Solid fills represent captive-born individuals and no fill is wild-born individual. All individuals enclosed within the red box are related.

### Perspectives for future management

With actually fewer than 30 individuals at Sarahan, the priority is to increase the size of the collection by encouraging breeding in reproductively active individuals. A husbandry regime close to the behavioural ecology of the species, such as is in practice during 2012-2014, which allows the expression of natural breeding behaviours and reduced stress levels promotes better breeding.

A ten-year perspective is proposed with two 5-year phases; phase-I spanning 2015-2019 and phase-II during 2020-2024. At the end of phase-I, the progress of the program should be reviewed to examine the proposed and achieved activities. The experienced breeders of the collection are aged and a number of individuals in the breeding age class still have

The captive stock consists of fewer than 30 individuals and has low viability. The priority is to increase the size of the collection as much as possible to reduce extinctions risks due to stochastic events such as disease and natural calamity.

reproductive problems associated with the production of thin shelled eggs. During the plan period and under the given keeping conditions, it is realistic to assume around 5-6 individuals/year are added to the stock by breeding. Furthermore, mortality of individuals which are in the upper age class (5-8 years) and which are older than 10 years due to ageing can also be expected. It can hence be expected that by the end of 10-year period, the size of the collection would approximately grow to about 60 individuals. This would require the erection of new enclosures to accommodate the additional birds. It may also be considered to distribute birds between zoos nationally or internationally as part of coordinated breeding programs as described later. Since the viability of populations consisting of the less than 100 individuals is supposed to be low (Traill et al. 2010), towards the end of plan-period, efforts should be focused on achieving a number greater than 100 individuals, distributed in several locations, to improve the chances of long-term persistence of the population.

#### *Demographic, genetic and behavioural management*

Demographic management in the current context refers to the management of individuals as pairs. The composition of the breeding pairs established in 2008 and before (especially, pairing of individuals 11♂ and 19♀) led to a high degree of relatedness. The priorities for the future management should be to ensure that the newly born offspring have a low degree of relatedness. This can be achieved through the establishment of new breeding pairs and possibly through addition of new wild-born founders. For composing breeding pairs, in addition to genetic aspects (relatedness), other parameters relevant for successful reproduction such as age, origin and previous breeding experience should be given equal consideration. As per records, all the eggs produced by females born 2012 and

New pairs have to be established as soon as possible to improve the genetic prospects of the captive

later are normal. Therefore, it is recommended that pairing of these females is done as soon as possible which increases the probability that more offspring are born annually.

An important recommendation is to pair individuals of wild origin with each other as long as they are available, instead of pairing them with F<sub>1</sub> individuals. Secondly, as a polygynous system in the species is assumed, instead of long-term pairing of individuals, changing mates periodically is also recommended. Pairing of individuals with more than one mate (either a single male mates with multiple females or vice versa) is proposed. This ensures that an individual has increased chances to breed successfully in case one of the mates fails to reproduce. This system also compensates for the slightly higher number of females in the collection and in increasing the number of pairs available per unit time. The system also provides more options to increase the genetic diversity of the collection. The existing enclosures allow this to be achieved without the need to capture individuals. The potential pairing options for the plan period is indicated in Table 1.

The high degree of relatedness suggests that inclusion of new wild-born founders might be a necessity in future. A possible approach on how founders can be added to the collection is described in the next section. Females with no previous history of breeding, primarily due to the production of large proportion of thin-shelled eggs (ID's 008 and 023 specifically), should be temporarily separated, preferably away from the breeding units in enclosures under specialized care to investigate and possibly reduce the problem.

<b>Male ID</b>	<b>Potential pairs (Female ID's)</b>
<b>003<sup>#*+</sup></b>	006 <sup>#*+x</sup> , 009 <sup>#+x</sup>
<b>004<sup>#+</sup></b>	006 <sup>#*+x</sup> , 008 <sup>*+</sup> , 009 <sup>#+x</sup>
<b>005<sup>+</sup></b>	008 <sup>*+</sup>
<b>012<sup>#x</sup></b>	009 <sup>#+x</sup>
<b>015</b>	006 <sup>#*+x</sup> , 009 <sup>#+x</sup>
<b>024<sup>x</sup></b>	016 <sup>#x</sup> , 023 <sup>x</sup>
<b>031<sup>x</sup></b>	016 <sup>#x</sup> , 023 <sup>x</sup>

Table 4: Pairing options (<sup>#</sup>: experienced breeder [bred at least once], <sup>\*</sup>: age ≥ 10 years, <sup>+</sup>: wild-origin, <sup>x</sup>: number of related individuals ≥ 5)

### *Addition of wild-born founders*

The genetic perspective of the captive population is poor and as described earlier, therefore, the addition of wild-born founders is necessary. Capturing wild-born individuals is neither feasible given the field conditions nor justified given the rarity of the species. Removal of eggs from wild nests, if any found, is not advocated and supported by the author. A “temporary-capture” method

Innovative methods should be explored for the addition of new genetic material from wild-born individuals. Natural populations should not be disturbed during this process through capture of individuals.

is proposed. The principle is to temporarily confine wild-individuals and allowing them to mate with captive individuals and later releasing them. The breeding facility is located in the habitat of Western tragopan and this can be advantageous in attracting wild birds and triggering them to enter aviaries without forcefully capturing them. In the previous years, wild individuals of Western tragopan have been observed in the pheasantry premises. They can then be facilitated to mate with captive birds and released thereafter. The process should be carefully planned and executed under extreme precaution specifically with reference to high possibility of injury to wild birds and transmission of infectious diseases. The proposed methods has been adopted from Olney et al. (1994).

### *Husbandry*

The management of the species in captivity should be developed based on the behavioural ecology of the species. The principles required for establishing such conditions are described here. The location of the

A husbandry regime close to the behavioural ecology of the species should be followed.

breeding centre lies within the distributional range of the species. This provides optimal conditions for housing the species under natural climatic conditions and especially under natural light cycles which possibly mediate physiological processes especially associated with the onset of breeding activities in early spring. Artificially reduced light hours (reduced) accompanied by forceful spatial confinement (housing in dark indoor areas for longer durations) should be avoided as it disrupts physiological processes and can be counter-productive.

Western tragopan is a high altitude pheasant species inhabiting temperate forests with dense undercover, which temporarily offers protection against the predators. A strongly developed

vigilance behaviour and readiness to fleeing, however, is an important aspect of predator avoidance. Fleeing is realized either by skulking or gliding/flight. Roosting is done in richly structured forest canopy. Although they are ground dwelling, a significant amount of time is spent above the ground on rocks and trees. The housing conditions should refer to these specializations and should consider the following aspects:

- The enclosures have to be as large as possible. A minimum size of 150m<sup>2</sup> per breeding pair is recommended. The enclosures should have sub-units for temporary separation of individuals. Pair management could involve separation of males during the breeding season.

Large vegetated enclosures, undisturbed living conditions and an appropriate diet with a large proportion of fresh vegetative matter are key requirements of the species in captivity.

- Compartments can help in mate separation without the need to capture them. Such interconnected compartments also allow the birds to ‘move-away’ from keepers during feeding and cleaning.
- The possibility of optional merging of multiple aviaries into a single large aviary to manage birds as flock during winters (non-breeding season – November-February) should be considered.
  - The enclosures should have trees or tree-like structures, and undergrowths which provide an opportunity for the birds to ‘hide-away’ when threatened. The above-ground structures within the enclosures should be complex mimicking forest canopy. The placement should permit “long-distance walks” to access different areas of the enclosure without forcing the birds to fly to the ground or longer distances during which they could gain greater momentum.
  - Perches should be rough textured, about 4-5" diameter (branches of trees such as *Robinia pseudocassia*, *Picea smithiana* and *Pinus wallichiana*) and provide calm and un-disturbed roosting grounds.
  - The distribution of the vegetation within the enclosure should be such that it allows sunlight to reach the enclosure floor. The areas receiving sunlight dry faster and can be dust-bathing sites for the birds.

- Access to artificial surfaces like cemented structures and iron by the birds should be avoided. During sub-zero winter temperatures when the birds are in contact with such materials, freezing can occur and lead to foot problems.

The overall disturbance levels during all seasons within the enclosures and pheasantry premises should be minimal. Stress management should be an important component of husbandry, especially during the breeding season (from March-July). The stress management should address the following aspects:

- Aviaries with breeding birds should be off-exhibit.
- Noise level (caused by activities such as construction, loud conversations by humans) near the breeding aviaries have to be minimal and none especially during the breeding season
- Bird keepers who perform feeding and cleaning of the enclosures are an integral part of the husbandry regime. They should be sensitized to inculcate the habit of least amount of disturbance from their activities.
- Keeper movement within enclosures with egg-laying/incubating females should be minimal.
- Capture: Unnecessary capture of birds should be avoided under all circumstances. Capturing of birds just prior to breeding season and post-breeding season should be avoided. If a need arises to capture birds for veterinary intervention, it should be done in a calm and planned manner. For, movement of birds between enclosures, special transport cages can be used, to avoid the stress of capturing.
- No personnel or individuals should enter the enclosure for photographing eggs, nest or chicks.

The males are territorial during breeding season occupying large home ranges and polygamous mating is assumed. Western tragopan nests on elevated grounds (often several meters above the ground level) in undisturbed areas. With these considerations, some important aspects of management of birds in breeding season are:

- The breeding males should be visually isolated from each other to prevent territorial conflict and stereotypic pacing behaviour

- Distinct breeding areas should be established within the aviary. These areas should be less disturbed and less visited by keepers than the rest of the aviary.
- Multiple elevated nesting platforms at multiple heights and distributed at various locations within the enclosure have to be provided to the birds prior to the breeding season (should be provided before the last week of March)
- Multiple nesting opportunities have to be provided for all the females (at least 3 nests per female)
- Females spend a significant amount of time near the nest just prior to and during egg-laying. Males often display (lateral display) in the proximity of nest which could possibly disturb the female at the nest. In case such male activity is observed near the nest, the male has to be immediately separated from the female, without disturbing the females.
- Towards the end of egg-laying the males have to be separated from the females.
- No human activity should be allowed near the nests during the breeding season. Nest monitoring for egg laying activity should be carried out once a week. The nest monitoring should be done extremely carefully and quickly when the female is not present in the vicinity of the nest. Monitoring can be done using a long stick with a mirror fixed at one end (the tool was prepared by the author and is available for use at the pheasantry).

A frugivorous and folivorous diet is predominant in the Western tragopan. There is a peak in the foraging activity at dawn and dusk and dietary constituents vary across seasons. With these considerations, some important aspects of dietary regimes are:

- As their major diet consists of mostly vegetative matter, greens must be fed year round. Around 50% of the diet should consist of fresh vegetative matter (fruits, vegetables and greens). Seeds and grains, sprouts and animal protein should comprise of 25%, 15% and 10% respectively.
- The time of presenting the food should match their natural feeding cycles i.e. the main diet should be offered as early as possible in the morning (0600-0700h).
- A flexible food presentation system should be adopted and additional food items such as insects, wild food items (such as berries, flowers, leaves etc.) can be offered at random

times during the day. Extreme caution has to be exercised when feeding wild items as many species of plants and insect can be poisonous to the birds.

The keeping conditions should mimic wild conditions and allow the expression of the species-typical behavioural patterns. The birds should be slowly and carefully habituated to keeper movements within the enclosures. However, a high degree of tameness should be avoided and practices such as offering food by hand should not be followed, as this can have negative consequences such as low survival of reintroduced individuals.

Parent rearing (production of parent-reared offspring) is propagated as it allows appropriate socialization of the offspring. Given the keeping system is practiced as proposed, with improvements whenever necessary, it is evident that breeding by means of natural incubation

The living conditions should allow the birds to display species-typical behavioural patterns especially with reference to incubation and parent-rearing.

and rearing by tragopan hens is possible. Foster rearing by domesticated chicken or use of incubator and hand-rearing offspring is therefore not advocated as part of this plan. However, cross-fostering is to be considered in case of abandoned eggs. This involves translocation of the abandoned eggs from one female into the nest of another potential female for incubation and rearing purposes. This process has to be executed carefully and should not induce unnecessary disturbance at the nest where the eggs are being trans-located. However, care has to be taken to ensure that accurate parentage records are maintained. Parent-reared offspring has to be housed together with the mother until the following breeding season.

An important aspect of captive animal management is hygiene. At Sarahan, the chance of transmission of infectious diseases from wild-birds, rodents and keepers is high. Hygiene (cleaning of enclosures) would involve activity within the enclosure and often in close proximity to the birds. An optimal balance should hence be achieved between hygiene and the disturbance levels resulting due to this. This is especially with reference to the timing of the proposed activities, human movement within and in the vicinity of the enclosures and proper planning. The husbandry practices should also minimize of the possibility of disease transfer from animals to humans, and vice-versa. The following aspects have to be considered:

- Rodent management should be followed rigorously through rodent-proofing of enclosures and rat-traps. No rodent poison should be used within the enclosures or in the premises.

- The food items have to be tested for toxins like pesticides and aflatoxins monthly. Hygiene during food preparation should be ensured. The food storage containers and refrigerators have to be cleaned using detergent and disinfected weekly.
- The foot-baths have to be cleaned and the disinfectant (Safeguard®) should be replaced regularly.
- Food and water bowls should be removed from the enclosures every evening (between 1700-1730h during winter and between 1800-1830h during rest of the year) washed and disinfected (using Safeguard®).
- Top soil (about 5") in the aviaries should be removed and replaced with fresh soil annually (before March).
- Regular disinfection of walls and wooden parts of the enclosures should be done through lime-wash (in February)
- Nests have to be removed and disinfected after every breeding season (during February)
- Uniforms, knee-high boots and face masks should be used by all personnel entering the enclosures. These accessories should not be taken / used outside the pheasantry premises.
- Outsiders or visitors should not be allowed inside the enclosures

### *Infrastructure*

The key resources required to support the ongoing breeding program are:

- *Aviaries*

Under the given conditions, the population size at the end of the 10 years is expected to be around 60 individuals. No spare aviaries are available at Sarahan to house the offspring. Therefore, an immediate requirement is the erection of new enclosures to house offspring born in 2014 and onwards. It is proposed that housing of up to a maximum of 50 birds should be planned at Sarahan. Once this is achieved, additional birds should be planned to be housed at a satellite facility or other zoos. It is therefore recommended to plan the construction of at least 10-12 new enclosures at Sarahan in a phased manner, during the plan-period.

- *Personnel and record keeping*

It is to be emphasized that the conservation-breeding program for the Western tragopan involves the only captive stock of this species in the world. Therefore it is important that personnel at the centre have to be motivated and inclined to work with this precious stock of birds. The management should be science-based and overseen by a qualified and trained zoo-biologist. This person should preferably be based long-term at the centre. The zoo biologist (employed by the forest department) should oversee day-to-day activities concerning the management and husbandry of the birds. The biologist should minimally have a Masters degree in Zoology or related sciences and have previous experience with bird care and husbandry.

Regular training programs have to be conducted to educate the keepers with basic aspects of the birds' biology and husbandry. As keepers generally work closely with the birds, they have to be educated (at least be a matriculate) and trained. As stress management forms a very important component for maintaining this

The optimal management of Human resources is the key requirement for the success of the program. Trained keepers and a strict scientific supervision are emphasized.

species in captivity, keepers have to be regularly sensitized specifically in this aspect. This would involve avoiding movement in proximity to the birds, providing opportunity to birds to avoid keepers when working inside the enclosures as this can lead to stress and fleeing responses (speedy flights), which may injure the birds. The supervisor (Forest guard and Deputy Ranger) overseeing the activities of the keepers at the centre should minimally be a college graduate in science with advanced training with bird keeping and husbandry. Veterinary protocols needs to be developed and followed in collaboration with the state veterinary department (at Shimla) to prevent outbreak of diseases. A veterinarian specialized with wildlife medicine should be involved as part of veterinary interventions at the centre.

It is recommended to establish a strict record keeping system to monitor and record activities at the centre comprising of: 1. Veterinary intervention; 2. Record of illness observed; 3. Breeding activities; 4. Capture history and pair re-constitution; 4. Daily observation records of individuals birds; and 5. Personnel and keeper schedules. Information obtained through record-keeping like breeding activities, commonly occurring health issues can be of immense help in improvisation of the husbandry and management regime. Information obtained can also be used to optimize regular activities and to train the personnel with various aspects of bird keeping and management.

- *Research*

For a species such as the Western tragopan living in habitats difficult to access and with almost no information on their biology, these captive individuals can serve as representatives for wild conspecifics in behavioural and physiological research. The management and husbandry of these birds in captivity

Basic and applied research should be an integral component of the activity schedule at the breeding centre. Infrastructural conditions required to establish the same should be established.

should be based on information from both applied and basic research. Research investigations, whether observational, behavioral, physiological, or genetically based, should have a clear scientific purpose with the expectation that they will increase our understanding of the behavioural ecology of the Western tragopan and may provide results which benefit the conservation of wild populations. An important issue is long-term collaborations with academic-cum-scientific institutions for initiating and carrying out research projects. The zoo-biologist in-charge should be an integral part of the research activities. The zoo-biologist should act as an interface research outcomes and its application in management of the captive birds.

- *General infrastructure*

Aspects of general infrastructure requiring special considerations are:

→ Renovation of aviaries: Old aviaries (Enclosures 1-14) constructed using wood should be renovated at the earliest. The wood and the wire-mesh used in the construction of these aviaries are weak and may not sustain for long.

The breeding centre is remotely located and hence there is high risk of damage by humans or during winter. Infrastructural conditions to prevent such damages should be established.

→ Barriers: Barriers to prevent visitor entry in off-exhibit facility should be established. As human movement in the vicinity of the breeding centre is high, to prevent theft or intentional damage by humans, a perimeter fence around the breeding centre should be established.

→ Winter management: Sarahan receives heavy snowfall. The accumulated snow on the enclosures should be removed as soon as possible to avoid damage to the aviaries. A dedicated and trained group of workers should be made available during winters.

→ Predator proofing: The perimeter fence would prevent large predators like bears and leopard from entering the premises. However, smaller predators such as yellow-throated marten, Himalayan weasel and rats should be managed on a finer scale mainly through trapping.

→ Conditions to conduct research:

- Un-interrupted power supply is an immediate requirement. During winters, power outages are frequent and monitoring during night is difficult. A generator needs to be installed at the centre for use under such conditions.
- A better communication system should be established at the breeding centre. Dedicated telephone and internet connection is a pre-requisite for most research programs and effective dissemination of information to department.
- Remote monitoring cameras should be installed at the centre for round the clock monitoring and recording of bird activities.

#### **Future management and scientific supervision of the breeding program**

It recommended that a few individuals from Sarahan are shifted to another facility, instead of housing all the individuals of the collection at one site. A satellite can act as a reserve in case of catastrophe like disease outbreak or environmental adversity at Sarahan. Individuals to be shifted should be carefully selected based on their genetic status, breeding experience and living descendants and generation. Ideally, in the initial phase, young individuals having a high degree of relatedness within the collection can be selected and with eventual establishment and experience gain at the new centre, more individuals can be transferred. More satellite facilities may be identified with increasing size of the stock.

As already mentioned above, it is mandatory that a scientific manager in-charge or curator/zoo-biologist should oversee the activities at the centre so that a high-level of local competence is achieved at Sarahan. The in-charge should have know-how in bird biology, husbandry and should be acquainted with the broad principles of captive animal management as described

A high level of local competence should be established at Sarahan headed by a Curator/Zoo-biologist. Satellite facilities should be established to distribute birds once the stock size at Sarahan reaches a maximum. A scientific advisory group may be established to periodically evaluate the program.

by Kleiman et al. (2010). The key decision-making ability such as selection of keepers, supervisors and local management should be vested with the in-charge. As the key manager, the in-charge would prepare the necessary plans for new pairings, aviary designs and revision in husbandry regimes and coordinate with forest department for its implementation.

It is recommended to constitute an advisory group to evaluate the activities of the program comprising of experts with long-term in-situ and ex-situ working experience with the species, experienced zoo-biologists specializing with birds. Associations such as European Association of Zoos and Aquariums (EAZA), Association of Zoos and Aquariums (AZA), Singapore Avian Conservation Projects (SACP) might be explored in this regard.

### **Conclusive remarks**

The species is currently housed as a small stock of less than 30 individuals at one facility in Himachal Pradesh. A critical and science-based approach is required to establish a “reserve” population, starting with such a small stock. ‘*Human Resources*’ plays an important in the overall success of the program. The research project during 2011-2014 considerably contributed to the knowledge transfer regarding the said aspects to the keepers and supervisors at the centre. The new husbandry practices introduced during the project period resulted in better breeding and improved overall health of the population. The practices have to be continued and improved, as and when necessary. A list of key references related to principles of captive animals management, specifically in the context of the conservation breeding programs is provided in the table below. The plan should be updated as new information is acquired with reference to the principles of “active adaptive management” as proposed by McCarthy and Possingham(2007). The use of previous experience to design future decisions is the basic principle. The preliminary results of the recently completed research project already were used in improvising management regimes. There is strong need, however, to further use the results from the ongoing and future studies on the species as both practical know-how and basic knowledge about the biology and the conservation of the Western tragopan are still poor and needs to be increased.

### **List of key references**

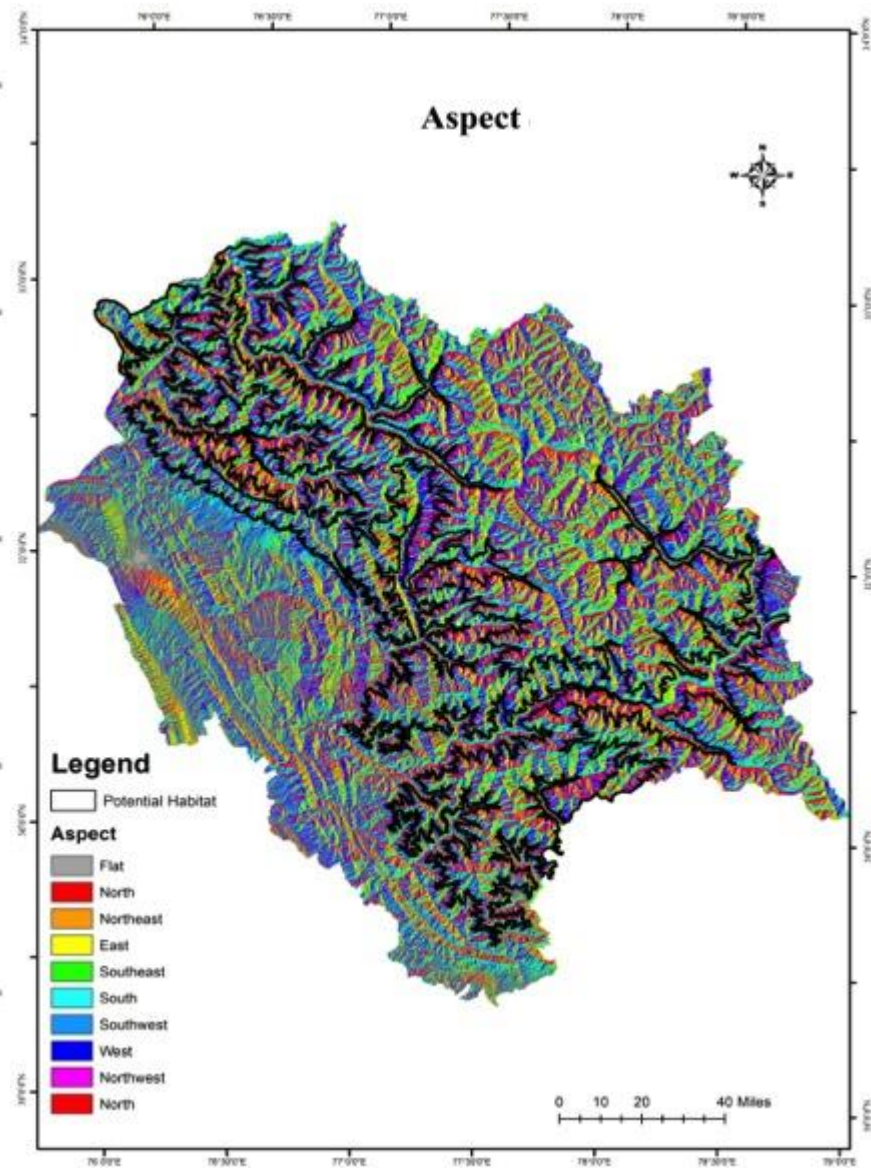
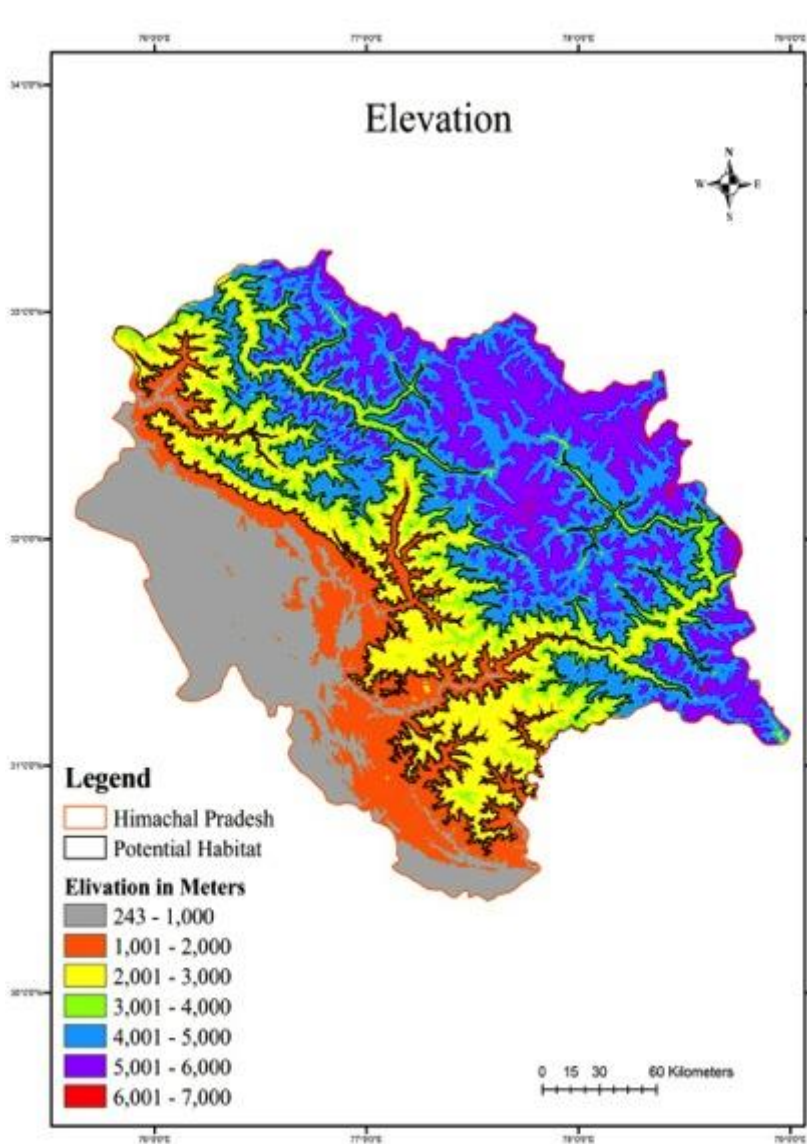
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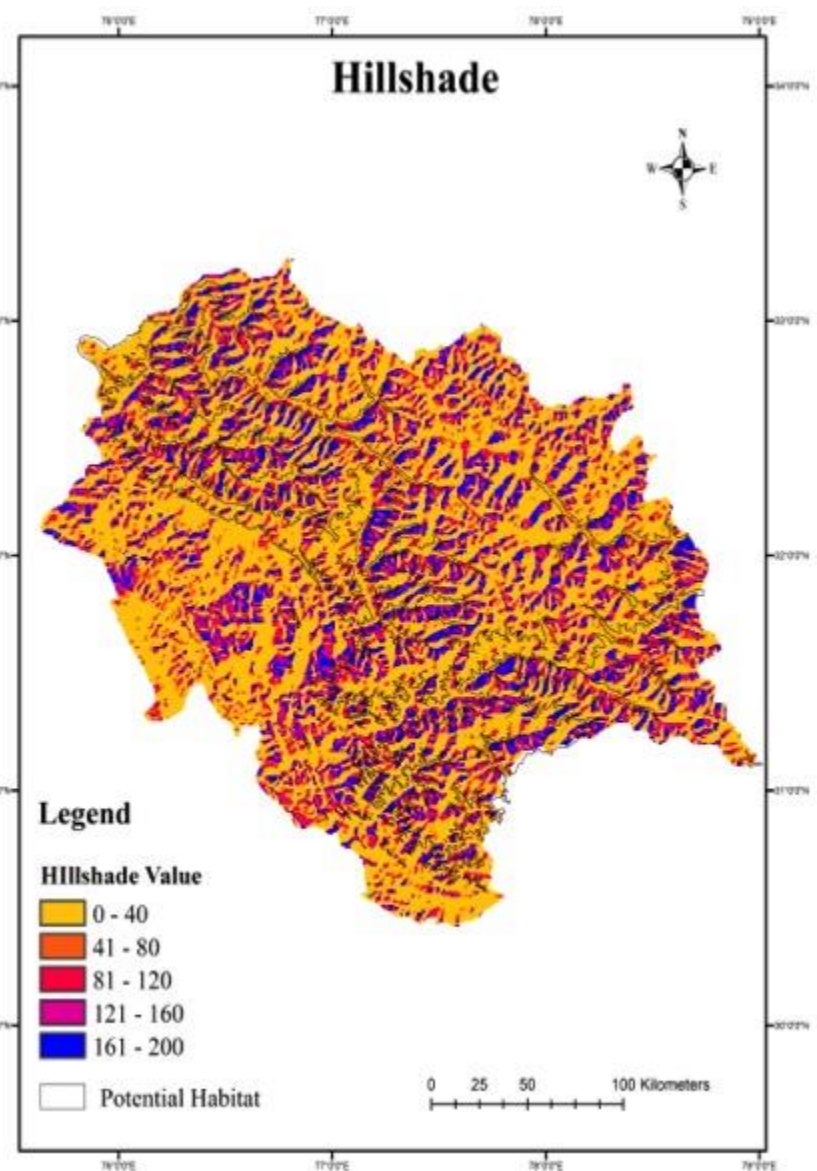
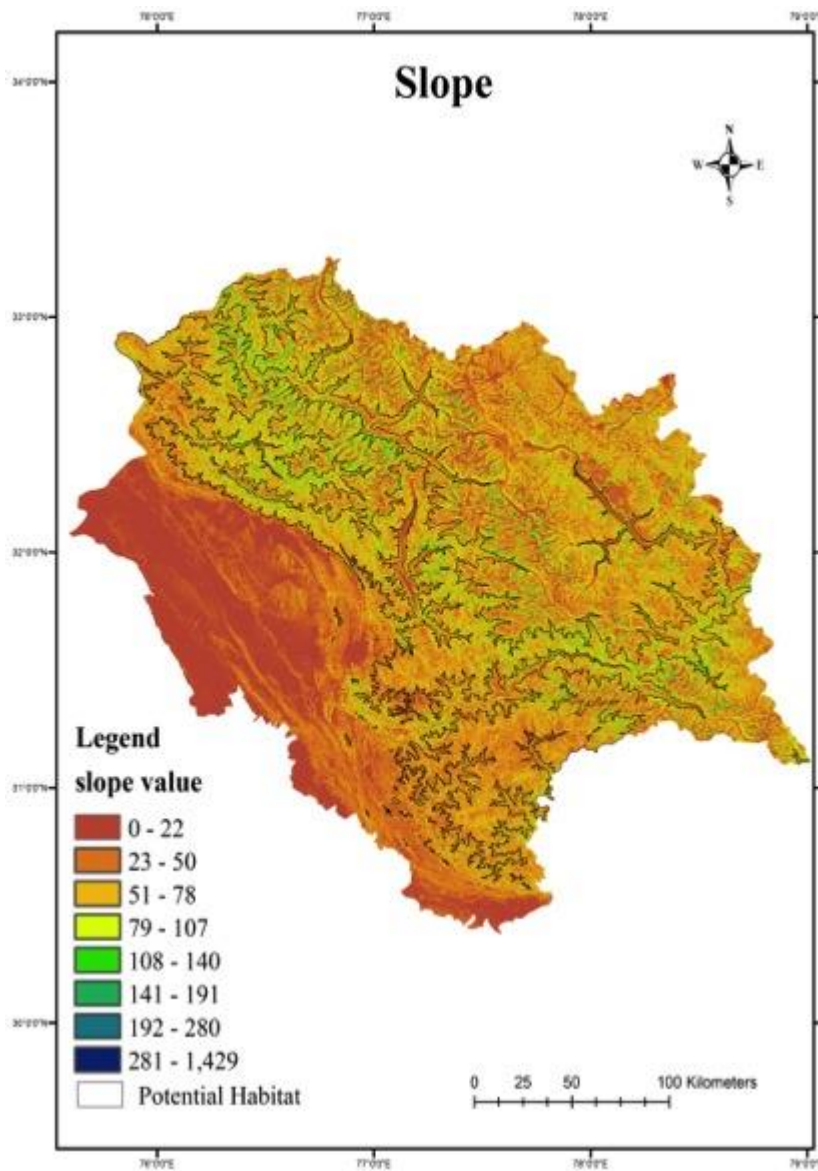
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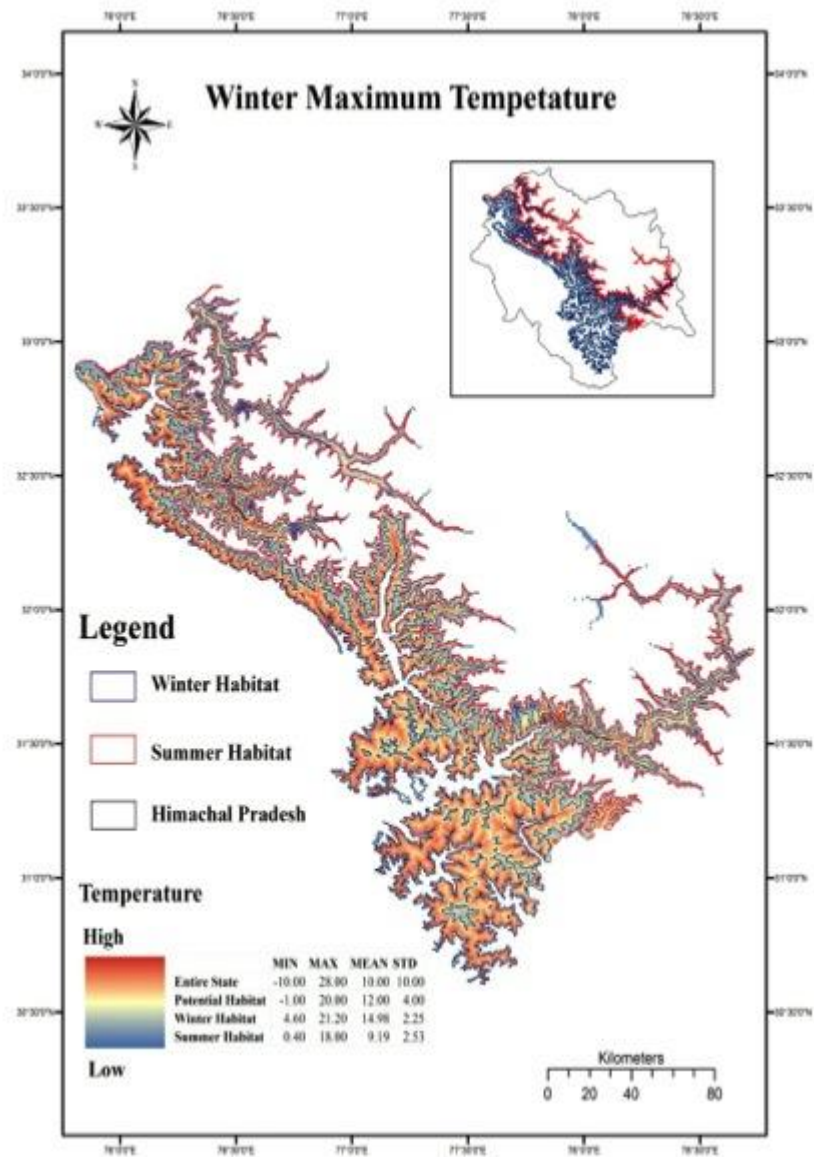
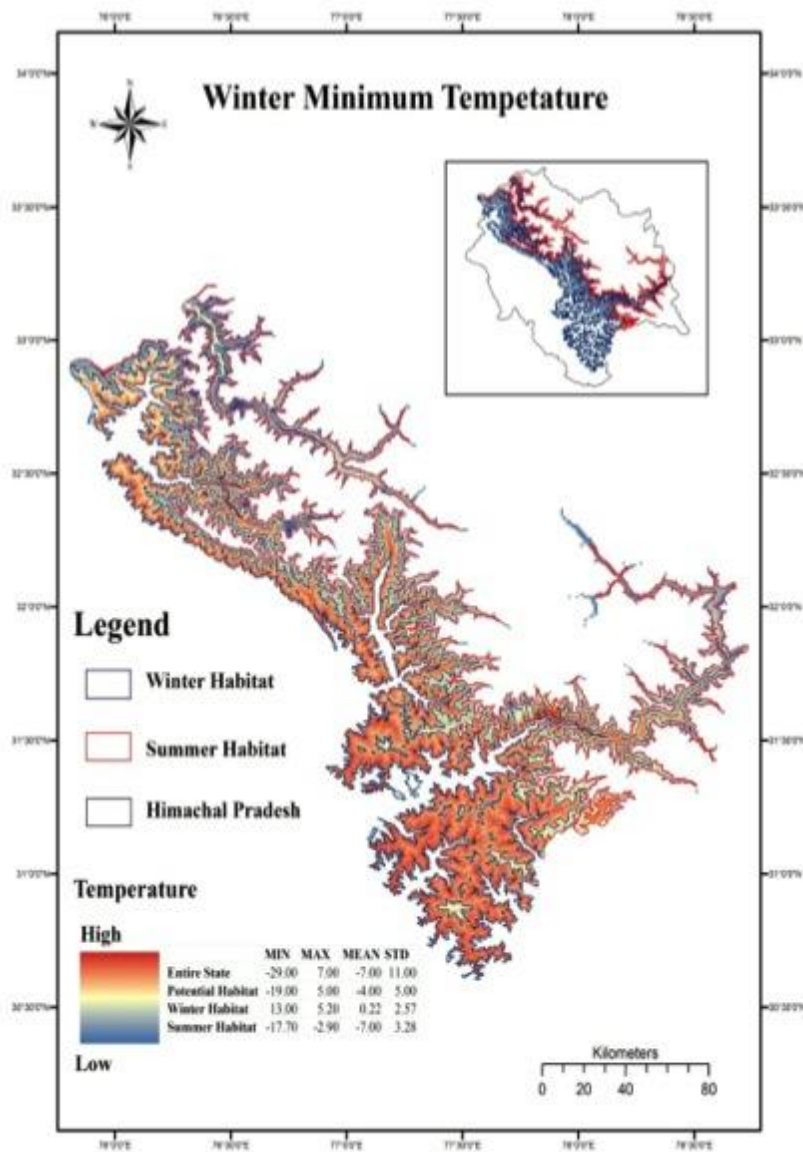
<b>principles, advanced concepts and limitations</b>	Kleiman et al. (2010), Hosey et al. (2013)
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<b>Integrating <i>ex-situ</i> and <i>in-situ</i> conservation</b>	Olney et al. (1994), Swaisgood(2007)
<b>Nutritional aspects of captive animal management</b>	Dierenfeld (1997), Klasing(1998), Kleiman et al. (2010)
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<b>Population management: Demographic and genetic management</b>	Lande(1988), Caro and Laurenson (1994), Harcourt (1991), Young (1991), Frankham et al. (2002), Lacy(2012), Lacy et al. (2013), Penfold et al. (2014)
<b>General concepts of behavioural ecology</b>	Davies et al. (2012)
<b>Veterinary aspects of bird management in captivity</b>	Ritchie et al. (1994), Tully et al. (2009), Samad (2013)
<b>Behavioural management</b>	Olney et al. (1994)
<b>Animal Welfare</b>	Mason (1991), Mason and Rushen (2008)
<b>Captive propagation material specific to birds</b>	Klasing (1998), Reed (1999), Saint Jalme (2002)

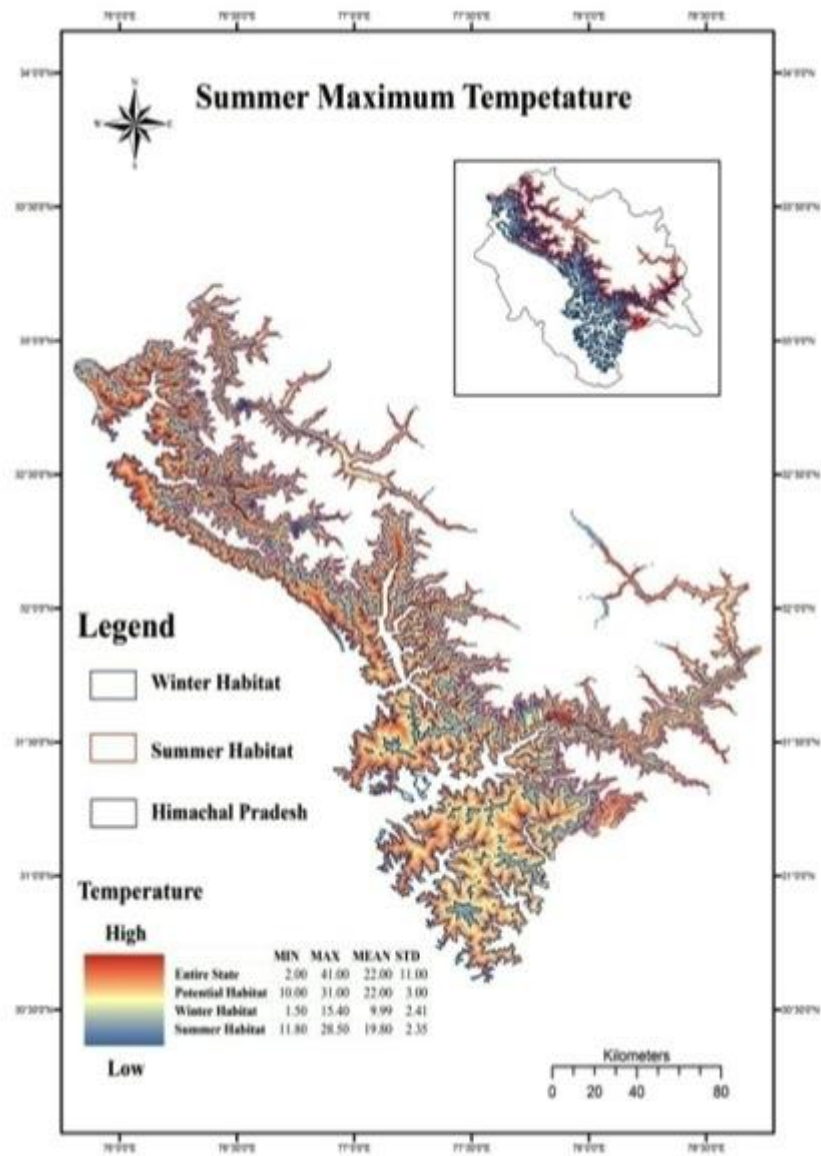
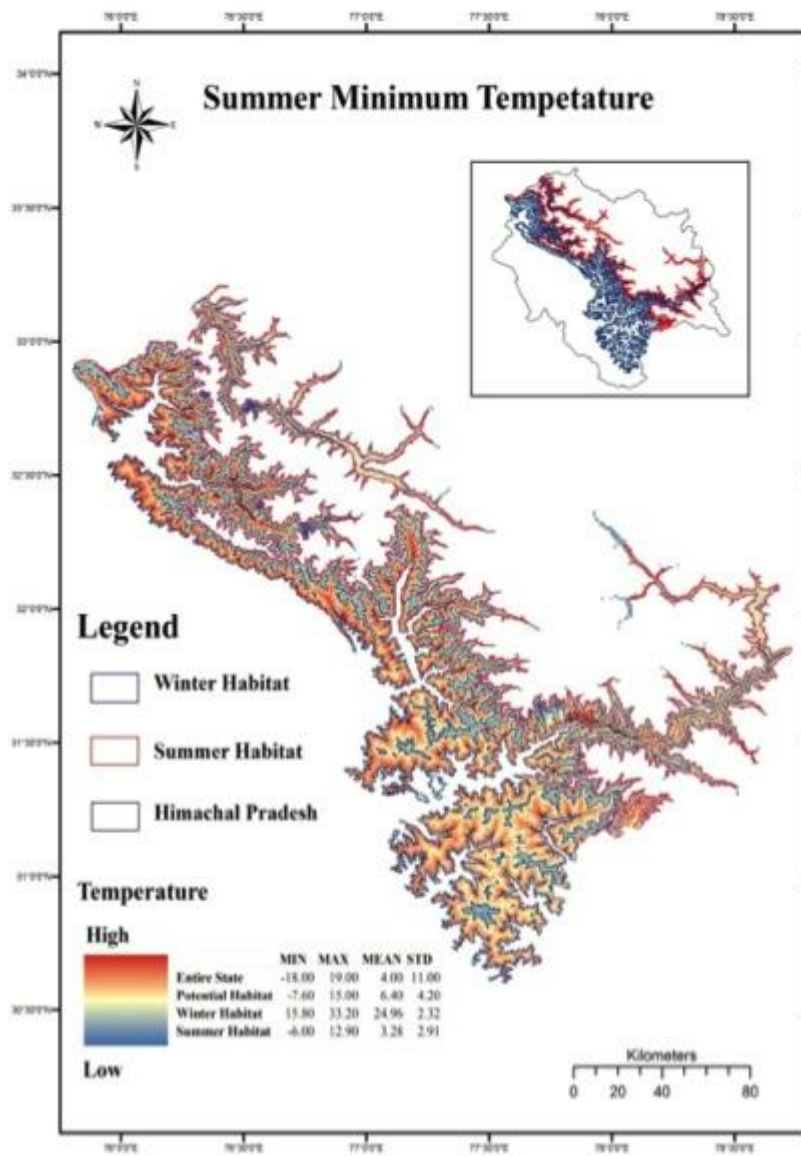
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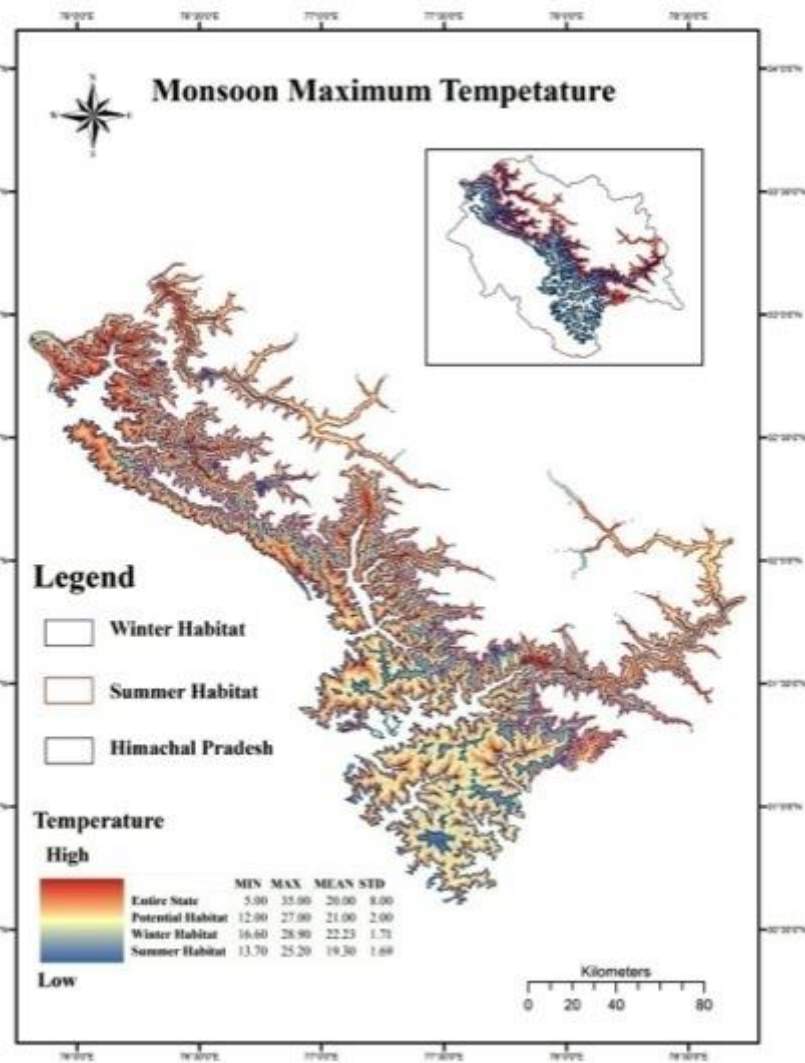
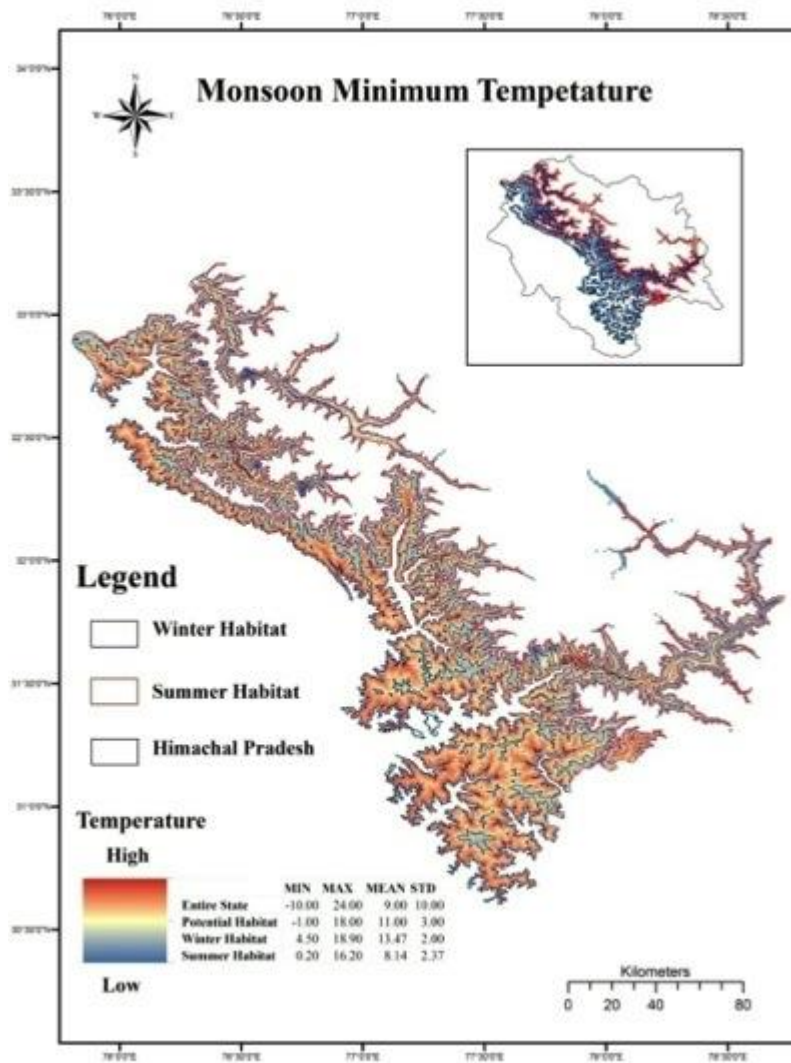


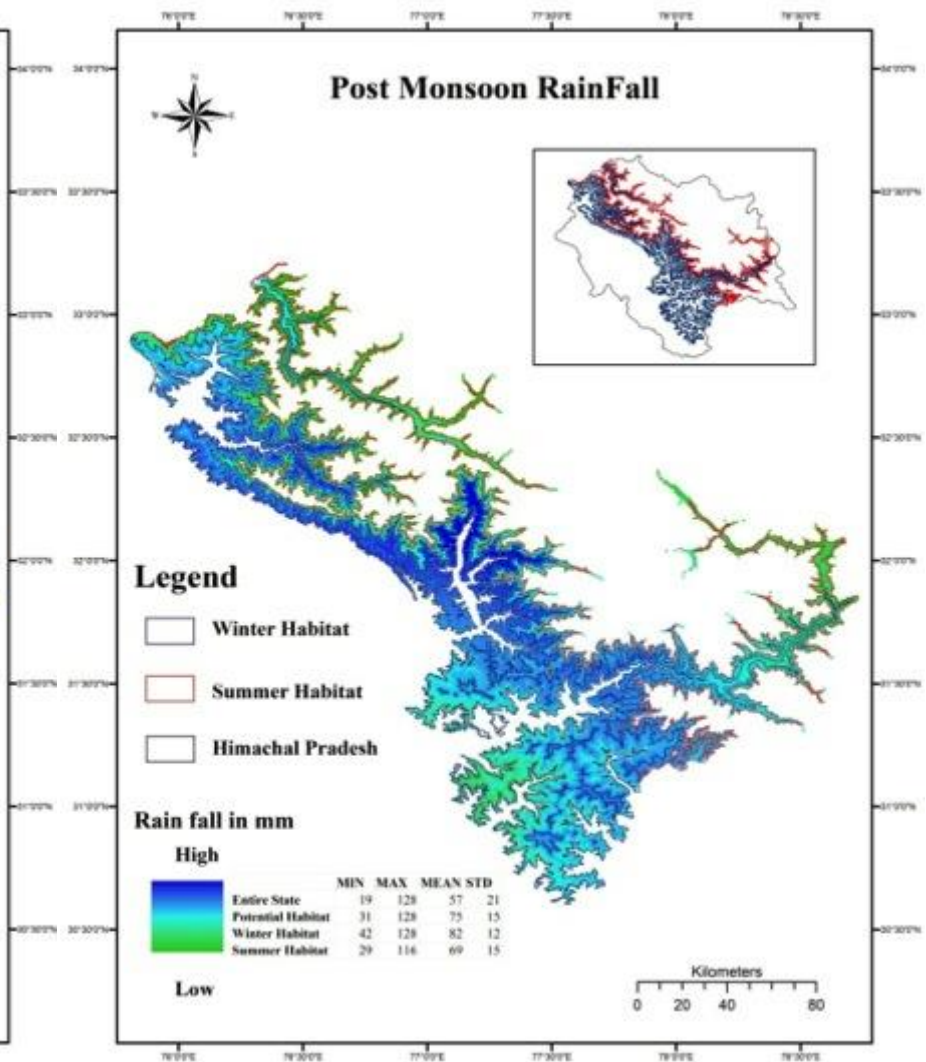
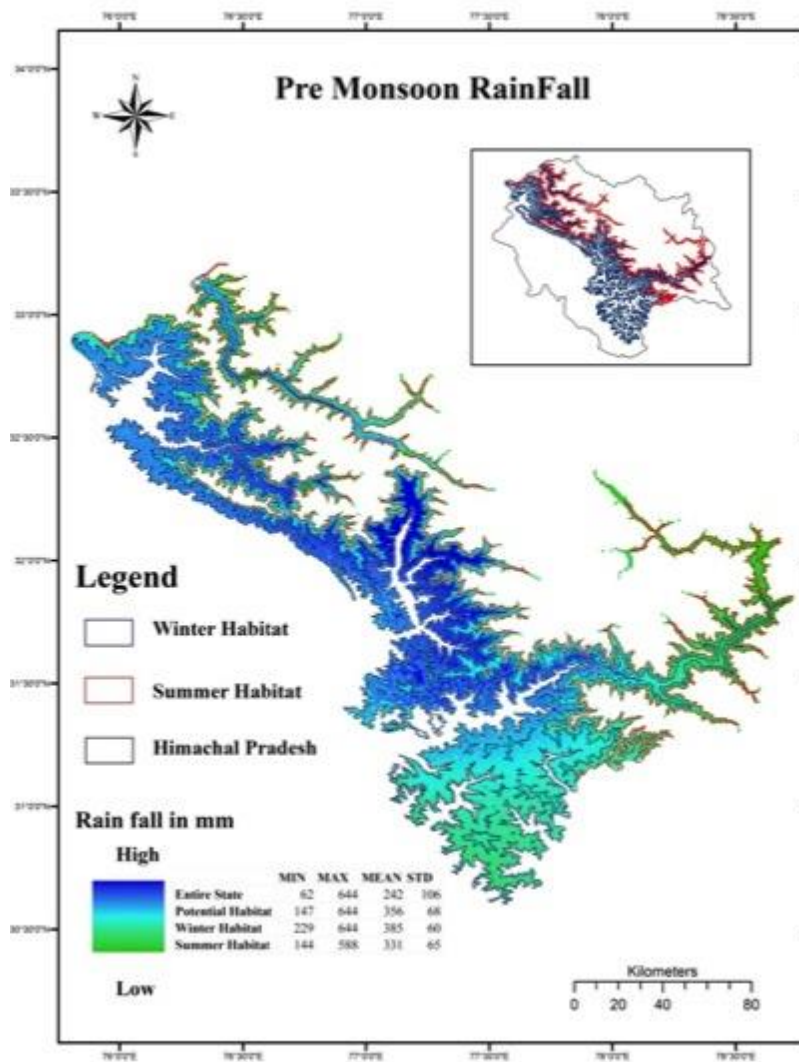


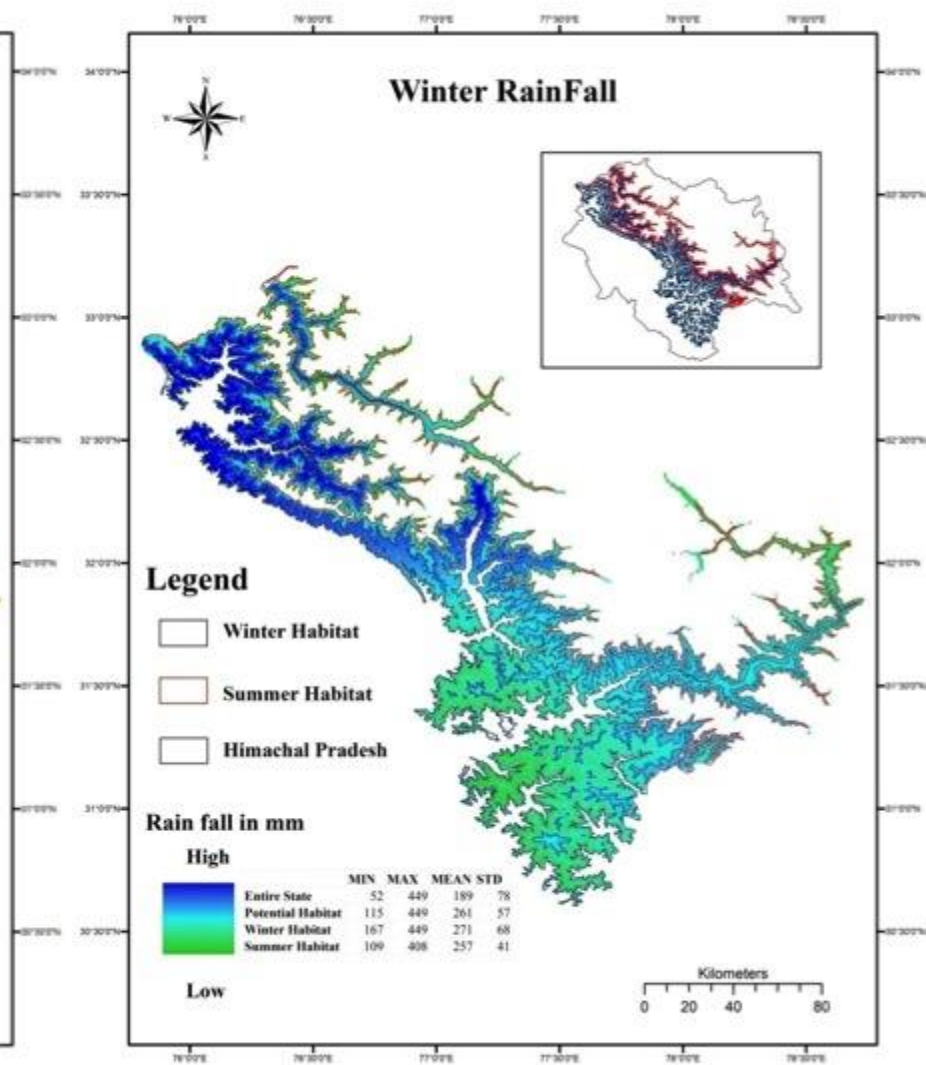
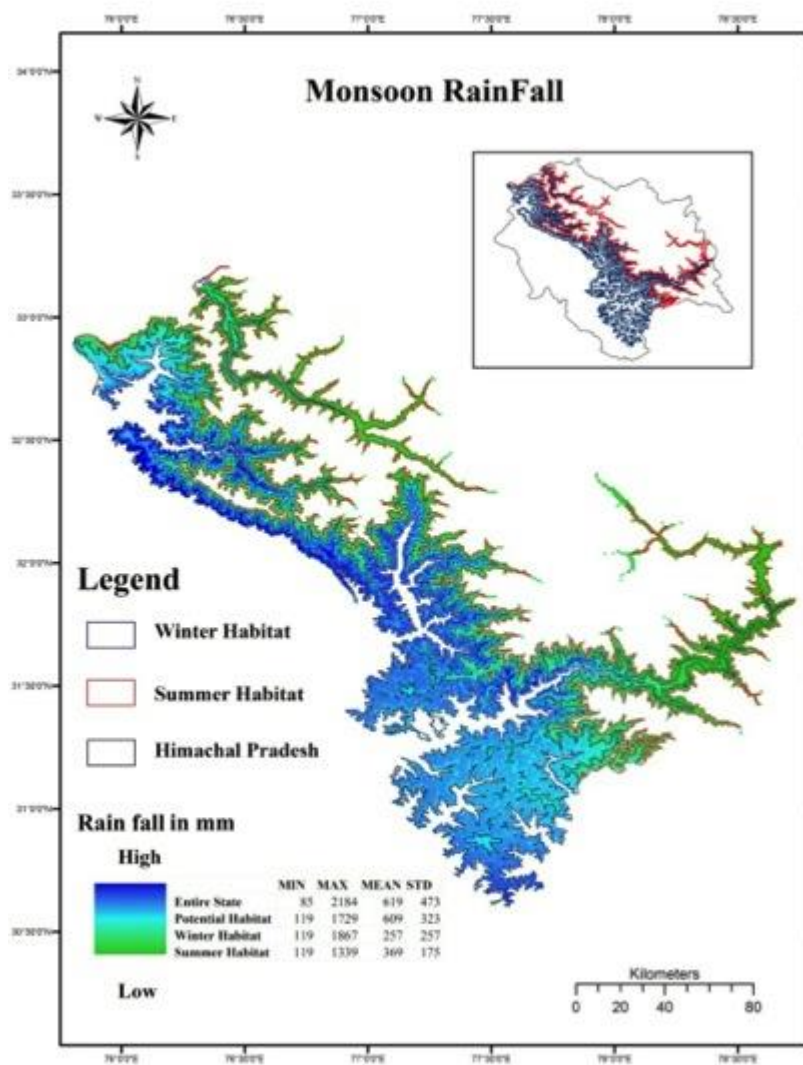


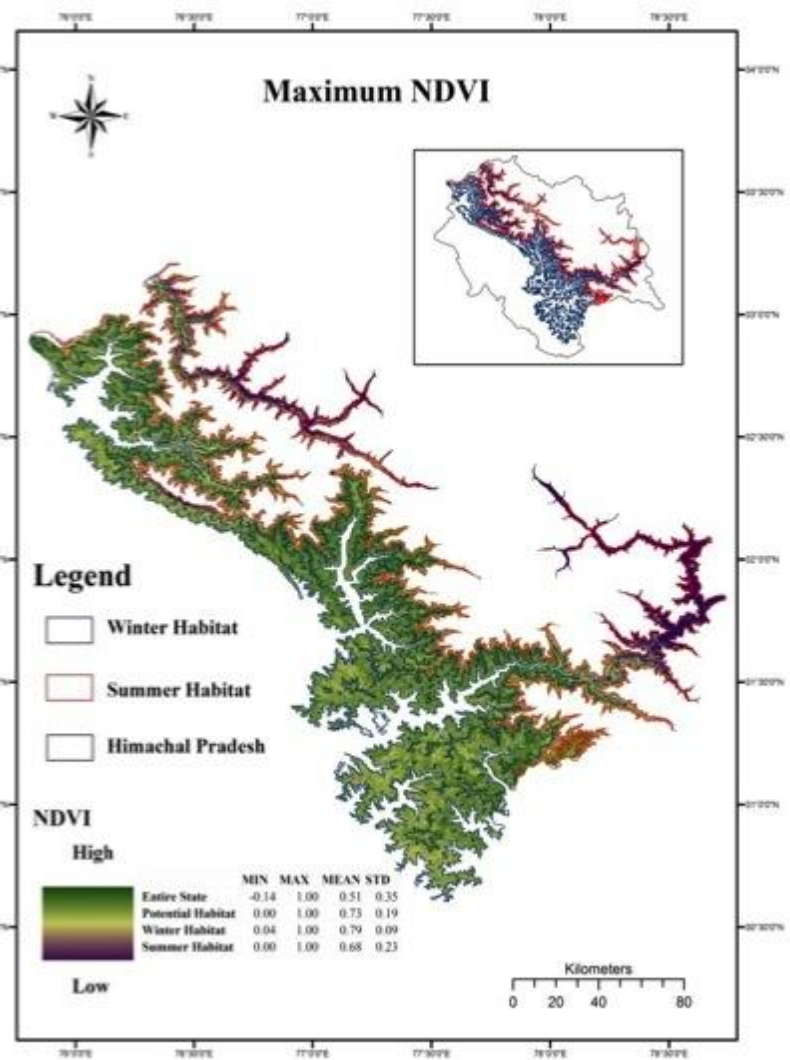
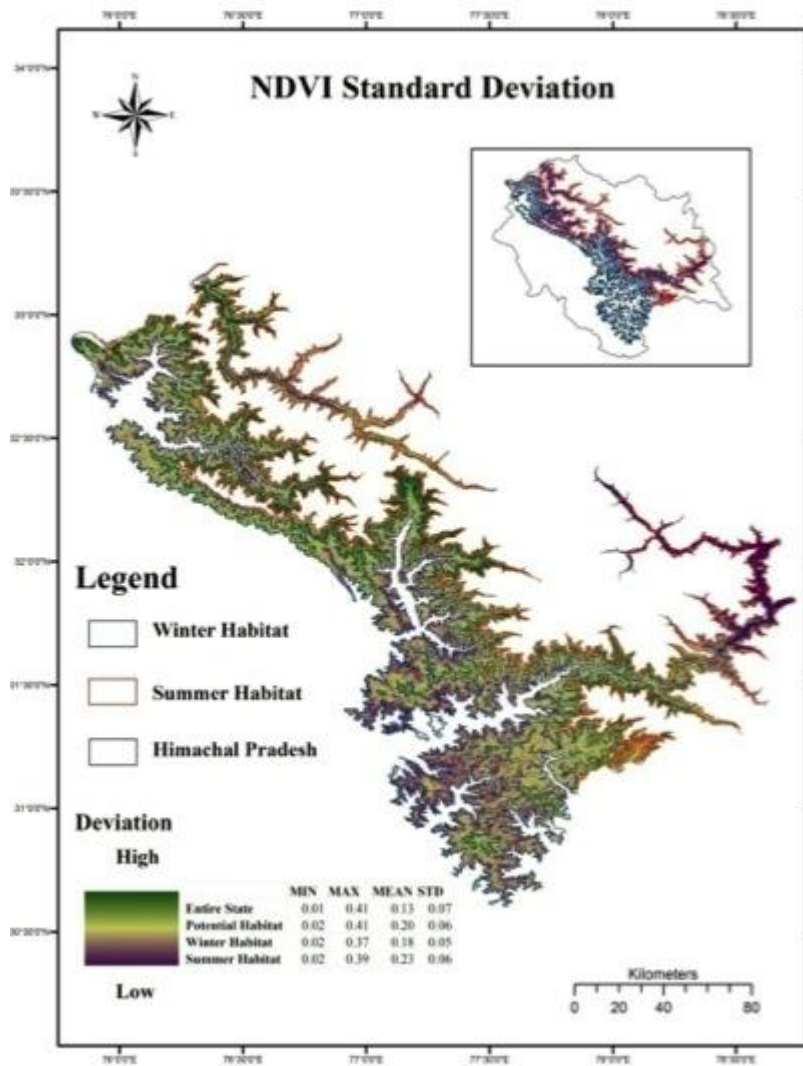


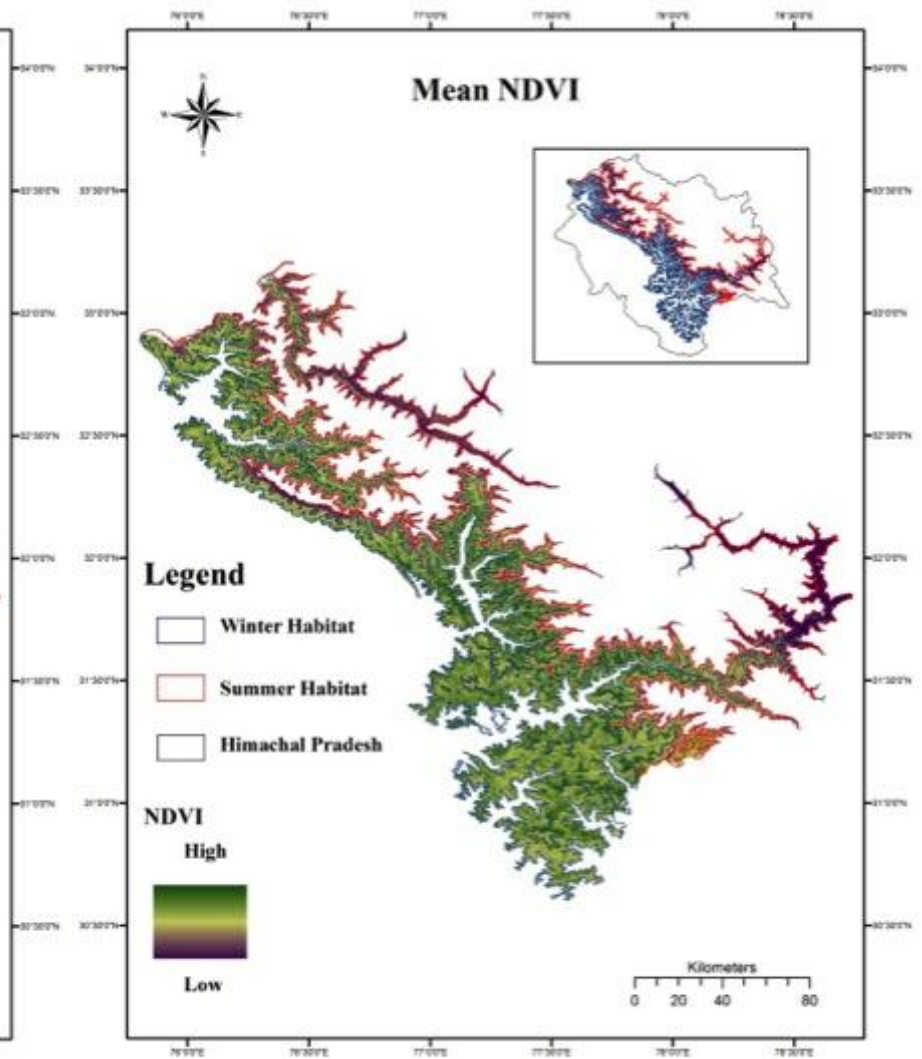
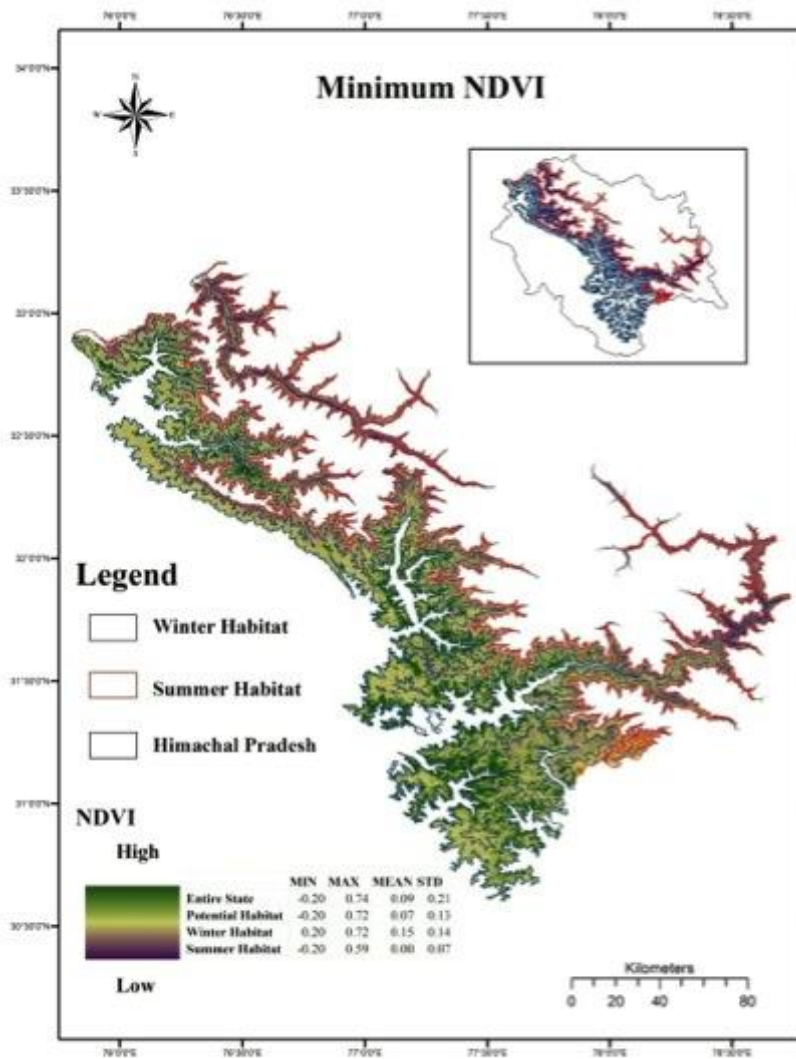


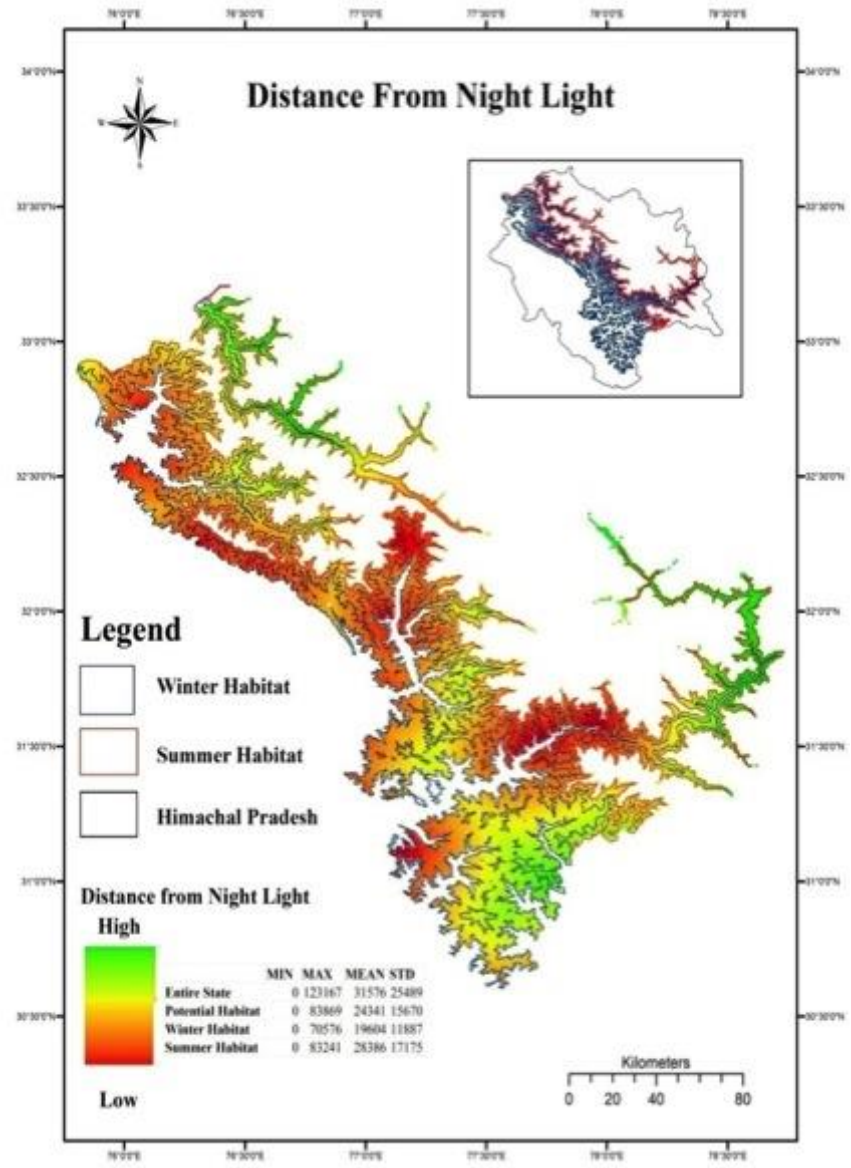
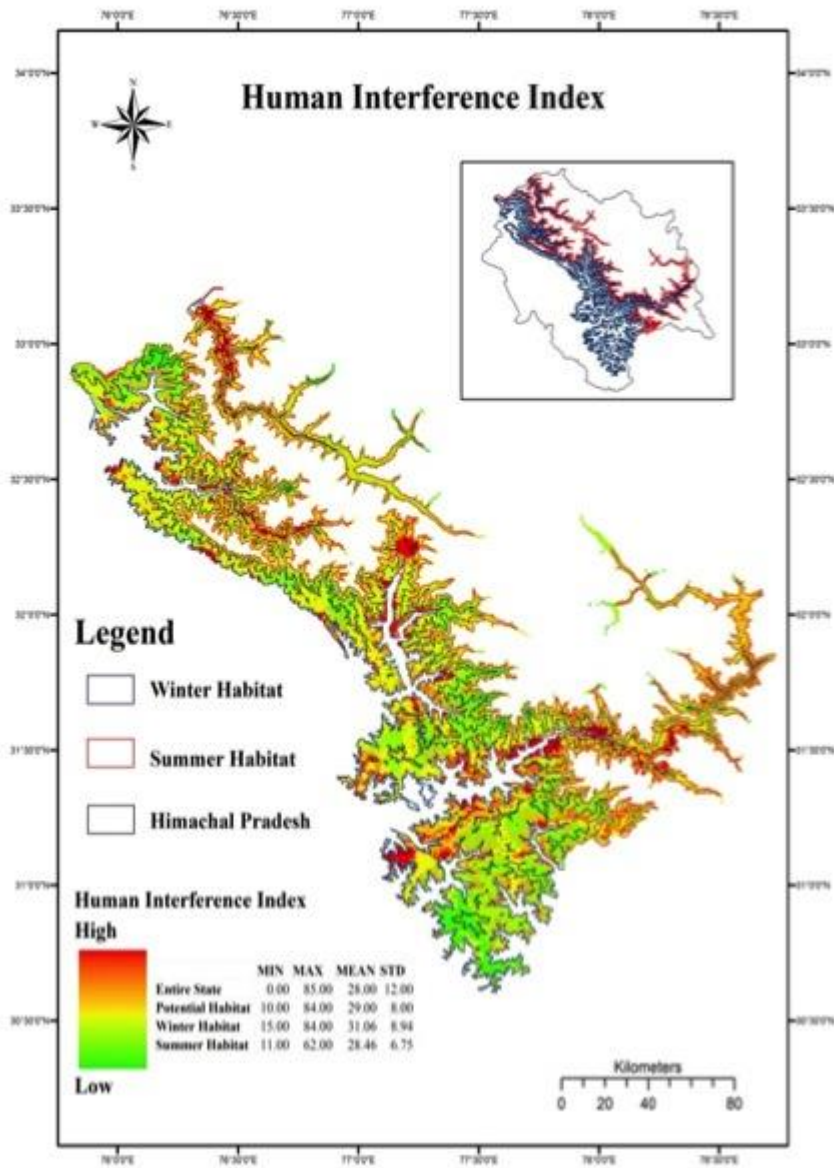


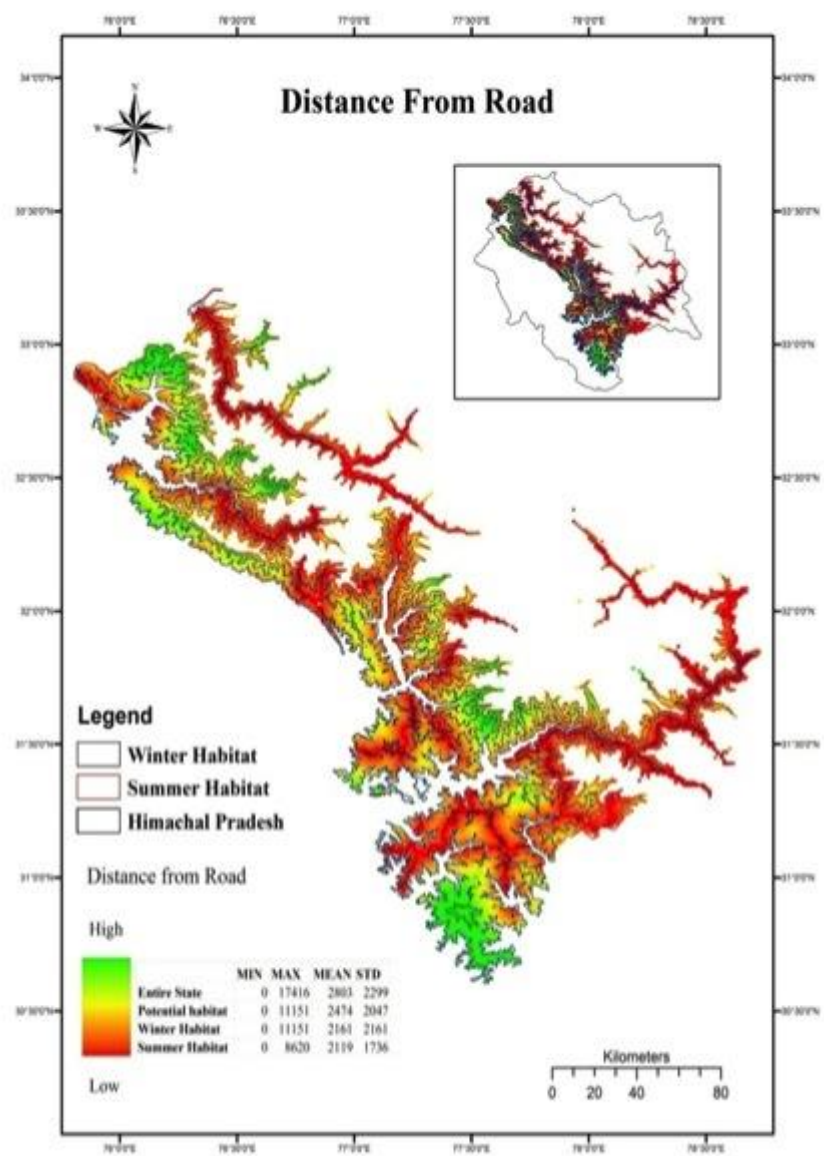
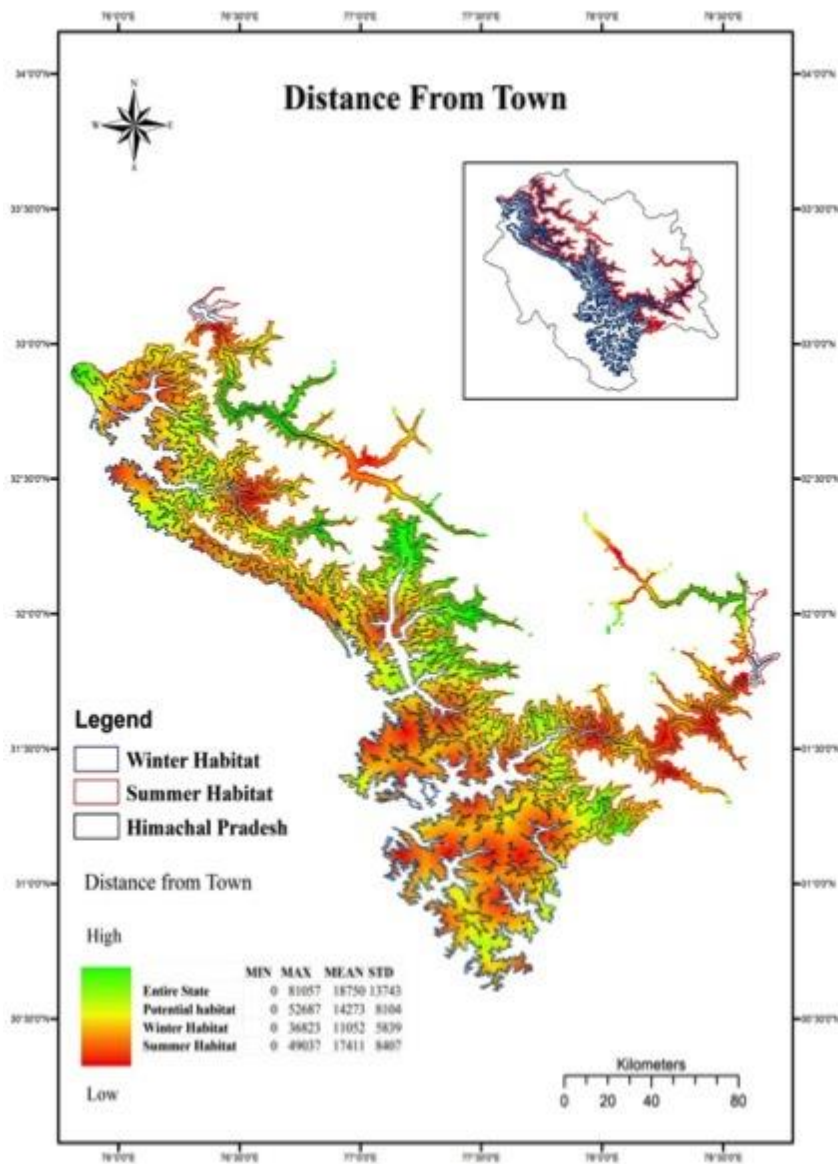


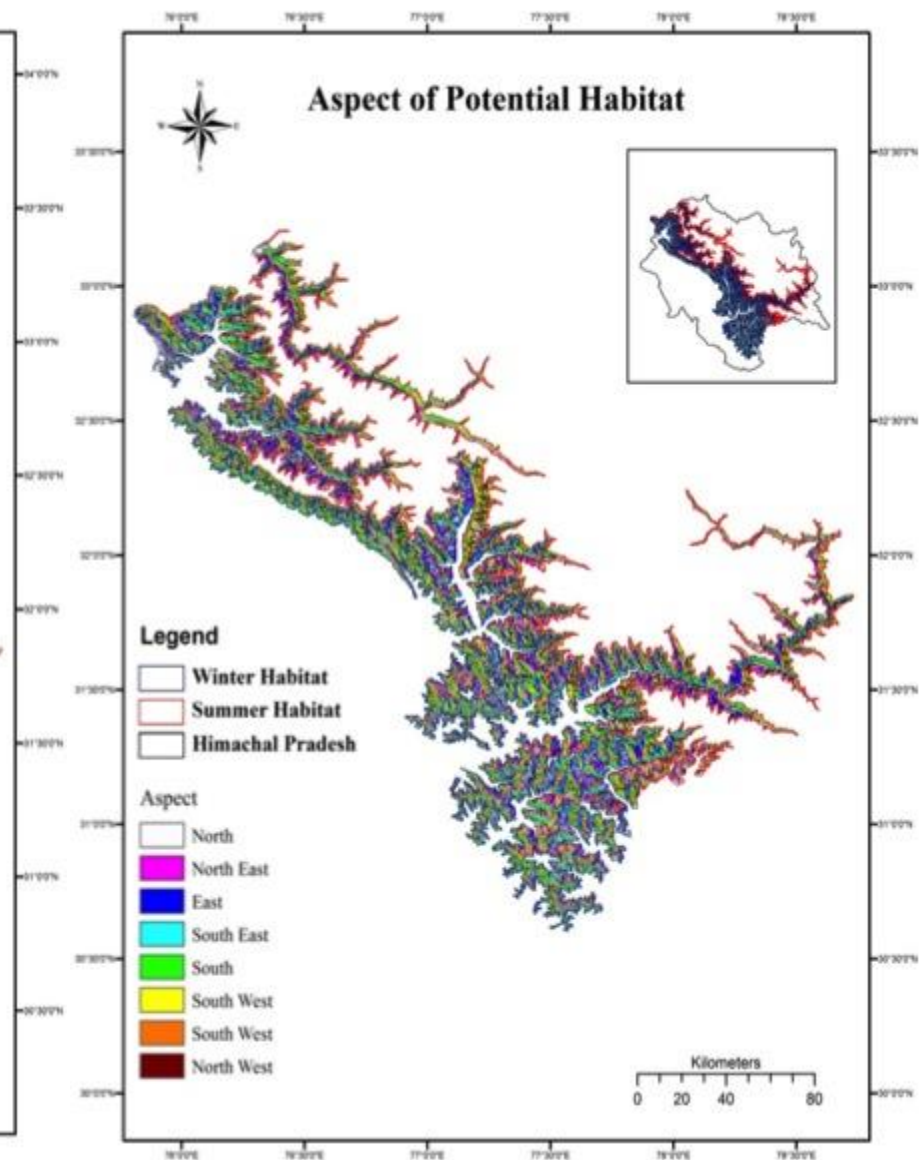
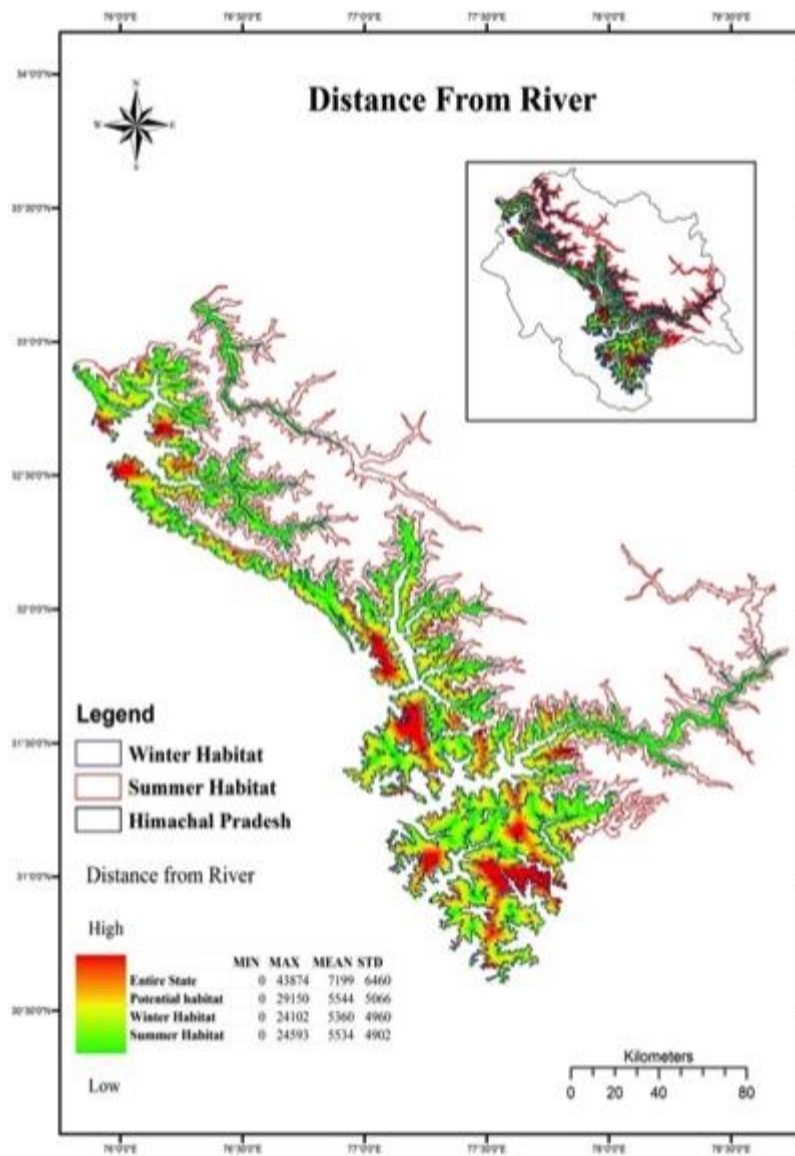








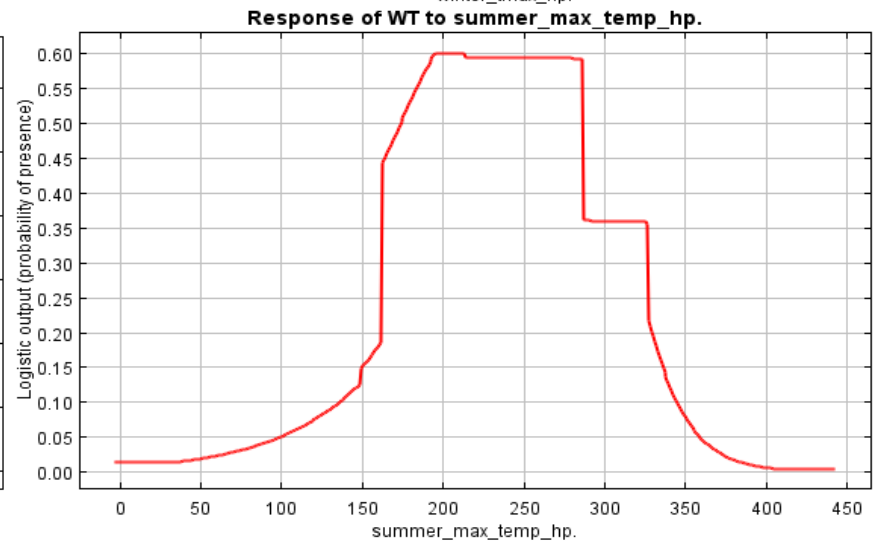
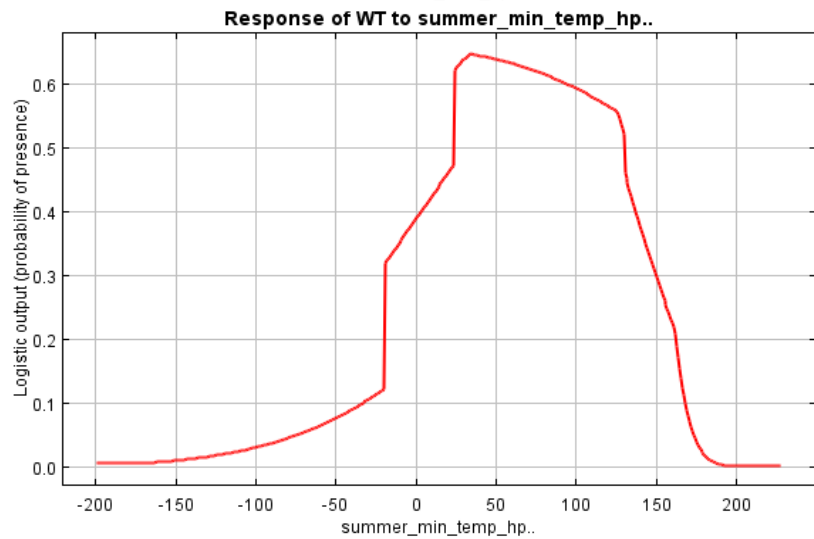
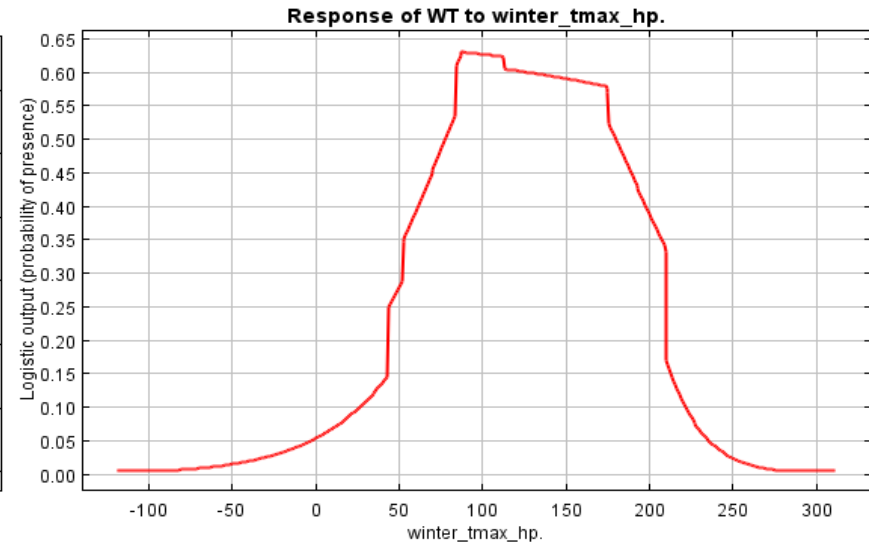
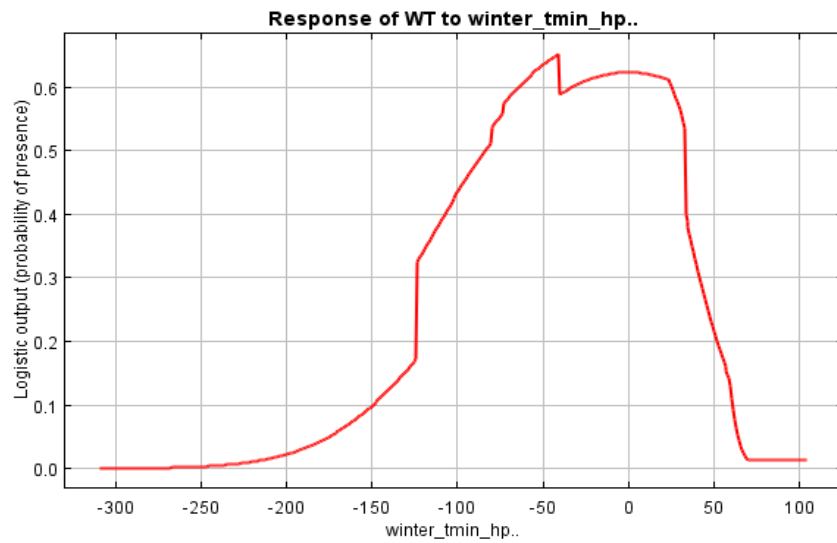


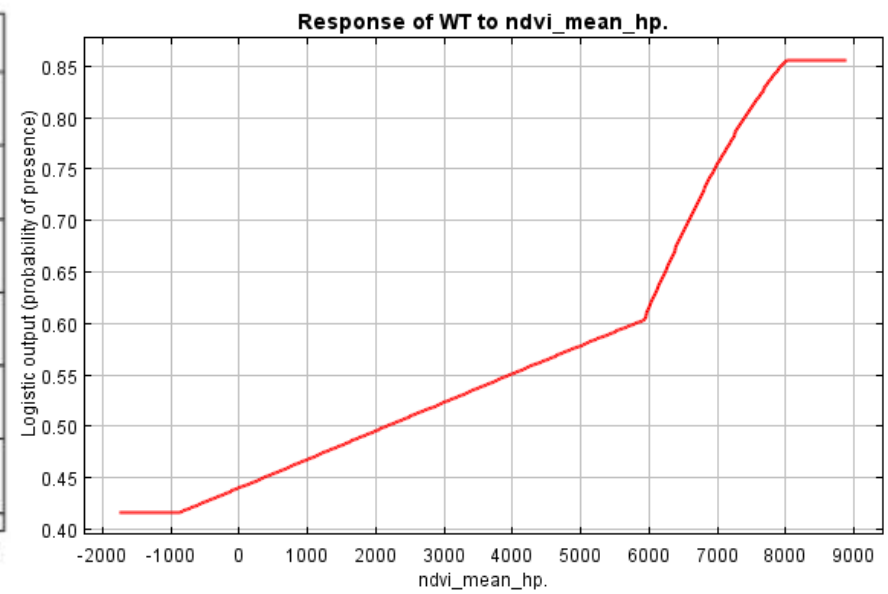
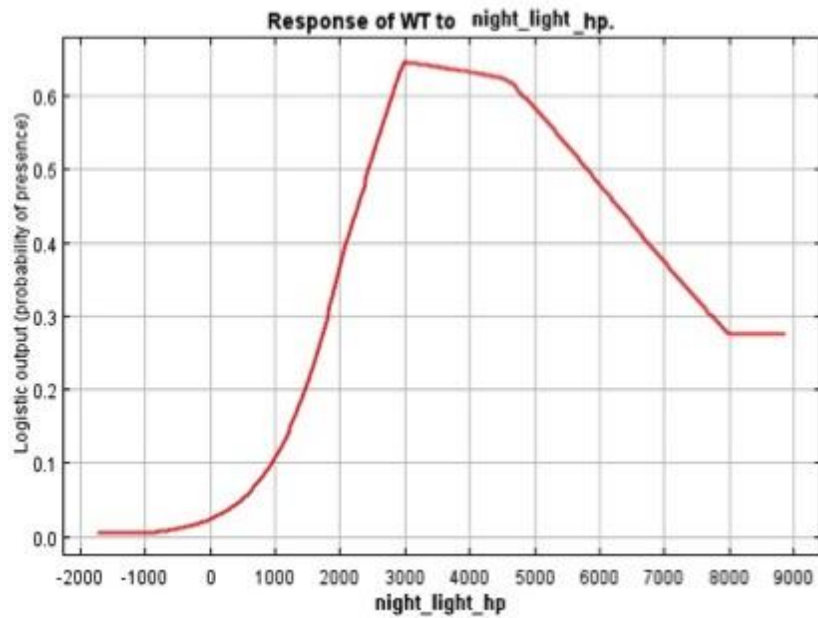
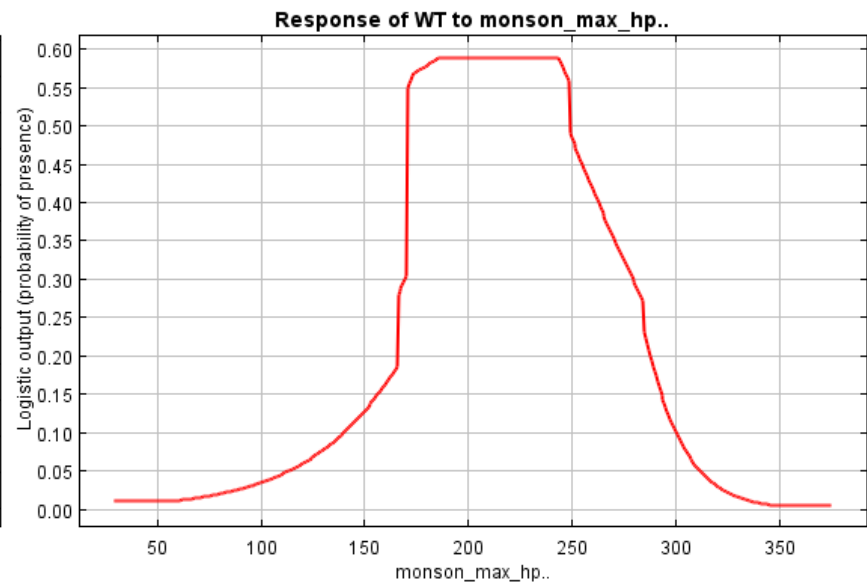
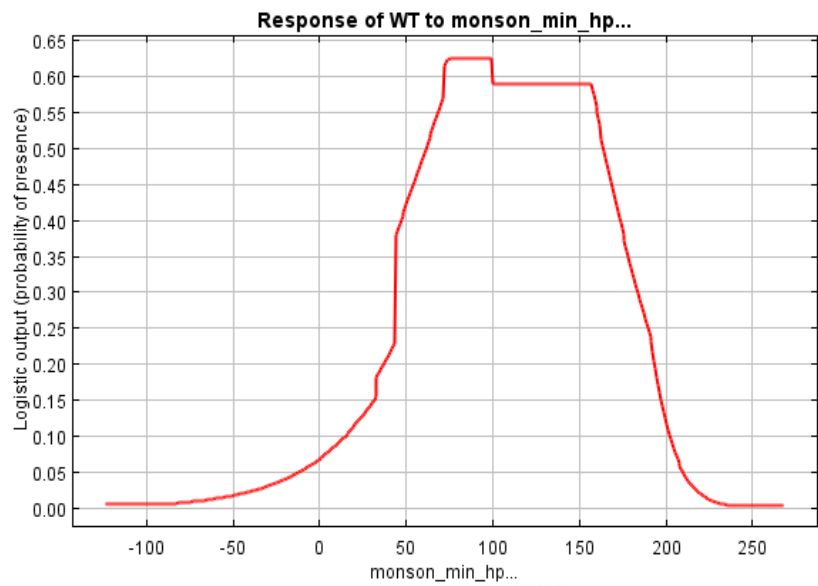


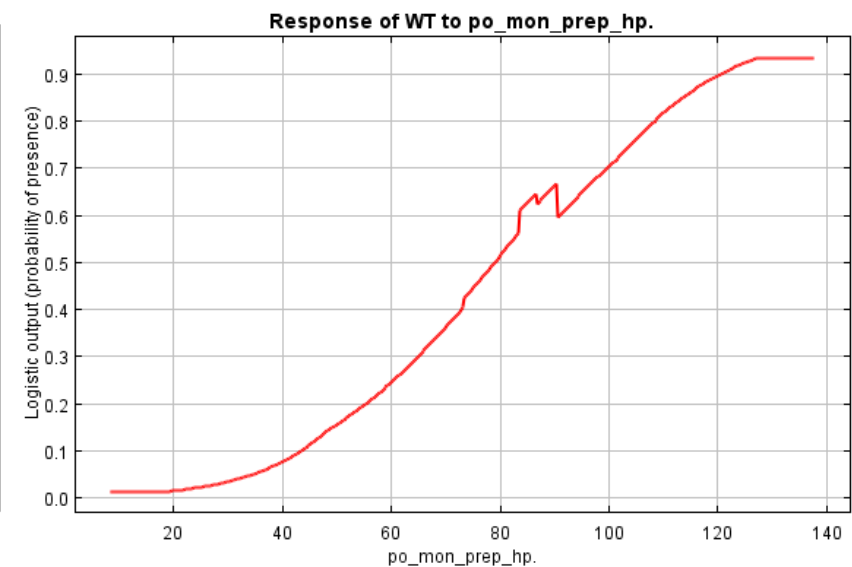
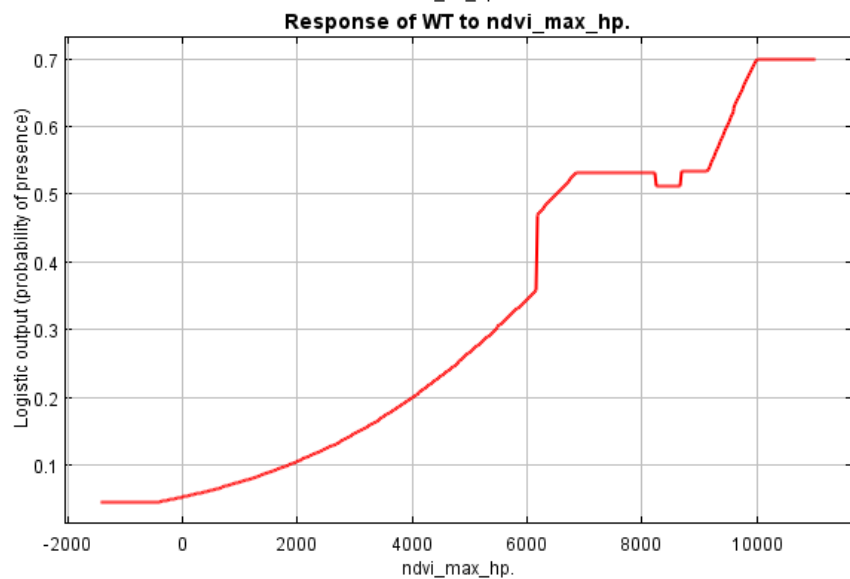
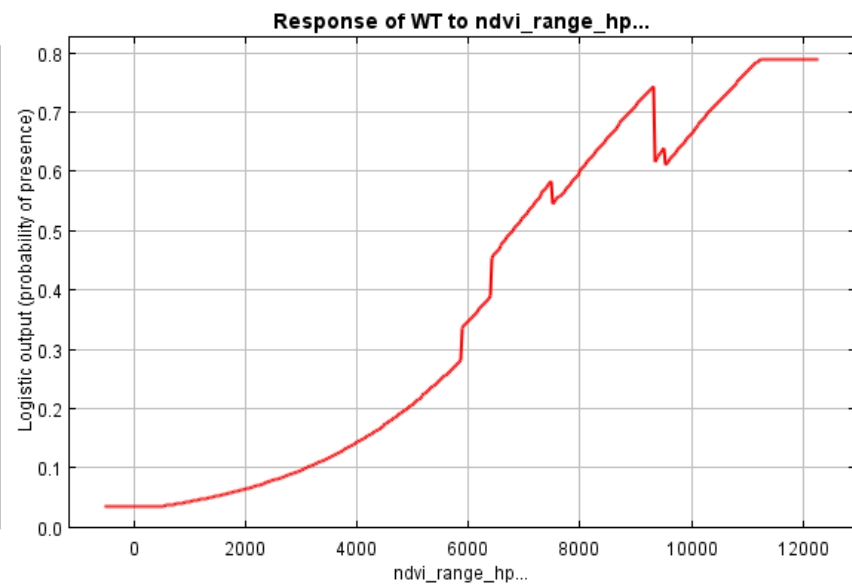
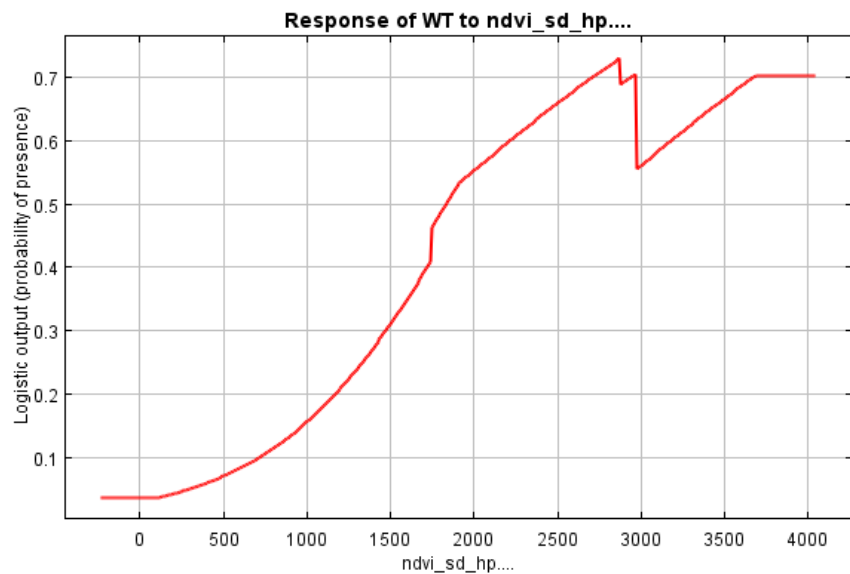
## Appendix IV: Grid-wise Categorization of Study Area

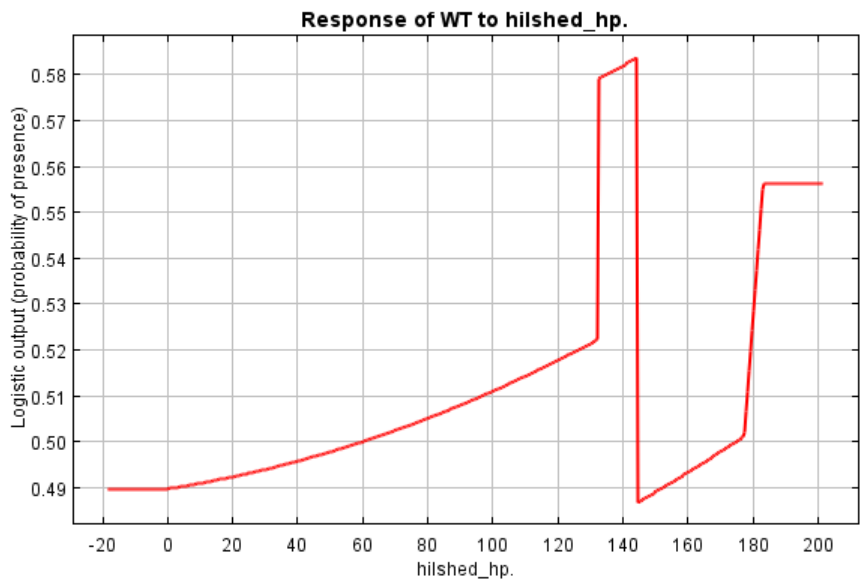
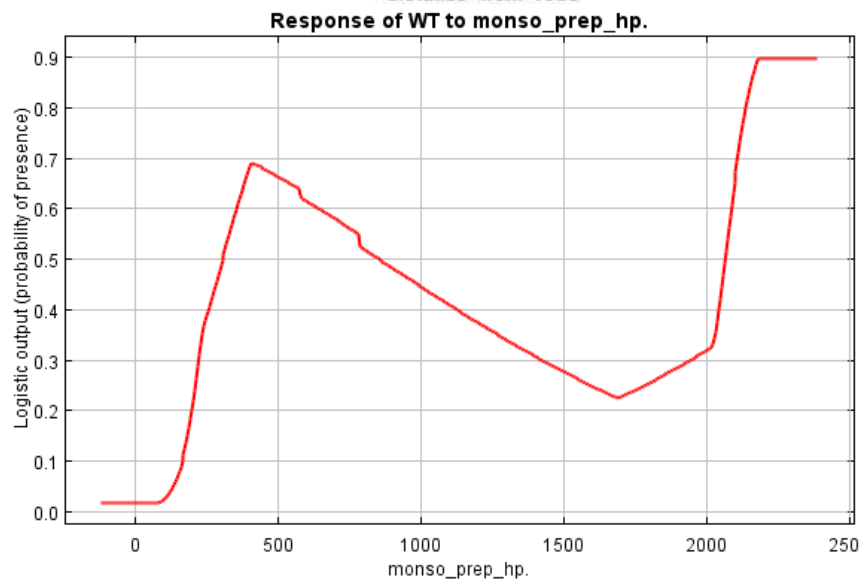
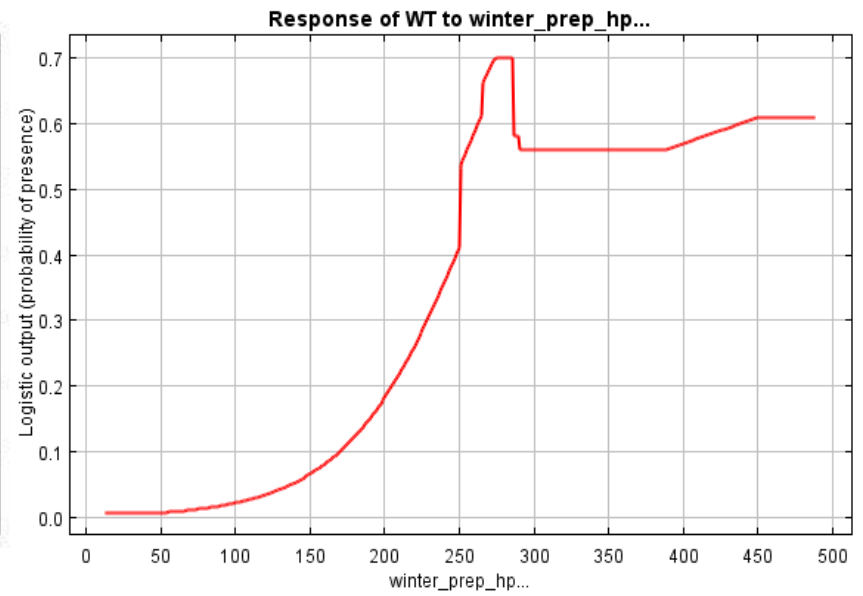
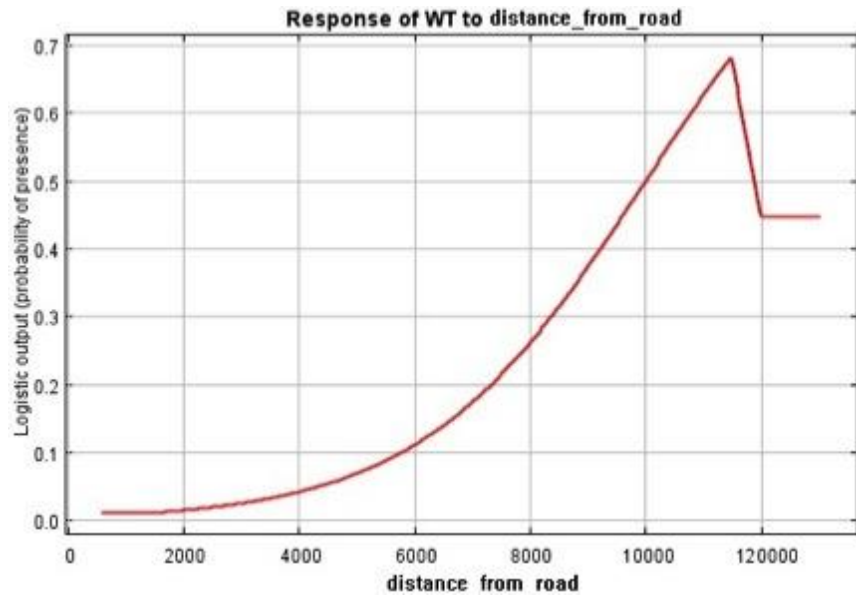
District	Grid ID	Grids having Both summer and winter habitat	Grids having only winter habitat	Grids having only summer habitat
Chamba	5-104	64, 65, 77, 80, 82-84	19-50, 52, 63, 66-69, 70-76, 78, 81, 86	79, 85, 90- 92
Kangra	143-268	223, 245- 248, 251- 253	194, 195, 198- 205, 207, 208, 215, 216, 218, 219, 221, 222, 224, , 225-244, 249-251	254, 255
Shimla	269-392	330-365	287, 305, 306, 310-312, 315, 317-329	361, 366-381, 383
Kullu	524-609	528- 592	528, 593	527, 588
Mandi	610-684	636- 640	623- 635, 642- 644, 663-666, 669	
Lahul and spiti	782-999	815, 831, 832	822	801, 814, 817, 824, 825, 827, 828- 830, 833, 834, 838, 845-847, 849- 856
Kinnaur	1000-1097	1001- 1055, 1057, 1059, 1061-1063, 1066	1068	1056, 1058, 1060, 1067, 1069
Bilaspur	Grid ID 685 to 732		None of the grids having neither summer nor winter habitat	
Una	Grid ID 733 to 781			
Hamirpur	Grid ID 105 to 142			
Nahan	Grid ID 393 to 459			
Solan	Grid ID 460 to 523			

## Appendix V: MaxEnt response curves

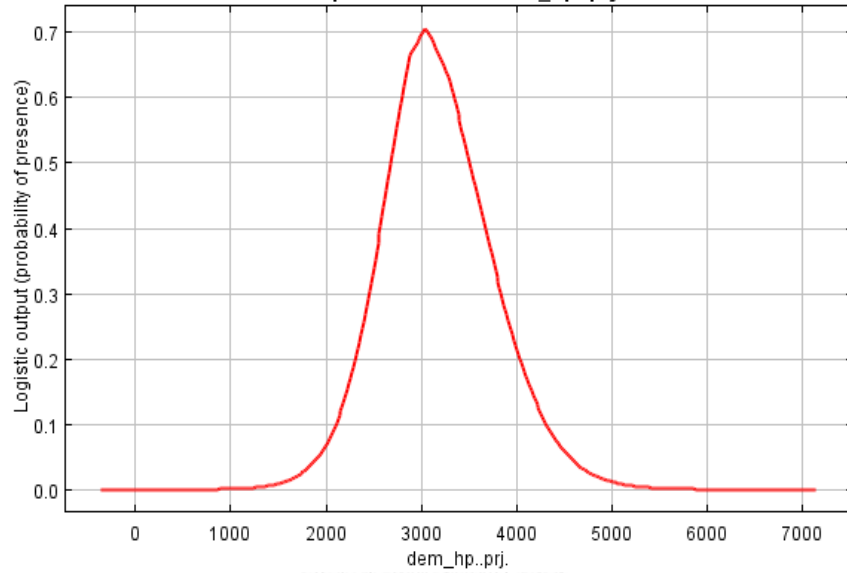




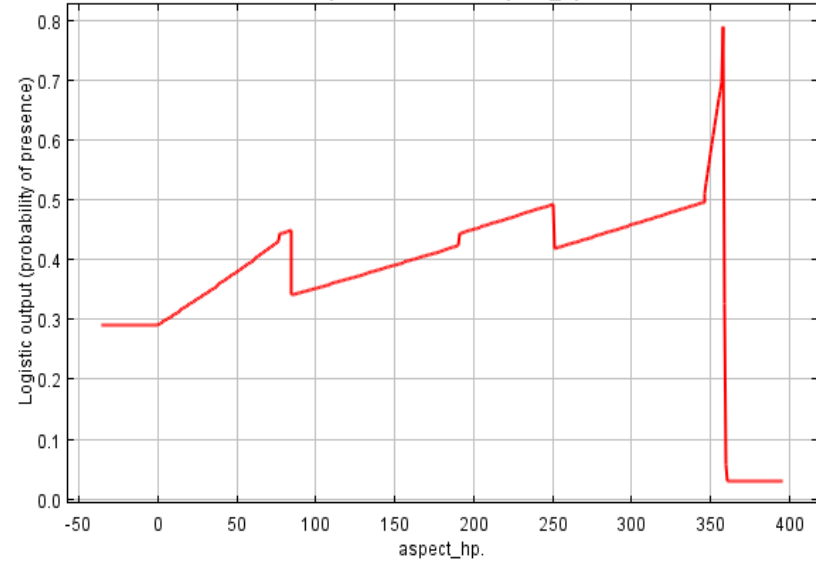




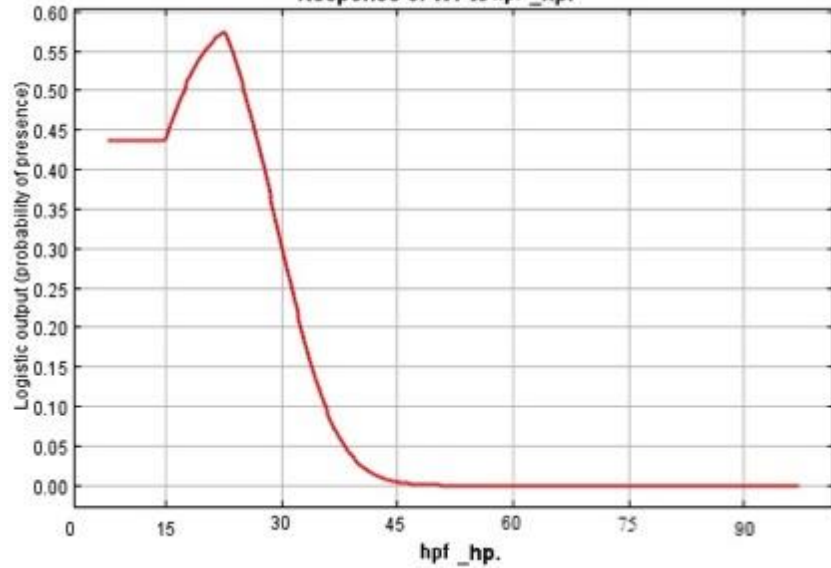
Response of WT to dem\_hp..prj.



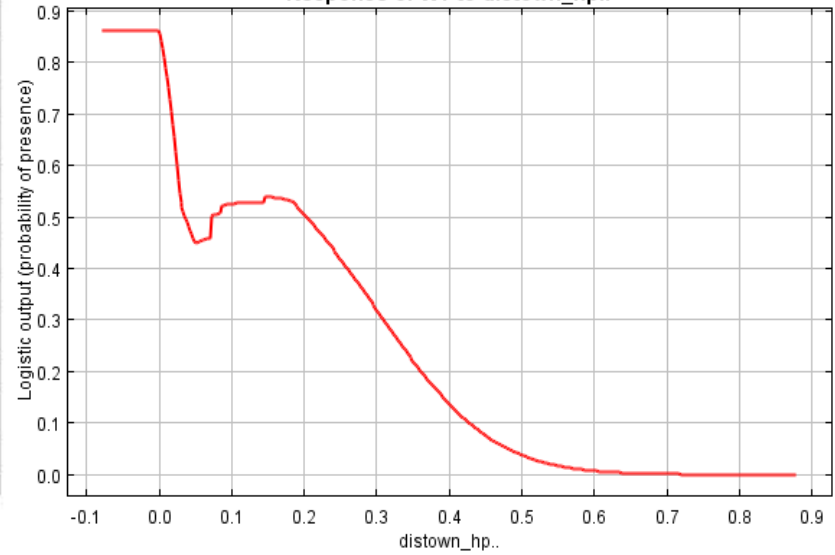
Response of WT to aspect\_hp.

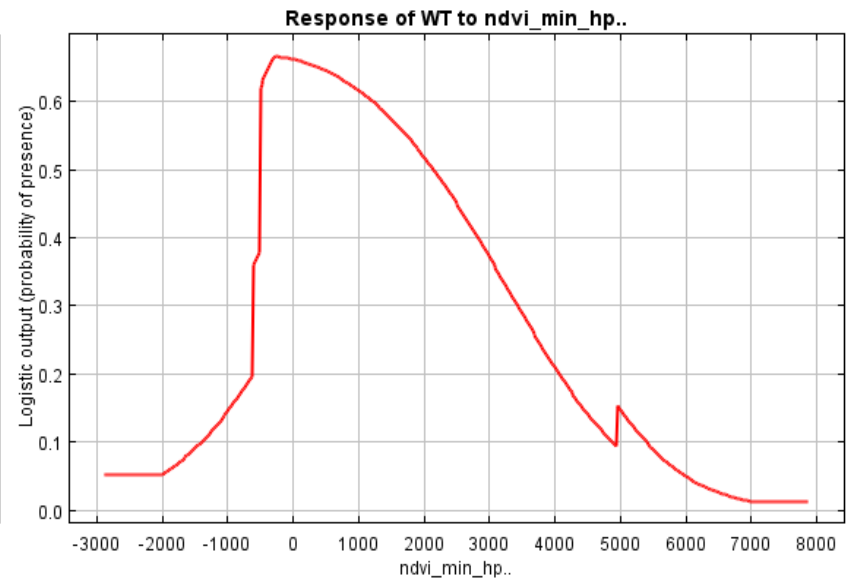
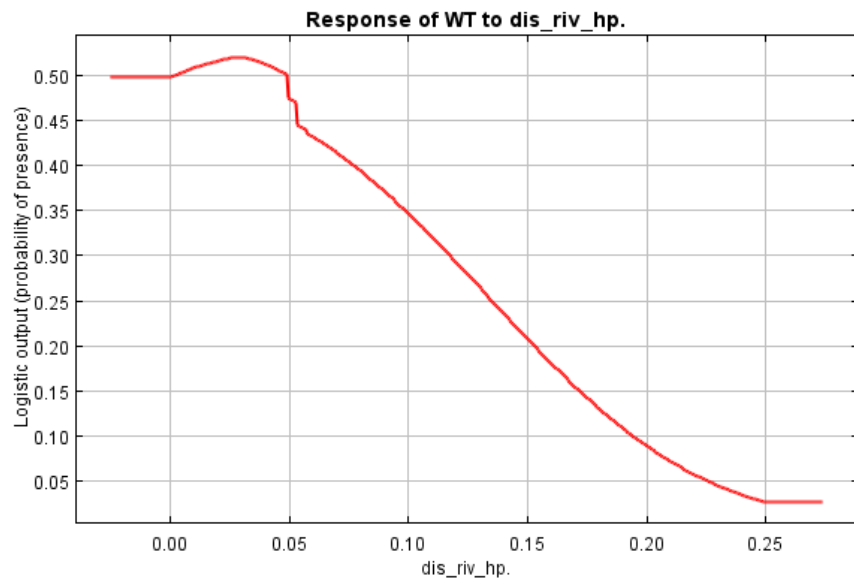


Response of WT to hpf\_hp.



Response of WT to distown\_hp..





## Appendix V: Updated Status of Western Tragopan at Sarahan Pheasantry: June 2014 to February 2018

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At the time of completion of the collaborative project between the Himachal Pradesh Forest Department and Wildlife Institute of India titled ‘Reproductive Biology and Behavior of captive and wild populations of Western Tragopan (*Tragopan melanocephalus*) in Himachal Pradesh’, between June 2011 and May 2014, the captive stock at Sarahan pheasantry comprised of 32 (+2 that was transferred to Kufri zoo) individuals. The project focused on studying and providing technical inputs for the management of the Western Tragopan captive population housed for conservation breeding purpose at Sarahan Pheasantry, and additionally carrying out surveys to assess population status of the species in the wild. This write-up follows the development of the Western Tragopan population at Sarahan Pheasantry following the three years of the projects’ completion.

A husbandry protocol was in place at the end of the collaborative project period, an outcome of the project (appended to the project report) that described the management perspectives of the population over a 10-year period along with proven – protocols developed during the project period for science – based captive care of the Western Tragopan. In 2015, one of the project fellows (Mr. Lakshminarasimha R.), who focused on conservation breeding aspect of the project, was engaged in the Pheasantry as a Zoo Biologist, continued to provide the technical inputs, although could not fully focus in Sarahan due to engagements in other zoos in the state.

### Census

The current population at Sarahan comprises of 33 individuals (14 males, 11 females and 8 juvenile birds), plus the two males housed at Kufri Zoo. In the years following the project period (2015 – 2017), 10 chicks were added to the population, mostly in the year 2017 (while 2015 had two and 2016 had none), bringing the captive stock to its current size. The age distribution of the breeding stock at the onset of 2017 breeding season is presented in Figure.1. It clearly depicts concentration of individuals at the base which are in breeding age-group, born during the previous breeding seasons. The breeding success achieved during 2017, contributed significantly to the growth of the captive population. The decreased population growth rate observed during the last two years was mainly due to mortalities of the older individuals from the captive stock,

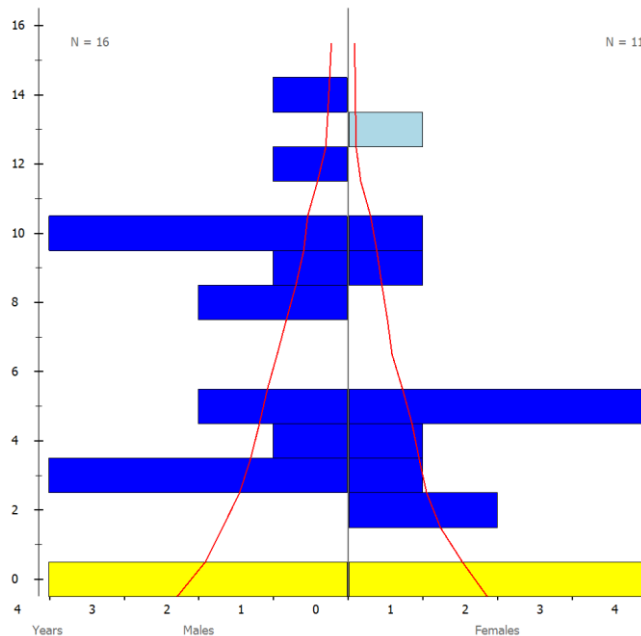
including both wild-rescued and captive-born individuals, and events like this have highly pronounced effects in small captive populations, such as this (Snyder et.al. 1996). Given the large number of young individuals (including those born in 2017) which currently constitute the captive stock (see Figure.2), optimal population growth can be expected in the following years.

Population growth, structure and lineage

The population growth rate is  $\lambda = 1.083$ , which shows that the population is in its growth phase. The demographic profile of the population is presented in Table.1. Positive spontaneous growth rates, net reproductive rates are all indicative that population is still in its growth phase.

Parameters	Value
Lambda $\lambda$	1.083
Spontaneous rate of growth r	0.080
Net Reproductive rate R0	1.746
Generation length T	6.6 years
Current gene diversity	90%
Potential gene diversity	93%

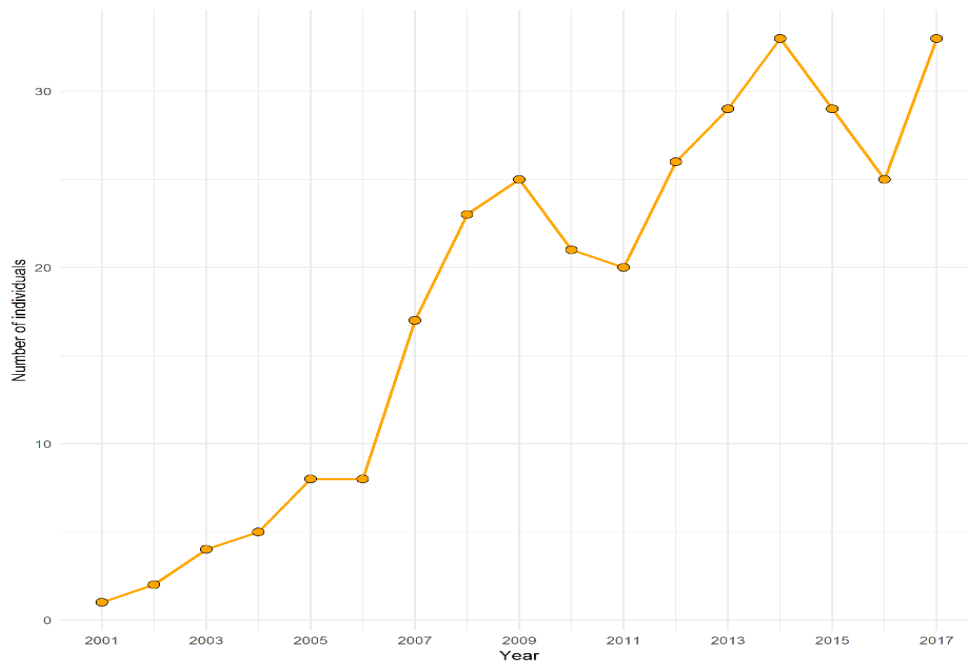
**Table 1: Demographic and genetic profile of the captive stock of Western Tragopan at Sarahan**



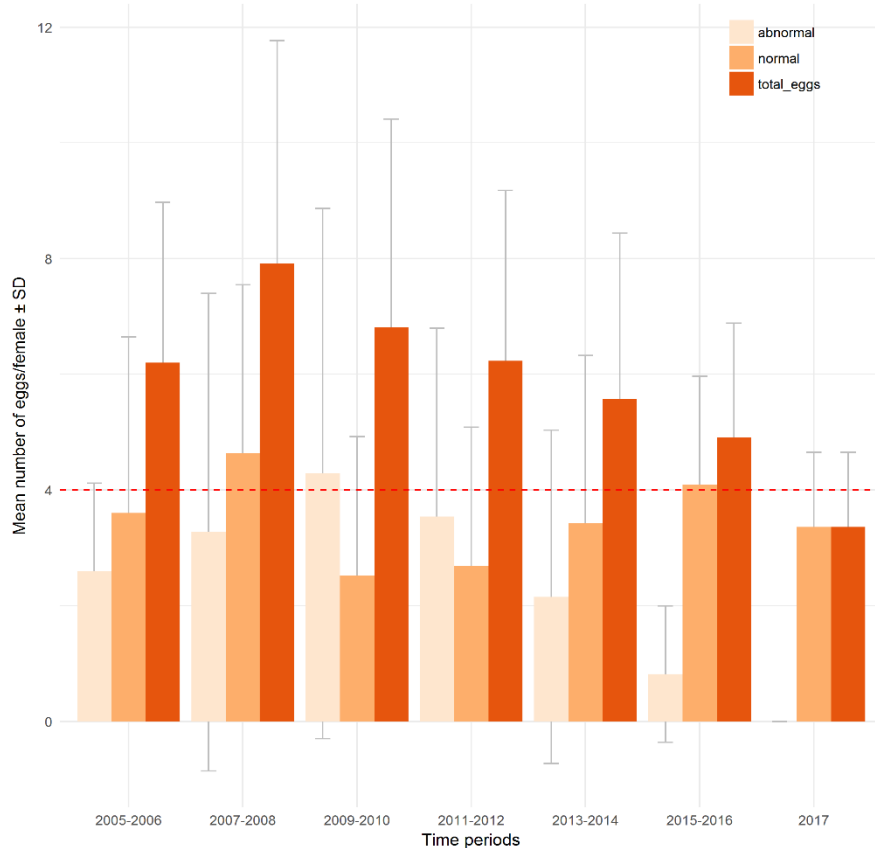
**Figure 1: Age-pyramid of the Western Tragopan captive population at Sarahan pheasantry - December 2017**

Reproductive performance of the captive stock

During 2015, two chicks fledged and in 2016, no births were recorded. During the 2017 breeding season, a total of 32 eggs were laid by nine breeding females. All the eggs were normal and no instance of abnormal eggs (thin-shelled, under-sized eggs) were reported. This is a significant achievement with reference to improvement in the reproductive health of females, as thin-shelled eggs constituted a significant proportion of the total eggs laid in the previous breeding years (Figure 3). It is evident from the figure that the changes in the husbandry regimes following 2012 have contributed significantly in improving the health of the birds at the pheasantry. Also, to note is the normalization of the clutch size, i.e. the number of eggs laid by each female per breeding season is close to the natural clutch size of the species. Natural incubation and rearing has been observed in all the females, which is the trend observed since the implementation the new husbandry practices.



**Figure 2: Census trend of the Western Tragopan captive population: 2001-2017**



**Figure 3: Pattern of egg-laying in breeding females between 2005 and 2017. Dashed horizontal line indicates the clutch size of the species in the wild.**

### Perspectives for the stock

The approach at the centre strongly adopted the principle of ‘adaptive management’, to plan and take robust decisions under uncertain conditions and consequently learn via systematic monitoring, and further applying what is learnt to optimize the decisions. Viability of small captive populations, especially those with fewer than 100 individuals is low (Traill 2010). With just over 30 individuals at Sarahan Conservation Breeding Centre, the priority is to increase the size of the collection by promoting breeding in reproductively active individuals. A husbandry regime close to the behavioral ecology of the species, such as the one currently in practice, which allows the expression of natural breeding behaviors and reduced stress levels, promotes better breeding as demonstrated. The breeding results are indicative of improved reproductive performance of females, especially given that no abnormal eggs were recorded during the 2017

breeding season. The poor reproductive performance of the stock observed during 2015 and 2016 can be attributed to the death of proven founder females, which had aged and there was no alternative plan to include suitable founders from wild populations. Also, a large proportion of breeding females in the stock, are young and lack sufficient breeding experience and hence, overall survival of the chicks is comparatively low. The breeding success observed during 2017, offers a positive outlook to the breeding program. Given that the target is set at expanding the population in the proximate future, the immediate requirement is to develop the infrastructure in order to offer optimal housing conditions to the birds. Two approaches are being undertaken to address this which includes redevelopment of old aviaries to suite modern zoo standards and construction of new aviaries to increase the carrying capacity of the centre. Option should also be explored to establish conservation breeding facility in other places in Kullu District.

Studbook of the captive Western Tragopan is regularly updated using SPARKS (Single Population Analysis and Record Keeping System) program and further analyzed using PMx (version 1.4.7) (Ballou et al. 2010). The results of this analysis are used for managing the captive stock for retaining maximum genetic diversity and ensuring low degree of relatedness among newly born individuals. The immediate demographic goal is to ensure that each wild-born individual and founder have a minimum of 10 descendants (Ballou et al. 2010). For achieving this, pairing of individuals with more than one mate (either a single male mate with multiple females or vice versa) is adopted with some breeding wild-born individuals. This ensures that wild-born birds have an increased chance to breed successfully. This system also compensates for the slightly higher number of females in the collection and in increasing the number of pairs available per unit time. The genetic diversity is planned to be maintained at close to 90% for the next ten years. As the current captive population is founded with low number of wild-born individuals, addition of new genetic material may be necessary in near future and innovative methods (those which do not disturb natural populations) are being explored for this purpose.

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Ballou, J. D., Lees, C., Faust, L. J., Long, S., Lynch, C., Bingaman Lackey, L., & Foose, T. J. (2010). Demographic and genetic management of captive populations. *Wild mammals in captivity: principles and techniques for zoo management*, 219.

Ballou, J.D., R.C. Lacy, and J.P. Pollak. 2010. PMx: software for demographic and genetic analysis and management of pedigreed populations. Chicago Zoological Society, Brookfield, Illinois, USA.

Snyder, N. F., Derrickson, S. R., Beissinger, S. R., Wiley, J. W., Smith, T. B., Toone, W. D., & Miller, B. (1996). Limitations of captive breeding in endangered species recovery. *Conservation Biology*, 10(2), 338-348.