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Habitat Characterization of Western Tragopan (Tragopan melanocephalus), Great Himalayan National Park, India

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Abstract
The *T. melanocephalus* is one among the poorly studied threatened pheasant of the world. It is endemic to North Western Himalaya with a narrow range from Hazara in north Pakistan through Jammu & Kashmir to Garhwal in India. The study was a part of multidisciplinary research project undertaken in the Great Himalayan National Park Conservation Area (GHNPCA), Himachal Pradesh, India as GHNPCA is one of the two national parks in the world that supports a substantial population of *T. melanocephalus* and their population is on the decline. The Study area is highly undulating and very difficult to cover by ground, and hence, Remote Sensing and GIS based modeling study was taken up to understand and predict the spatial occurrence pattern of this species in GHNPCA for preparing better conservation plan. Satellite data were used to prepare land use and land cover map about the study area. Ground based survey was conducted to do sighting and inventory. Based on sighting data the spatial parameters like altitude, slope, aspect, and distance from human interference, interspersion, and juxtaposition were analyzed for extracting carrying capacity of individual classes. The integrated evidence based class weights were derived from these individual carrying capacity values and in combination with expert's importance weights the final habitat suitability map was derived. This model is based on the occurrence of the species during the non-winter majority of the time period. The study revealed that only 10.44% of the area is highly suitable and which is spread over the western part of the study region. The species moves to completely different places during winter and this dynamism need to be taken into account in future studies to arrive at definite conclusions about their spatial occurrence pattern.

Keywords: GHNPCA, western tragopan, interspersion, juxtaposition, habitat characterization, habitat suitability index

1. Introduction

Habitat is a combination of landscape elements often characterized by vegetation, landform and hydrology [1] It has also been defined as the location that supports a population including space, food, cover and other animals [2]. Habitat forms crucial component for any living organism and any negative impact on the habitat generally affects the survival of the species. Human population, pollution, change in climate, habitat alteration due to deforestation; fragmentation and degradation are the main threats to biodiversity [3]. Surveys conducted in the late 1990's indicated that pheasant populations in the Great Himalayan National Park, Conservation Area (GHNPCA), Himachal Pradesh were declining. Populations of pheasant species; Western tragopan, Koklass Pheasant and Himalayan Monal were subsequently surveyed in the park during the breeding season (April–May) in 2008 [4]. The Western tragopan (*Tragopan melanocephalus*) is listed as "Vulnerable" by the IUCN and on Schedule I of the Indian Wildlife (Protection) Act of 1972 [5]. *T. melanocephalus* occurs in low density and inhabits understory forest in temperate region [6].

The contribution of ecological components strongly influences the overall decision making in habitat characterization and natural resource utilization. Integration of spatial and field based information is an important process in habitat characterization. GIS technology, on account of its ability to compile and analyze spatially related data is a powerful tool for habitat management [8, 9]. So far no modelling has been done on habitat suitability of *T. melanocephalus* using Remote Sensing (RS) and Geographical Information System (GIS) although few ecological studies have been undertaken on this species [10, 11, 12], there is still inadequate information available on this species, for developing holistic species conservation plans. Moreover with the exception of [13], who has mapped the potential habitat zones of *T. melanocephalus* using RS, all other studies were based on ground methods that have limitations due to vast rugged terrain and limited resources.

RS and GIS technologies in ecological studies have been in use for the past 30 years mainly for mapping, but in the last two decades spatial modeling efforts were prominent to predict the habitat suitability of interested species [14, 15, 16, 17, 18, 19]. Although for bird distributions relative to remotely sensed habitats in Great Britain: Towards a framework for national modeling was also studied [20]. Likewise for critically endangered Himalayan Quail (*Ophrysia superciliosa*), mapping the potential distribution of the using proxy species and species distribution modeling was also done [21].

T. melanocephalus are endemic to the Western Himalaya region of South Asia and are threatened by change in land-use, hunting and fragmentation of its habitat [22]. GHNPCA is one of the two national parks in the world that supports a substantial population of *T. melanocephalus* [23]. This bird is locally known as "Jujurana" (King of Birds). It is endemic to North Western Himalaya with a narrow range from Hazara in north Pakistan through Jammu & Kashmir to Garhwal in India [7]. *T. melanocephalus* has a disjunct distribution in the western Himalayas [24], occurring from the Indus-Kohistan district, north Pakistan, east through Kashmir and Himachal Pradesh to Uttarakhand, north-west India [25]. It is been considered to be as a range restricted species (ICBP, 1992). The global status of the population is precariously low (<5000individuals) and seem that they have about only 2000-3000 km^2 for survival in the entire distribution range [26, 27]. These are distributed in temperate coniferous forest having sufficient understory with vegetation fir (*Abies pindrow),* blue pine (*Pinus wallichiana),* spruce (*Picea smithiana),* maple (*Acer caesium),* birch (*Betula utilis),* walnut (*Juglans regia)* and horse chestnut (*Aesculus indica)* or at the upper edge of the tree line, between 2500-3000 m in summer [28, 10]. It occupies the dense coniferous forest of the northern aspect at 2000-2800m, during winter [10]. Inhibits area with dense vegetative cover (canopy cover) [13]. Maximum use areas mixed conifer and broad-leaved forest with Arundinaria undergrowth and, sub-alpine Oak Forest in spring season [12]. The diet of *T. melanocephalus* includes newly sprouted leaves, roots, flowers, insects, acorns, seeds, and berries. However, the major portion of their diet consists of leaves of various plants [28]. They are found at higher elevations in Blue pine, Spruce, Fir, and Birch vegetation in the breeding season while in winter they inhabit the dense Oak patches mixed with Deodar on drier slopes [28, 29]. During winter, when the habitat is snow bound with little resource availability they move to lower elevations. This is the period when they face competition for food and other resources from other pheasants and are also affected by poaching incidences.

Efforts were made to generate the Habitat Suitability Index (HSI) for *T. melanocephalus* in GHNPCA between 1996-2000 using RS and GIS technologies. The present study provides valuable and significant inputs for management of wildlife habitats and monitoring in GHNPCA. For that, information on food, water, and shelter and site condition suited to a particular animal species should be known accurately. The spatial relationship between cover types, their respective areas, nearness to water, suitable corridors for daily movement and seasonal migration are also important in determining the habitat suitability for wildlife. However, such studies generally require elaborate surveys on the ground along with rational scientific methodology. To achieve this, pseudo spatial indicators based on ground evidences, which would be indirectly revealing ground situation, were utilized for grading and selecting various sites in the study area so as to facilitate the development of appropriate management practices. The study would help in the conservation and reveals the spatial distribution of potential occurrence, of *T. melanocephalus* in GHNPCA.

2. Methodology

2.1 Study Area

The study was conducted in GHNPCA over an 1171 km^2 area lying between 31^0 33' 00" N to 31^0 56' 56" N and 77^0 17" 15" E to 77^0 52' 05" E. The study area terrain is highly undulating in nature with minimum and maximum altitudes vary between 1344 m and 6248 m respectively (Fig.1).

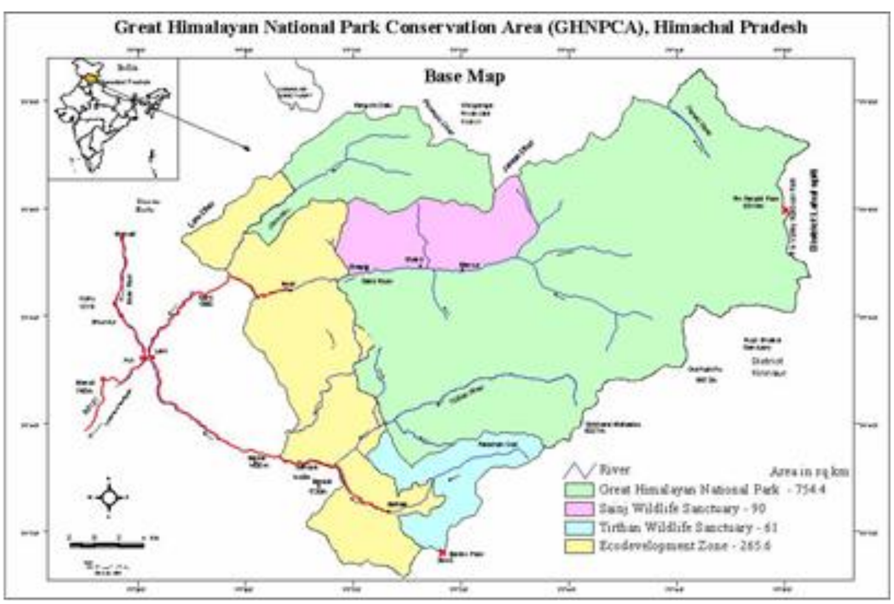

Fig 1: Base Map, Great Himalayan National Park Conservation Area

Visual interpretation of Indian Remote Sensing Satellite (IRS-IB) LISS II data was carried out for land use /cover mapping. Other ground data and restrictive factors for animal species were incorporated based on inventory data. Contours were digitized and interpolated to develop a Digital Elevation Model (DEM) and a slope map was derived. Landscape characteristic metrics like interspersion and juxtaposition were calculated. All the habitat, terrain and landscape parameters were evaluated using software routines developed in database management system interfaced with ARC/INFO software. Spatial modeling was done to determine the habitat suitability of *T. melanocephalus.* Following sections explain the data and methods in detail

2.2 Field Observations and Habitat Range Identification

The inventory data and locations of *T. melanocephalus* were mapped during 1997-99. The sightings were used for habitat characterization [30, 12]. The territory of the bird was worked out to be about 500 m [12]. On the basis of sighting evidences the minimum and maximum elevation has been determined to be between 2750m and 2890m. Likewise slope condition ranges have been considered as Min. 25^0 and Max. 45^0. Aspect use range was found Min. SE and Max. NW. Vegetation map was used determining habitat preferences. Based on the physiognomy and dominance with combination of vegetation types [31] present in the study area have been recognised as Sub-tropical Pine Forest (9/C1b, Temperate Moist Deciduous Forests (12/C1e, Temperate Broadleaved-conifer mixed Forests (12/C1d; 12/C2b, Temperate Coniferous mixed Forests (12/C3a),Temperate Broadleaved (Evergreen) Forest (12/C2a) Kharsu Oak Forests, Himalayan Temperate Secondary Scrub, Birch-Rhododendron Scrub, Alpine Scrub, Temperate Grasslands, Alpine Pastures [30]. The range identification map for *T. melanocephalus* was developed using ground-sighting data along with slope, elevation and aspect values. In addition to this, weightages were assigned to various parameters, used for habitat characterization through overlay analysis (Fig.2).

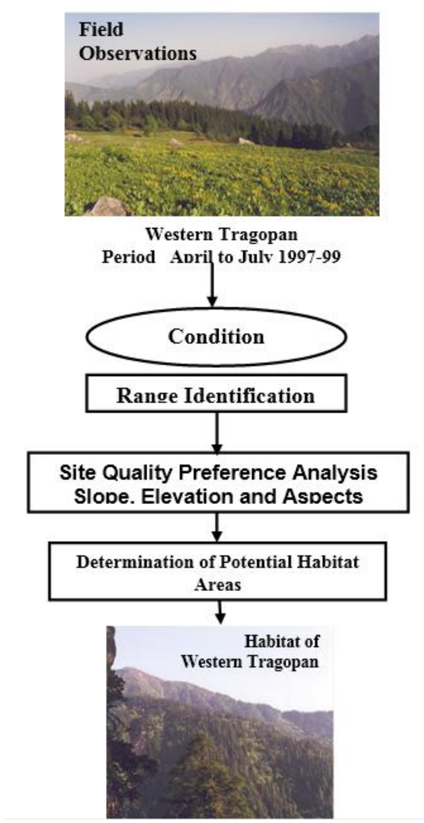

Fig 2: Delineation of Sighting Areas for *T. melanocephalus*

2.3 Habitat Analysis

GIS technology is playing an increasingly important role in conservation biology and wildlife management because it provides an efficient means for modelling potential distributions of species and habitats [32, 19, 33]. GIS modelling of species-habitat associations is one form of land suitability analysis. The deductive approach extrapolates known habitat requirements to the spatial distributions of habitat factors. HSI can also be calculated from the spatial configuration of a single data layer [15].

2.3.1 Interspersion

The interspersion is a measure of spatial intermixing of habitat/landuse and is calculated in a non species- specific manner. In GIS domain a window is panned over vegetation map and an interspersion value is assigned to the central grid to prepare the interspersion map. Interspersion of central cells is calculated as the number of surrounding cells, differing from the central cell [19]. The maximum limit of interspersion is 8 for a 3x3 neighbourhood grids. As raster data is more appropriate for this operation; grid GIS was used for parameter derivation. Grid size can be changed as per the required level of details. Considering the territory/home range size of *T. melanocephalus* grid size of 500m by 500m were used. Interspersion values provide an indication of an area in terms of homogeneity and heterogeneity (table no. 1).

Table 1: Area Statistics for Interspersion Grid size 500 m x 500 m

	Area in km^2	Percentage
Homogeneous	209.96	17.93
	143.24	12.23
	152.35	13.01
	172.94	14.77
to	164.43	14.04
	137.27	11.72
	103.97	8.88
	67.99	5.81
Heterogeneous	18.85	1.61
Total	1171	100

The dispersal ability of species depends on the spatial organization of landscape. Certain fragile/rare species occur only in highly connected landscape mosaic. From this point of view, calculation of interspersion gives the zoomed view of resistance, the central pixel or central class has with respect to its surrounding. Higher value of interspersion means the dispersal ability of central class will be low or in other words the influence of the resistance by neighbors will be much which may lead to the obliteration of the central class.

2.3.2 Juxtaposition

The juxtaposition is a measure of adjacency of vegetation types, accomplished by defining the grid, placed on a forest type map based on the field observation of the habitat size [19]. Juxtaposition map has two components.

1. Spatial adjacency weightage definition
2. Class / Type adjacency weightage definition

Under second component, as per the field observations over the requirement of the species, *T. melanocephalus*, necessary vegetation type combination, which are suitable for the species were given the weightages as depicted in table no. 2.

Table 2: Spatial Adjacency and Conversion into Weightages The above spatial type adjacency was converted into weightages (table no. 3). Grid wise Interspersion and juxtaposition was calculated in GIS domain for habitat characterization.

<table>
<tr><td colspan="7">Forest Type</td></tr>
<tr><td colspan="3">Subalpine Broad leaved</td><td colspan="3">Subalpine Broad leaved</td><td>Temperate Broad leaved</td></tr>
<tr><td colspan="3">Subalpine Broad leaved</td><td colspan="3">Subalpine Broad leaved</td><td>Temperate Broad leaved</td></tr>
<tr><td colspan="3">Subalpine Broad leaved</td><td colspan="3">Subalpine Broad leaved</td><td>Temperate Broad leaved</td></tr>
<tr><td colspan="7">T. melanocephalus</td></tr>
<tr><td colspan="3">1</td><td colspan="3">1</td><td>0.9</td></tr>
<tr><td colspan="3">1</td><td colspan="3">x</td><td>0.9</td></tr>
<tr><td colspan="3">1</td><td colspan="3">1</td><td>0.9</td></tr>
<tr><td colspan="7">Matrix for T. melanocephalus, juxtaposition measure is Σ Matrix 1 * Matrix 2</td></tr>
<tr><td>1</td><td>2</td><td>1</td><td rowspan="4">*</td><td>1</td><td>1</td><td>0.9</td></tr>
<tr><td>2</td><td>X</td><td>2</td><td>1</td><td>x</td><td>0.9</td></tr>
<tr><td>1</td><td>2</td><td>1</td><td>1</td><td>1</td><td>0.9</td></tr>
<tr><td>1</td><td>2</td><td>1</td><td>1</td><td>1</td><td>0.9</td></tr>
<tr><td colspan="7">1*1+2*1+1*0.9+2*1+2*0.9+1*1+2*1+1*0.9 = 11.6</td></tr>
</table>

Table 3: Juxtaposition Weightages Matrix

	Pinus roxburghii	**Temp. mixed conifer**	**Subalpine M-conifer**	**Conifer & broad leaved mixed**	**Broad leaved & conifer mixed**	**Sobtropical broad leaved**	**Temp. broad leaved**	**Subalpine broad leaved**	**Riperian**	**Secondary scrub**	**Dryalpine scrub**	**Subtropical grassland**	**Temperate grassland**	**Subalpine grassland**	**Alpine grassland**	**Habilation/Agri/Orchard**	**Cliffs**	**Exposed rock with slope grasses**	**Alpine exposed rocks with grasses**	**Landslide**	**River**	**Sand bar**	**Lakes**	**Morain**	**Morainic island**	**Glacier**	**Permanent snow**	**Plantation**
Conifer (*Pinus roxburghii*)	0	0.1	0.4	0.3	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temp. mixed conifer	0.3	1.0	0.6	0.8	0.6	0.2	0.8	0.6	0.3	0.2	0.1	0	0.5	0.5	0.2	0.1	0.7	0.5	0	0	0.8	0	0	0	0	0	0	0.2
Subalpine M-conifer	0	0.6	0.3	0.4	0.1	0	0.1	0.7	0.1	0.1	0	0	0	0	0	0	0.3	0.7	0	0	0.5	0	0	0	0	0	0.1	0
Conifer & broad leaved mixed	0.2	0.5	0.7	0.5	0.1	0.3	0.4	0.6	0.5	0.4	0.3	0	0.8	0.5	0.1	0.1	0.2	0.2	0.1	0	0.7	0	0	0	0	0	0	0.5
Broad leaved & conifer mixed	0.2	0.5	0.3	0.6	0.2	0.3	0.6	0.5	0.4	0.3	0.2	0	0.3	0.6	0.3	0.1	0.3	0.3	0	0	0.2	0	0	0	0	0	0	0.3
Subtropical broad leaved	0	0.5	0.3	0.3	0.3	0	0.6	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temp. broad leaved	0.1	0.7	0.4	0.4	0.5	0	0.5	0.8	0.2	0.1	0.1	0.1	0.1	0.1	0	0	0.5	0.7	0	0	0.5	0	0	0	0	0	0	0
Subalpine broad leaved	0	0.7	0.8	0.5	0.7	0	0.9	1.0	0	0.1	0.7	0	0.4	0.6	0.1	0	0.5	0.6	0.1	0	0.7	0	0.4	0	0	0	0.4	0.1
Riperian	0	0.3	0.1	0.5	0.4	0	0.2	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Secondary scrub	0	0.2	0.1	0.4	0.3	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dryalpine scrub	0	0	0	0	0	0	0.1	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtropical grassland	0.1	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperate grassland	0	0.5	0.1	0.3	0.2	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subalpine grassland	0	0.1	0.3	0.4	0.2	0	0.4	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alpine grassland	0	0	0.1	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Habilation/Agri/Orchard	0	0.4	0.2	0.3	0.2	0	0.1	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cliffs	0	0.7	0.5	0.2	0.3	0	0.3	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exposed rock with slope grassess	0	0.7	0.5	0.4	0.2	0	0.2	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alpine exposed rocks with grasses	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Landslide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
River	0	0.8	0.5	0.7	0.2	0	0.5	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sand bar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morain	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Morainic island	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glacier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Permanent snow	0.2	0.2	0.1	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantation	0	0.2	0	0.5	0.3	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2.4 Habitat Model

For modeling, the sighting based statistical evidential weightages were assigned for *T. melanocephalus* for the period April –June from 1997 to 1999. The statistical evidence approach considers the sighting data as its prime source and these sighting was overlayed over other input data so as to extract carrying capacity of each class in sighting. These individual carrying capacity values were converted into weights after combining values of all the individual classes in a map. Likewise, the same approach was used for the buffer map. All these contributing weightages were were used for habitat suitability analysis. These assigned values are depicted in the tables 3, 4 and 5. The approach for habitat suitability analysis is depicted in Fig 3.

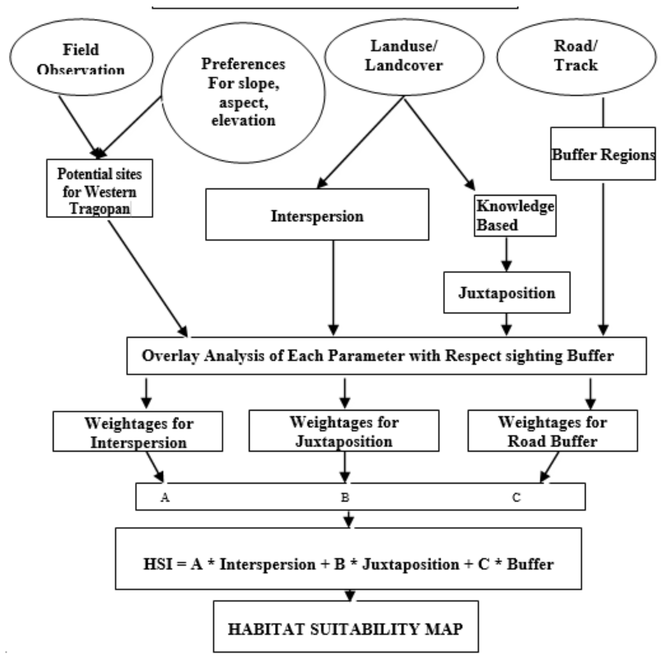

Fig 3: Habitat Suitability Model

Step 1.

Class carrying capacity index *= Area of a class coming under sighting / Total area of the class*

This can be done by crossing vegetation map with sighting map or interspersion with sighting or juxtaposition with sighting.

Step 2.

Class contributing index or Class evidential index = *Class carrying capacity index / Sum of the entire classes carrying capacity index*

The weightages are given from Table 4 and 5.

Table no. 4 Juxtaposition, Buffer and Interspersion Weightages

Juxtaposition Weightages		Buffer Weightages		Interspersion Weightages	
Value	Weightage	Value	Weightage	Value	Weightage
0	0.01	0	0.00	0	0.02
1	0.07	2000m or m 2km	0.02	1	0.05
2	0.10	1800m	0.04	2	0.08
3	0.08	1600m	0.06	3	0.09
4	0.07	1400m	0.10	4	0.12
5	0.09	1200m	0.12	5	0.15
6	0.10	1000m or 1km	0.14	6	0.16
7	0.12	800m	0.14	7	0.16
8	0.09	600m	0.14	8	0.16
9	0.07	400m	0.13	Total	1.00
10	0.06	200m	0.11		
11	0.07	Total	1.0		
12	0.07				
Total	1.00				

Table 5: Landuse/ Landcover Map Weightages

Forest type	Weightage	Forest type	Weightage
Pinus roxburghii	0.00	Permanent snow	0.00
Temp. conifer & broad leaved mixed	0.13	Habitation/Agriculture/ Orchards	0.05
Temp. broad leaved & conifer mixed	0.12	Glacier	0.00
Reparian	0.04	Morain	0.00
Temp. secondary scrub	0.12	Plantation	0.00
Alpine scrub	0.00	Morainic Islands	0.00
Exp. Rocks with slope grasses	0.04	Temp. broad leaved	0.13
Escarpment	0.01	Kharsu forest	0.11
Alpine exp. Rocks with slope grasses	0.00	Temp grassland	0.08
Landslides	0.13	Sub alpine grassland	0.03
Lakes	0.00	Alpine grassland	0.00
River	0.08	Temp. mixed conifer	0.05
		Subalpine fir	0.01
Total Weightage = 1.0			

The ground sighting condition-extracted map was used to assign weightages. It has been considered as a restrictive factor. Roads/Tracks were considered as a potential habitat disturbance factor. This map was also prepared by generating a distance buffer around roads. The contributing weightages were given for each zone i.e. 200m based on animal sighting data. The Buffer map is shown in Fig 4.

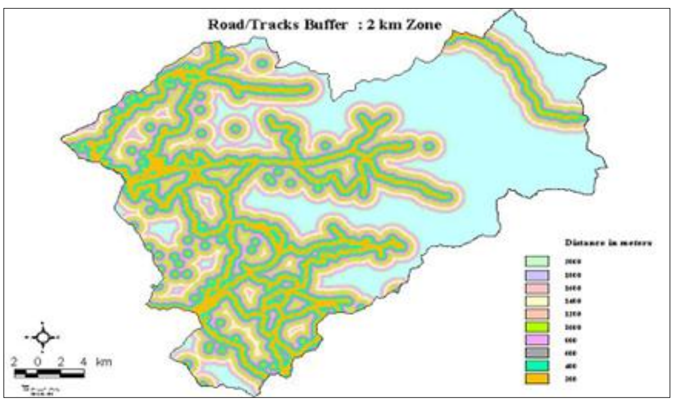

Fig.4 great Himalayan National Park Conservation Area (GHNPCA), Himachal Pardesh, Road/Track Buffer: 2 km Zone

2.4.1 Habitat Suitability Index (HSI)

HSI for *T.S melanocephalus* was developed by assigning appropriate weightages to each parameter, i.e., Landuse/Landcover, interspersion, juxtaposition and restrictive factors. The equation for HSI is as follows:
$HSI = \Sigma W_I * P_{wi}$ Where W_I = *Importance weightage* P_{wi} = *Parameter contributing weightage for* i^{th} *class* Here parameters are interspersion (Is), juxtaposition (Jx) and restrictive factor (Rf) *Habitat Index* $= (0.2*Is) + (0.6*Jx) + (0.2*Rf)$ Since the juxtaposition Index represents the required spatial suitability of vegetation types for the species, its presence is felt important on the ground, and hence the higher weightages were given. Each cell was assigned a HSI ranging from 0 to 1.

3. Results and Discussion

An extensive literature search has revealed that models using remote sensing and GIS have not been developed for *T. melanocephalus*. Hence, no real comparison could be performed. Model provides an index of habitat suitability on a numerical scale (0.0 to 1.0, where 0 indicates unsuitable habitat and 1 indicates optimum habitat) [33]. The models are based on the assumption that a positive relationship exists between the index and habitat carrying capacity. It is important that these models be considered as a hypothesis of species-habitat relationships rather than positive proof of cause and effect relationships. A similar study has also been performed using the model for the Musk Deer (*Moschus chrysogaster*) in Great Himalayan National Park [34].

In our study the locations of *T. melanocephalus* were mapped in ARC/INFO GIS domain during the fieldwork. Thus the influence of field observations were already taken into account in terms of the contributing weightages by overlaying the field sighting buffer with ground layers *viz.* like vegetation, slope, aspect, interspersion and juxtaposition. Besides the physical parameters of macro-habitat (DEM, slope and aspect), accuracy of biological parameters such as land cover is vital to generate potential distribution maps for any species [35].

It is apparent from table 6 that a substantial area (24%) is under low suitability class for the *T. melanocephalus* and only about 10.44 % of GHNPCA provides a highly suitable habitat for this species whereas about 43.49 % of the area is not at all suitable for *T. melanocephalus*. By overlaying climatic zones on the habitat suitability map for *T. melanocephalus under* alpine zone 305 km^2 (97%) comes under low suitability; 8 km^2 (2%) comes under medium suitability and 1 km^2 (0.3%) comes under high suitability class. The suitable areas are possibly the ecotone areas between subalpine and alpine zones. Specifically in Parvati valley the Alpine zone was detected around 3% (40 km^2), perpetually snow bound and therefore does not provide suitable habitat for the *T. melanocephalus.*

Table 6: Area under Each Habitat Suitability Class One of the methods of validation of *T.* melanocephalus HSI model was done by overlaying field sighting map with Habitat suitability map

Habitat Suitability Class	Area km	Percentage
Low	279.79	23.87
Medium	259.73	22.18
High	122.3	10.44
Very High	0.01	0.00
Not Suitable	509.37	43.49
Total	1171	100.00

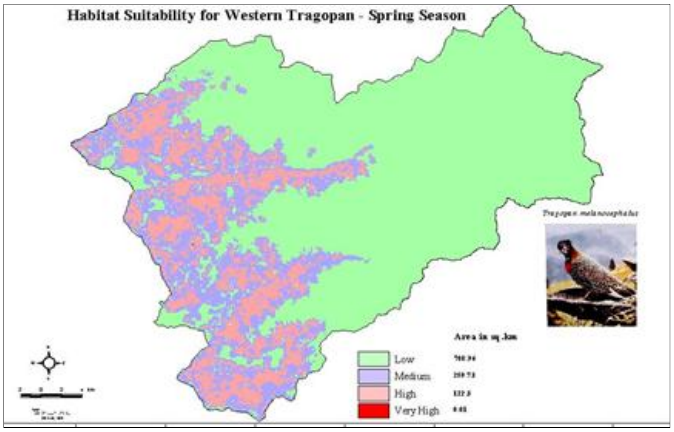

Fig 5: habitat suitability for *t. melanocephalus*: spring season. graet himalayan national park conservation area (ghnpca) himachal pardesh

The attempt was made to determine the habitat suitability and availability of potential habitats of *T. melanocephalus*, based on several ground based parameters as well as using spatial analytical techniques in GHNPCA. A survey report of the potential areas of *T. melanocephalus* was also prepared for finding habitat contiguity and presence of pheasants population in parts of Uttarkashi, U.P. using RS and GIS [13], reflected the habitat contiguity of *T. melanocephalus* in Himachal Pradesh and in Western parts of U.P. Himalayas.
The study has amply demonstrated the potential of RS and GIS in conjunction with ground data for determining the habitat suitability for this vulnerable species. Though the estimation of microhabitat can be done using high spatial resolution data such as canopy density, shrub cover and litter cover. This would further refine the inference of the potential distribution of the *T. melanocephalus*. Some end users of GIS analysis accept that the output products should be critically evaluated with respect to accuracy. The usefulness of GIS is now limited more by data availability and quality as well as by the reliability of habitat preference models. In this study, medium to low-resolution satellite data used, high spatial resolution data can significantly improve estimation of the biological features of microhabitat, such as canopy density, shrub cover and litter cover. Under-storey vegetation is a critical component of biodiversity and an essential habitat component for many wildlife species [22].
Based on the available information appropriate management interventions are needed to ensure long term conservation of this species in its habitat range. The model parameters will need to be reviewed and refined on the basis of better datasets on the species distribution and abundance will have to be taken into account. This would further refine the estimation of the potential distribution of the T. *melanocephalus*.

4. Conclusion
GHNPCA, considered with unique Himalayan biological diversity, provides shelter for several endangered species. Because of Forest loss, land conversion, hunting, fodder and fuel wood collection, disturbance by human, the quality and carrying capacity of habitat are declining and these are the major threats for species and for their habitat. The survival of the *T. melanocephalus* depends on protecting their habitat. The current study provides the information about the species of specific habitat requirements. It is required to execute such an approach for the species, which are vulnerable and will extinct due to shrinkage and conversion of their habitat. Similarly, further refined studies must be undertaken for developing HSI models for this species in the GHNPCA for ensuring their effective conservation.

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