Mapping Equus kiang (Tibetan Wild Ass) Habitat in Surkhang, Upper Mustang, Nepal

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Introduction

Satellite technology and GIS are now well-accepted tools for establishing and modeling spatial information about wildlife habitat (Mongkolsawat and Thiragoon 1999). Habitat is any spatial unit that can be occupied by an individual animal, no matter how briefly (Liu 2001). All habitats include at least a source of food, protective cover, space, and water (Dasmann 1981; Best 1984). A habitat map records the structure of the landscape. The map structure, related directly to real features on the ground, can help in understanding the environment. It shows the inter-connectivity of landscape features, their immediate context, and the wider area in which environmental influences operate. This type of map helps to show how ecological principles can explain patterns of biodiversity. By understanding the extent and distribution of an organism’s habitat, resource managers can predict the distribution and abundance of target wildlife species populations (Morrison et al 1992).

Knowledge of habitat type is of vital importance for species conservation and restoration activities. The availability of a suitable habitat determines the existence of an individual species. Similarly, a complex of various habitat types, with their spatial dimensions and contingencies, can either favor or hamper the potential for existence of a species, depending on the type. This is of greater importance in terms of species ecology than habitat mapping. Habitat classification involves grouping of components into homogeneous habitat units, on the basis of characteristics significant to wildlife species. It also distinguishes between land cover categories (Best 1984). Habitat mapping is similar to any type of land cover mapping (Lindgren 1985; De Wulf et al 1988; Liu 2001).

Habitat analysis at the landscape level, using remotely sensed data and GIS, offers the potential to help explain species diversity patterns at fine-scale resolutions (Debinski et al 1999). Wildlife issues that can be addressed with GIS technologies include determination of wildlife and habitat distribution and abundance, identification of wildlife–habitat associations, and development of long-term habitat and population monitoring programs (Ramsey et al 1999).

General description of the kiang

Equus kiang, the Tibetan wild ass, is one of the world’s least-studied species. The kiang (Table 1; Figure 1) was originally
Equus kiang is widely distributed in Tibet (China), Nepal, and India (Wilson and Reeder 1993; Schaller 1998; Moehlman 2002; Wang 2002). It is found in the Dolpo and Mustang areas of Nepal (Schaller 1998; Moehlman 2002). The species was first spotted in Nepal in June 2001 (37 individuals in Chhusang, Upper Mustang or UM), raising the recorded number of mammalian species in this country to 185 (TRN 2002). The recording of the kiang as a new species in Nepal has increased concern over its habitat status in UM. Land cover classification and habitat mapping were carried out for this VDC over an area of about 784 km². The region is situated in the Himalayan rain shadow and receives less than 100 mm of rainfall annually (HMGN 1999). Altitude ranges from 3000 m to over 6000 m. The entire area is under snow cover for about 4–5 months from November to March. The UM region is considered the southernmost extension of the Tibetan plateau. Alluvial fans, jutting sandstone ridges, abandoned glacial moraines, and broad sandy terraces are the visible forms of landscape in the region. Mean annual daytime temperature is usually around 21°C, but at night it may fall to 5°C. Only herders and pastoralists visit the wilderness area of this VDC to the north, often for only 2–3 months in summer.

More than 40% of the UM is rangelands and pastures at altitudes from 3000 m to higher than 5000 m (Blamont 1997). The area is known to be extremely rich in flora and fauna, especially steppe habitats. Though UM covers only 1.74% of the country’s total land area, it contains a high percentage of threatened mammal species. This region is relatively undisturbed and serves as an excellent refuge for Tibetan wildlife species (Shah et al 2002). It is also a corridor for many trans-Himalayan migratory birds. Its high-altitude rangelands are home to the endangered snow leopard and other species, including the Tibetan wolf, the Tibetan argali (a mountain sheep), lynx, brown bear, and endangered plant species (UNDP 2000).

**Materials and methods**

**Study area**

The present study was carried out in Surkhang, one of the 7 Village Development Committees (VDCs are the smallest administrative unit in Nepal) of UM, Nepal. The study area ranges approximately from 28°50’19”–29°09’10” N and 83°49’41”–84°15’16” E. Land cover classification and habitat mapping were carried out for this VDC over an area of about 784 km².

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**Remote sensing data**

The most recent surface radiance image (October 2002) and a digital elevation model (DEM), both obtained from ASTER (Advanced Spaceborne Thermal
Emission and Reflection Radiometer Sensor, were used for land cover classification. ASTER covers a wide region, with 14 bands from the visible to the thermal infrared, with high spatial, spectral, and radiometric resolution. The spatial resolution varies with wavelength: 15 m in the visible and near-infrared (VNIR) region, 30 m in the short-wave infrared (SWIR) region, and 90 m in the thermal infrared (TIR) region.

The image of the study area, consisting of only 9 bands from VNIR to SWIR (the bands in the thermal region were excluded owing to their coarse resolution), was geo-referenced with the help of topographic map sheets. Naturally visible features such as ridges and river joins were used to locate Ground Control Points (GCPs), as they offer the advantage of easy location. A first order polynomial transformation with a nearest neighbor resampling technique was used, as this method offers the advantage of computational simplicity (Lillesand and Kiefer 2000) by directly assigning the digital number (DN) in the input file that most overlaps the pixel in the output file, making it unnecessary to alter the original input pixel values (Richards 1993). The root mean square error was 0.21 pixels.

The Normalized Difference Vegetation Index (NDVI) was calculated from the reflected solar radiation in the near-infrared (NIR) and red (RED) wavelength bands using the algorithm:

\[
\text{NDVI} = \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + \text{RED})}
\]

The NDVI is a nonlinear function, which varies between −1 and +1, but is undefined when RED and NIR are both zero. The NDVI can be used as an indicator of the amount of green biomass, and is a promising tool for distinguishing regions with and without vegetation in image analysis, which is often used to improve classification results.

Principal component (PC) images allow redundant data to be compacted into fewer bands—that is, the dimensionality of the data is reduced. The PC bands are non-correlated and independent, and can often be interpreted more easily than source data. Moreover, they yield better classification results (ERDAS 1999).

Aspect in general has greater significance for vegetation characteristics, as it determines the amount of radiation available for plants. Aspect and slope are used as predictors of vegetation types throughout the world (Hamilton et al 1997). NDVI and PC images were obtained from the ASTER image. Similarly, images of altitude, slope, aspect, and stream networks were derived from DEM.

Supervised image classification is an essential tool used for extracting land cover information from remotely sensed image data (Richards 1993). Training areas were selected throughout the study area in order to obtain representative samples for each land cover class (Lillesand and Kiefer 2000). Field observations, aerial photograph interpretation, topographical maps, and GPS surveys were used at this stage. These training sites included all the types of land cover designed for classification work. Spectral signatures were collected from a wide range of altitudes, from 3000 to 5600 m, and from sites with differences in topographic slope and aspect, as species characteristics differ for varying slope and aspect. Ground truth data were collected for both classification and evaluation. The region was classified into 6 land cover types based on relevance for habitat mapping. These classes are described in Table 2.

### Table 2: Description of land cover classes used to classify the study area.

<table>
<thead>
<tr>
<th>Land cover class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture and settlement</td>
<td>Villages and community settlements, adjoining crop fields and tree stands. Usually trees and crop fields are near the clustered houses. Almost all of this class lies along riverbanks. This is the pattern of settlement throughout the UM region.</td>
</tr>
<tr>
<td>Bare land</td>
<td>Land surface with little or no cover (i.e. less than 10% vegetation cover). Rockfall areas are also included in this class.</td>
</tr>
<tr>
<td>Water bodies</td>
<td>Perennial rivers, streams, rivulets, glacial lakes (frequently found above 5000 m), and other permanent water bodies; small rivers that remained dry during the time of image acquisition are not included.</td>
</tr>
<tr>
<td>Grassland</td>
<td>Prevalent land cover in the area, occurring above 4000 m. All high-altitude pastures with smooth slopes consist of alpine grasses. Habitat highly favored by blue sheep and other grazers.</td>
</tr>
<tr>
<td>Shrubland</td>
<td>Second most prevalent class as of 3000 m, with dominant <em>Lonicera obovata</em> and <em>Caragana</em> spp., sometimes also <em>Berberis</em> spp.</td>
</tr>
<tr>
<td>Snow cover</td>
<td>Peaks with permanent snow cover, usually found above 6000 m.</td>
</tr>
</tbody>
</table>
species. Although details of habitat quality can be assessed with the use of habitat suitability index models, the life form approach and the guiding approach, a general overview of the habitat in terms of vegetation type, land use, and geo-topographical features can also be used in predicting habitat (BCDP 1994).

Literature on the kiang and its habitat (Groves 1974; Schaller 1998; Walker and Nowak 1999; Moehlman 2002; Shah et al. 2002) was reviewed. First-hand information collected during the field visit was also used to describe the general habitat preference of the species. Suitability criteria were then developed and the region was classified into 3 habitat types, designated as primary, secondary, and non-suitable.

“Primary habitat” in this study is the type that kiangs can use throughout the year and which offers the basic habitat requirements of food, shelter, and water. “Secondary habitat” serves some specific needs, such as breeding, bathing, etc. This includes areas that are either not available throughout the year or not always required for all individuals. “Non-suitable habitat” is the type which serves no purpose for the kiang, either because of ecological factors such as the unavailability of food, water, and cover, or unsuitability due to topography, ie low altitude, higher slope, or disturbance factors such as demographic interference.

In classifying a place as unsuitable, disturbance factors must be taken into account. In addition, habitat that does not fall into the previous 2 categories, ie primary and secondary, is also classified as non-suitable. This habitat type cannot be used by the species for food, shelter, or water, but may be of limited use in connecting spatial units of discontinuous suitable habitat types.

Altitude is the major topographical factor that determines kiang habitat. Altitudes between 4650 and 6000 m were identified as a suitable habitat for the kiang. Similarly, slope is also an important topographical factor. A slope of less than 15° is a suitable habitat. An altitudinal range from 4650 to 5340 m was considered the primary habitat, as kiangs were observed there, while altitudes from 5350 to 6000 m were considered secondary. Altitudes higher or lower than this were considered non-suitable owing to ecological restrictions on the presence of kiangs.

Grassland, shrubland, and water are sources of food and cover. These cover types, in relation to the limitations of altitude, determine whether a place is a primary, secondary, or non-suitable habitat type. Similarly, water and bare land are other important habitat components that can be either primary or secondary, depending on the requirement of the species. Bare land within the 4650–6000 m altitudinal range serves as a breeding habitat (during July and August) and thus was considered to be secondary, as such areas are not used by the kiang throughout the year.

The nearest water source need not be close, as kiangs do not use water frequently. However, kiangs enjoy taking baths in summer. Two conditions were established in the habitat, ie for food requirements and social activities. An area further than 2 km from the nearest water source was considered to be secondary habitat, which kiangs use for social activities like bathing, while areas closer than 2 km were considered primary habitat, as water is required for drinking.

An undisturbed region is a must for the wild species to survive. Based on the topography and type of human movement in the region, areas closer than 5 km from the nearest community were considered non-suitable habitat, as kiangs do not tolerate the slightest level of disturbance by humans. In the remote areas of the UM region, it is less likely that local people visit more than 5 km of linear distance from their place of settlement, due to the harsh topography.

Transhumance is prevalent in Mustang, with people taking domestic sheep and goats to pastureland uphill during summer. The communities of Surkhang VDC take their domestic sheep and goats to a pastureland called Damodar Kunda Valley, a biodiversity hotspot.

### TABLE 3 Criteria for assessment of kiang habitat suitability.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Primary habitat</th>
<th>Secondary habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation</td>
<td>4650–5350 m</td>
<td>4650–6000 m</td>
</tr>
<tr>
<td>Distance from nearest community</td>
<td>&gt; 5 km</td>
<td>&gt; 5 km</td>
</tr>
<tr>
<td>Slope</td>
<td>0°–15°</td>
<td>0°–15°</td>
</tr>
<tr>
<td>Land cover</td>
<td>Grass/shrub/</td>
<td>Grass/shrub/water</td>
</tr>
<tr>
<td></td>
<td>water/barren</td>
<td>water/bare</td>
</tr>
<tr>
<td>Distance from water</td>
<td>&lt; 2 km</td>
<td>&gt; 2 km</td>
</tr>
<tr>
<td>Distance from temporal pasture</td>
<td>&gt; 5-km radius</td>
<td>&lt; 5-km radius</td>
</tr>
<tr>
<td>Habitat</td>
<td>Other than</td>
<td></td>
</tr>
<tr>
<td></td>
<td>primary</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 4 Description of band combinations (BC) and accuracy obtained.

<table>
<thead>
<tr>
<th>BC</th>
<th>Constituent bands</th>
<th>Overall accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bands 1, 2, 3, 4, 5, 6, 7, 8, 9</td>
<td>77.78 %</td>
</tr>
<tr>
<td>2</td>
<td>Bands 1, 2, 3, 4, 5, 6, 7, 8, 9 and Aspect</td>
<td>79.07 %</td>
</tr>
<tr>
<td>3</td>
<td>Bands 3, 5, 7, 8, 9, PC1, NDVI and Aspect</td>
<td>91.73 %</td>
</tr>
<tr>
<td>4</td>
<td>Bands 3, 5, 7, 8, 9, NDVI and Aspect</td>
<td>92.25 %</td>
</tr>
</tbody>
</table>
(Koirala and Shrestha 1997) located at 4900 m. This pastureland has been reported by Moehlman (2002) as one of the two potential *kiang* habitats in Mustang. This valley is also of religious significance to Hindus and Buddhists, and pilgrims visit this place during summer. The combined effect of transhumance and religious activities makes this area unsuitable for the *kiang* for about 4 months during summer. Thus, an area closer than 5 km from the center of the valley, where Damodar Kunda is located, was considered a secondary habitat. The criteria for habitat mapping based on the discussion above are summarized in Table 3.

Layers of data containing altitude, distance from community, slope, and land cover were prepared. The stream networks, derived from DEM, were used to find the distance from a water source, together with the water bodies identified by image classification. This was

<table>
<thead>
<tr>
<th>Class</th>
<th>Percent cover</th>
<th>Area in km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture and settlements</td>
<td>0.31</td>
<td>2.44</td>
</tr>
<tr>
<td>Bare land</td>
<td>20.19</td>
<td>158.31</td>
</tr>
<tr>
<td>Water bodies</td>
<td>1.82</td>
<td>14.25</td>
</tr>
<tr>
<td>Grassland</td>
<td>36.01</td>
<td>282.34</td>
</tr>
<tr>
<td>Shrubland</td>
<td>32.57</td>
<td>255.38</td>
</tr>
<tr>
<td>Snow cover</td>
<td>9.11</td>
<td>71.40</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.00</strong></td>
<td><strong>784.11</strong></td>
</tr>
</tbody>
</table>

**FIGURE 2** Land cover map of Surkhang, Upper Mustang, Nepal. (Map by Benktesh D. Sharma)
done to include water sources missing in image classification due to limited spatial resolution. Similarly, a layer with the distance from temporal pastures was also created. Analytical queries on the criteria mentioned in Table 3 were formulated and implemented in GIS, and the areas of each habitat type were identified. After the two suitable areas were identified and unified, all other areas were designated as non-suitable.

Results and discussion

Classification results

Detailed analysis of the available spectral and DEM information that showed 4 combinations (in Table 4) was promising in terms of distinguishing the 6 classes (Sharma 2003). To find the most suitable bands for classification, these combinations were classified using a maximum likelihood classifier with a 95% confidence interval, and the results were evaluated. The same set of signatures was used for each combination. The overall accuracy obtained is given in Table 4.

Since classification of band combination (BC) 4 gave the best overall classification accuracy, consisting of bands 3, 5, 6, 7, 8, 9, NDVI and aspect, this was used for final classification and preparing the land cover map of the region.

A 3 x 3 majority filter was applied in order to smoothen the salt-and-pepper appearance in the classified image according to the methods and rationale described by Eastman (1997). Land cover statistics, expressed as area in km² and as a percentage, are presented in Table 5, and the land cover map is presented in Figure 2.

Habitat suitability for the *kiang* in Surkhang, Upper Mustang

The spatial analysis carried out gave the following results for *kiang* habitat suitability:

Figure 3 shows that in Surkhang, an area of about 71 km² was found to be a suitable habitat for the *kiang*. This is 9.12% of the total area. Of the suitable habitat types, only 32.44 km² (about 4%) is primary, while slightly more, ie 39.04 km² (4.97%), is secondary.

A range of suitable areas was delineated by including all the suitable areas in one large polygon that would serve as the boundary of the region with *kiang* habitat suitability. Conservation efforts conducted with respect to *kiang* habitat should be carried out inside this boundary. The suitable range covers an area of 340.43 km². The range thus specified provides a general picture of the habitat status of the *kiang* in Surkhang, and includes some patches of non-suitable habitat type as well. These non-suitable habitat types inside the range can have limited use, extending from one suitable type to another. The habitat suitability map for the *kiang*, with the identified regions, is presented in Figure 4.

Conclusions

Classification of land cover is possible with a high level of accuracy by using an ASTER image of the region. Similarly, habitat suitability mapping is possible when information on habitat requirements for the target species is available. This is the first study that employed image analysis for these purposes in the study area. Very few studies have been carried out in UM in general, and little information is available on *kiang* habitat. As a species that lives on open terrain found in UM, the *kiang* has approximately 71 km² of suitable area available at the moment. The total area for suitable habitat was found to be about 340 km² within Surkhang, UM. However, if disturbance factors, especially transhumance, could be halted or regulated, the area suitable for the *kiang* would increase considerably.
This study provides information on land cover and kiang habitat that can be used in the management information system (MIS) of the King Mahendra Trust for Nature Conservation (KMTNC), which is currently managing the UM region. These data should be used for zoning activities such as zoning the kiang habitat types in any conservation or restoration activities planned in the area. Information coming from rangeland-related studies such as botanical studies could be used together with the data from this study to further advance kiang habitat studies. In future, a similar study using older remote sensing images could help increase understanding of the land cover dynamics of the region. Such a multitemporal analysis would show the changing land resource and development activities in the region and can help responsible authorities and institutions understand the impact of their work.

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REFERENCES


Koirala RA, Shrestha R. 1997. Floristic Composition of Summer Habitat and Dietary Relationships Between Tibetan Argali (Ovis ammon hodgsonii), Naur (Pseudois nayaur) and Domestic Goat (Capra hircus) in the Damodar Kunda Region of Upper Mustang in Nepal Himalaya [MSc thesis]. Osloveien, Norway: The Agricultural University of Norway.


