CHAPTER 5

HOME RANGE, RANGING PATTERN AND HABITAT

UTILIZATION OF RHINOCEROS IN

SAURAHA SECTOR, CHITWAN NATIONAL PARK
Chapter 5
Home Range, Ranging Pattern and Habitat Utilization of Rhinoceros in Sauraha Sector, Chitwan National Park

5.1 Introduction

Habitat is the place where animal can persist suitably by utilizing resources such as food, water, shelter and environment (Goddard, 1967; Mukinya, 1973; Smith, 1974; Frame, 1980; Conway and Goodman, 1989; Berger and Cunningham, 1995) that can ensure avoidance of potential competition for maintaining population through reproduction (Caughley and Sinclair, 1994). The environmental conditions influences distribution of different vegetation types and maintain heterogeneity among them in resource quantity and quality (Brahmachary et al., 1971). Resource quantity and quality are not uniform in all habitats and variations appear within a season between habitats and within a habitat between seasons (Bell, 1971; Lahan and Sonowal, 1973; Debroy, 1986; Roy, 2009).

The spacing behavior and home ranges varies among different megaherbivores (Owen-Smith, 1988). The sizes of the home ranges are directly related to animal body size (Owen-Smith, 1988); in addition the social structures and behavioral pattern (Laurie, 1982; Schenkel and Hulliger, 1969) of the animal species also have some bearings on the home range sizes (Schoener, 1968; Turner et al., 1969; Gittleman and Harvey, 1982; Lindstedt et al., 1986; Kenward et al., 2001; Jhala et al., 2009). Besides this availability of food, forest quality, sex differences
and metabolic requirements also influence the home range size in various species (Jennrich and Turner, 1969; Laurie, 1978; Harris et al., 1990; Fjellstad and Steinheim, 1996; Hazarika, 2007). Habitats with abundant food, water and least disturbance for wildlife usually have small home range sizes (Williams, 2002). Natural barriers such as rivers, hills and unfavorable habitats often impose restrictions along with several other artificial barriers such as dams, canals, walls, fencing and agriculture settlements (Johnsingh et al., 1990; Joshua and Johnsingh, 1995).

Analysis of habitat utilization pattern is an important aspect of wildlife conservation management ecology to draw a comprehensive conservation strategy relevant to any protected area (Dinerstein and Price, 1991; Jnawali and Wegge, 1991; Jethva, 2002). Roy et al. (1995) states that conservation of wildlife needs an entire knowledge of their spatial requirements commonly referred to as habitat. Habitat evaluation, an assessment of the suitability of land or water, for a particular species requires information on constraints pertaining to the biotic and abiotic components of the habitat, in particular the food, water and shelter (Kushwasha et al., 2000). Increasing anthropogenic pressures on the habitat has an alarming impact and threatening to the majority of wildlife habitat around the world (Panwar, 1991). Rhinoceros are in critical demographic crisis; primarily by over-exploitation through poaching for its valuable horn and other products and secondarily by loss of habitat due to expanding and developing human settlements (Foose & Strien, 1997; Dinerstein, 2003). Preferred habitat is defined as that area of land or water where wild animals can satisfy their nutritional
requirements well and found proportionately more often than other areas (Neu et al., 1974; Dixon and Chapman, 1980; Byers et al., 1984; Aebischer et al., 1993). The conservation manager needs to know which habitat is most preferred by the rhinoceros when a decision has to be taken to enhance the habitat management.

The greater one horned rhinoceros prefer to inhabit in the alluvial floodplain vegetation of sub-tropical climate where water and green grasses are available all year round (Laurie, 1978). Annual monsoon floods altered the spatial distribution of these successional grasslands but maintained prime grazing habitat and high rhinoceros densities (Lehmkuhl, 1989; Jnawali, 1995; Dinerstein, 2003). For greater one horned rhinoceros, major threats are habitat loss, alteration and fragmentation (Sukumar, 1989; Amato et al., 1995; Dierenfeld et al., 2006). Increasing human population around the protected areas and their associated activities are disturbing factors to the preferred rhinoceros habitats in Sauraha and other parts of the CNP.

Habitat use and habitat utilization pattern of the greater one horned rhinoceros have been conducted by Laurie (1978), Dinerstein and Price (1991), Jnawali (1995) and Subedi (2012) in the Terai grasslands of Chitwan and Bardia National Park of Nepal. A number of studies in CNP were carried out by several researchers on the aspects of space and habitat use (Jnawali & Wegge, 1993), dry season habitat use (Fjellstad and Steinheim, 1996), habitat preferences, diet analysis and ranging behavior of reintroduced rhinoceros in Bardia National Park and Suklaphanta Wildlife Reserve, Nepal in comparison to the source population.
of CNP (Jnawali, 1995). The present study carried out from 2009 to 2011 aims at finding out home ranges, movement pattern and habitat utilization of rhinoceros in Sauraha sector of Chitwan National Park, Nepal for drawing comparison how these parameters have changed with time by increasing human population and pressures around the area?

5.2 Methods

5.2.1 Data collection

The intensive study area of Sauraha sector, CNP was surveyed for collecting information on home ranges, movement patterns and habitat utilization of rhinoceros from April, 2009 to March, 2011. Ten identified individual rhinoceros mostly adult males and females with calf or without calf in various blocks of Sauraha sector were searched and on location their GPS coordinates were taken to overlay on classified map. Out of ten rhinoceros, five (M1, M2, M3, M4 and M5) were males and five other (F1, F2, F3, F4 and F5) were females. Among males, two (M1 and M2) were dominant, one old male (M3), two sub-dominant males (M4 and M5). Among females, F1, F3, F4 and F5 were adult females having calves attached and F2 was adult female without calf.

Systematic survey was conducted covering all 11 blocks of the study area of Sauraha sector, CNP. During the field visit whenever these 10 individuals were sighted, their GPS locations were registered and other additional information were recorded for two annual seasons. I used Garmin Etrex, GPS instrument for the purpose. The park staffs, field assistants and game scouts also helped me in
collecting various information on rhinoceros location and recording other related information. All these data were entered in excel (XL) sheets for computing and further analysis. The details of the methods used for the estimation of home ranges, core areas utilization, overlapping areas, habitat utilization, habitat preference and movement pattern are as given below.

5.2.2 Habitat map generation

The study site was surveyed to classify the vegetation types and land-use pattern. Several GPS points were collected from different landscape elements (LSEs). For each GPS location, types of landscape element and degree of biotic pressure were also recorded.

For this study, geo-database of different layers of information has been generated from topomaps scaling 1:25000 taken by aerial photography in 1992 and field verification in 1994 (Survey Department of Government of Nepal, 1994). I used mainly two toposheets (Sheet no. 2784 06D, 07C) which almost covered the study area (Sauraha sector). Scan data of toposheets were geo-referenced and projected on Modified Universal Transverse Mercator (MUTM) format based on WGS 84 datum in one scene covering the study area and used as reference. I have selected the intensive study area of 77.1 km² covering the grassland patches of the Sal forest in the south and 500 m outlying area from the Khageri Khola in the north-west. This is the place of Sauraha sector where most of the rhinoceros populations inhabit.
I used the USGS Landsat Satellite image from the Earth Explorer (www.earthexplorer.com). The spatial resolution of these images (Row, 41 and Path, 141 & 142) were 30m×30m which is suitable for vegetation monitoring in such type of landscape. Mainly 142 path image was used which covers the whole intensive study area. Both the scenes were relatively cloud free and recent imagery. Acquisition date of the image is 23 November, 2015. I used the false color composite (FCC) corresponding to red (R), green (G) and blue (B) with band combination of 5, 4 and 3.

ERDAS IMAGINE 9.2 (Leica Geosystems) was used for image processing and ArcGIS 9.3 (Environmental Systems Research Institute, ESRI) for final map preparation. Using the shape-file for both core area and buffer zone boundary prepared by DNPWC was clipped to extract the study area.

The image was registered geometrically in ERDAS Imagine 9.2 using Ground Truthing Points (GTPs) collected from field visits. I used 125 random Ground Truthing Points which were taken at the time of data collection from various parts of the study area. From each Ground Truthing Point (GTP) location, major species of vegetation was recorded. Signature for different category of habitat was prepared with the help of Ground Truthing Points and final supervised classified map was prepared for the analysis of home range, habitat utilization and habitat preferences. Before doing classification, cultivated lands and built up areas were omitted out from the image to avoid misclassification. Habitat mapping and land cover classification were mainly based on previous literatures.
For the convenience of the data analysis, habitat of intensive study area was classified into seven categories: riverine forest, Sal forest, tall grassland, short grassland, wooded grassland/scrub, water body and river bed. The vegetation habitat types with plant composition are illustrated greater details in Chapter 2.

I prepared the supervised classified image in ERDAS IMAGINE 9.2 and for the accuracy assessment of the image; I have generated 300 random location points and checked with reference points. They were verified after field visit during December, 2014. I checked all the points and compared with Kappa Coefficient value and 78.29 % accuracy was found.

5.2.3 Estimation of home ranges

Locations of individually identified rhinoceros were collected using Global Positioning System (GPS) along with date, time and related habitat information (Laurie, 1978; Bhattacharya, 1991; Dinerstein, 2003; Hazarika, 2007; Hazarika and Saikia, 2011). I used at least 1 to 5 locations per day for home range computation based on more than 250 m displacement. These locations were plotted on a prepared classified map of the study area and finally each individual rhinoceros was assessed for home ranges.

In this study, the two most common estimators were used, the Minimum Convex Polygon (MCP) (Mohr, 1947) and the Fixed Kernel Density Estimator (FKDE) (Worton, 1989; Silverman 1986). I used the Home Range Tools (HRT) software
version 1.1 of the Home Range Extension (HRE) for ArcView GIS, 9.3 to calculate Minimum Convex Polygons (MCPs) and Fixed Kernel Density Estimations (FKDEs) (Rodgers et al., 2007). I calculated using a fixed bivariate normal smoothing parameter that minimized the least squares cross validation score (Worton 1989, Kie et al., 2010). The fixed kernel method gave area estimates with very little bias when least squares cross validation was used to select the smoothing parameter (Kernohan et al., 2001). The cross-validated fixed kernel also gives surface estimates with the lowest error (Seaman & Powell, 1996).

The HRT tools automatically compute smoothing parameters (bandwidth) based on standardized or non-standardized data and directly estimated by least squares cross validation (LSCV) (Rodgers et al., 2007). I used 95% and 50% isopleths for computing fixed kernel density estimations. I used one-way ANOVA to check for variation in seasonal home ranges of rhinoceros (Zar, 2010).

I have computed the spatial overlapping of each rhinoceros to the other in ArcGIS 9.3 using Clip Analysis Tools.

5.2.4 Estimation of core areas

The core areas were estimated as 50% cluster polygons using Fixed Kernel Density Estimator with 50 percent volume contours in previous studies (Dinerstein, 2003). I used the point of inflection to determine the core area with area probability curve by plotting percentage of the fixed kernel density at
different contour levels against the kernel area. I calculated fixed kernel home ranges in each five percent interval contour from 95% to 40% for each individual rhinoceros. This inflection point determines the core area of the home ranges (Powell, 2000).

5.2.5 Analysis of habitat utilization pattern

To analyze the habitat utilization pattern of rhinoceros in the study area, ten focal rhinoceros were searched in all habitats in different seasons during the study period. All the sightings were recorded by handheld GPS (GARMIN, Etrex) in UTM from the possible place where rhinoceros were observed. In addition to this, activities of rhinoceros and the habitat types used were also recorded (Laurie, 1978; Jnawali, 1995; Hazarika, 2007; Hazarika and Saikia, 2011). Seasonal habitat use pattern was studied for individual rhinoceros to know how they use different habitat types in various seasons. The direct sighting locations data collected for each target animal was superimposed on the vegetation and the land use map. The use of a particular landscape element by each individual rhinoceros was analyzed by calculating the percentage of number of sightings in each landscape element used per different season and overall number of direct sighting locations. All analysis was carried out using computer software Arc GIS 9.3 using Spatial Analysis tool (extract values to points). Habitat selectivity of rhinoceros in the particular habitat was calculated by using the following formula:

\[
\text{Habitat Selectivity} = \frac{\text{Total no. of rhino sighted in a particular habitat}}{\text{Total no. of sighting record of rhino in all habitats}} \times 100
\]
5.2.6 Analysis of habitat preference

To estimate the habitat preference, the MCP home ranges were superimposed on the supervised classified vegetation and land use map of the intensive study area. The availability of habitat types within the home range was calculated by using Spatial Analysis Tool (extract by mask) in Arc GIS 9.3 from classified map. The used location points of particular rhinoceroses for each season were extracted (using Spatial Analysis Tool; extract values to points) and the percentages of both habitat use and habitat availability were calculated.

Habitat preference in relation to seasonal and overall study period was estimated by Compositional Analysis in Resource Selection Program (Aebischer et al., 1993). This program automatically ranked the habitat preference order in hierarchy from most preferred to less preferred or avoided. A consequence of the constraint is that an animal’s avoidance of one habitat type will almost invariably lead to an apparent preference for other types, so the interpretation of absolute preference or avoidance of habitat types is not appropriate (Neu et al., 1974, Byers et al., 1984). A chi-square value obtained from the compositional analysis provided the significance of the result. Ivlev Electivity Index (Ivlev, 1961) was also used to ensure the habitat preference order.

5.2.7 Estimation of diurnal movement rate

GPS points were collected at every half hour interval by handheld GPS instruments during continuous observation periods of activity patterns
simultaneously. These locations were generated in ArcGIS 9.3 and average distance travelled per day and hourly displacements were calculated therefrom.

5.3 Result

5.3.1 Home ranges

In total, 1774 GPS locations were recorded, out of which 998 for males and 776 for males. Annual and seasonal home range (Minimum Convex Polygon, MCP) and Fixed Kernel Density, FKD (95% & 50%) for individual rhinoceroses were calculated and presented in Table 5.1.

Average annual home range, MCP of five adult male rhinoceros was 10.67 ± 0.92 km$^2$ and 5.46 ± 0.65 km$^2$ for five female rhinos. The average male home range during hot season was 9.91 ± 0.96 km$^2$, monsoon season 7.94 ± 0.74 km$^2$ and 6.45 ± 0.65 km$^2$ in winter season. Likewise, average female home range for hot season was 5.01 ± 0.64 km$^2$, 4.36 ± 0.46 km$^2$ for monsoon season and 3.69 ± 0.45 km$^2$ for winter season (Table 5.1).

Annual and seasonal Fixed Kernel Density, FKD (95% & 50%) for each rhinoceros was also calculated. Annual average 95% & 50% of FKD were 11.38 ± 1.20 / 3.09 ± 0.45 km$^2$ for male and 6.29 ± 0.68 / 1.66 ± 0.18 km$^2$ for female. FKD (95% & 50%) for males were 14.2 ± 1.78 / 4.05 ± 0.62 km$^2$ in hot season, 12.79 ± 0.99 / 3.61 ± 0.44 km$^2$ for monsoon season and 10.09 ± 1.33 / 2.71 ± 0.43 km$^2$ in winter season. Likewise, females FKD (95% & 50%) were 6.97 ±
0.93 / 1.80 ± 0.24 km² in hot season, 7.01 ± 0.98 / 1.91 ± 0.24 km² in monsoon season and 7.13 ± 1.48 / 1.80 ± 0.41 km² in winter season (Table 5.1).

The variations between male and female home range as well as seasonal variations were calculated from the estimated home ranges. The data result (in one way ANOVA test) showed that there was significant variation between home range of male and female ($F_{1, 38} = 18.99; p < 0.0001$). I calculated the significance of variation in seasonal home range for male and female but there was no significant seasonal variation ($F_{2, 27} = 1.315; p = 0.2849$). The following Figures (5.1 to 5.13) depicted the annual and seasonal home ranges, locations of ten rhinoceros and 95% and 50% fixed kernel density for individual rhinoceros in the study area.
Table 5.1: Annual and seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of five males and five females Rhinoceros.

<table>
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<th>ID</th>
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<th>95%</th>
<th>50%</th>
<th>Hot Season Location</th>
<th>MCP (Km²)</th>
<th>95%</th>
<th>50%</th>
<th>Monsoon Season Location</th>
<th>MCP (Km²)</th>
<th>95%</th>
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<th>Winter Season Location</th>
<th>MCP (Km²)</th>
<th>95%</th>
<th>50%</th>
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<td>39</td>
<td>3.08</td>
<td>5.06</td>
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</table>

Mean (Male) | 10.67 | 11.38 | 3.09 | 9.91 | 14.20 | 4.05 | 7.94 | 12.79 | 3.61 | 6.45 | 10.09 | 2.71 |

S.D | 2.06 | 2.67 | 1.01 | 2.14 | 3.98 | 1.39 | 1.64 | 2.22 | 0.98 | 1.44 | 2.98 | 0.95 |

S.E 0.92 | 1.20 | 0.45 | 0.96 | 1.78 | 0.62 | 0.74 | 0.99 | 0.44 | 0.65 | 1.33 | 0.43 |

<table>
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<tr>
<th>S.N.</th>
<th>ID</th>
<th>Annual Location</th>
<th>MCP (Km²)</th>
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<th>50%</th>
<th>Hot Season Location</th>
<th>MCP (Km²)</th>
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<th>50%</th>
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<th>MCP (Km²)</th>
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<th>50%</th>
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Mean (Female) | 5.46 | 6.29 | 1.66 | 5.01 | 6.97 | 1.80 | 4.36 | 7.01 | 1.91 | 3.69 | 7.13 | 1.80 |

S.D | 1.45 | 1.53 | 0.40 | 1.44 | 2.07 | 0.54 | 1.02 | 2.20 | 0.53 | 1.00 | 3.30 | 0.92 |

S.E 0.65 | 0.68 | 0.18 | 0.64 | 0.93 | 0.24 | 0.46 | 0.98 | 0.24 | 0.45 | 1.48 | 0.41 |
Fig. 5.1: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of M1.

Fig. 5.2: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of M2.
Fig. 5.3: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of M3.

Fig. 5.4: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of M4.
Fig.5.5: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of M5.

Fig.5.6: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of F1.
Fig. 5.7: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of F2.

Fig. 5.8: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of F3.
Fig. 5.9: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of F4.

Fig. 5.10: Annual & seasonal Minimum Convex Polygon, MCP and Fixed Kernel Density, FKD (95% & 50%) of F5.
Fig. 5.11: Locations of all ten rhinoceros in the intensive study area of Sauraha sector.

Fig. 5.12: Annual Minimum Convex Polygons (MCP) of ten rhinoceros in the intensive study area of Sauraha sector.
5.3.2 Spatial overlapping of rhinoceroses

It was recorded that the most dominant male, M1 of the study area recorded the largest areas (17.8 km$^2$) and griped four females of that area within its own territory. One male (M5) and one female (F5) had home ranges without any overlap with others except themselves. Data showed that three males (M1, M2 and M3) had also spatial overlapping (5.40 km$^2$) with each other (Fig. 5.14). The four females (F1, F2, F3 and F4) were found having overlapping areas (1.31 km$^2$) along east west axis of the study area (Fig. 5.15; Table 5.2). These three males and four females overlapped by an area of 1.28 km$^2$. 

Fig.5.13: Fixed Kernel Densities, FKD (95% & 50%) of ten rhinoceros in the intensive study area of Sauraha sector.
Table 5.2: Spatial overlaps (km²) in MCPs of ten rhinoceros in the study area of Sauraha sector.

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<tr>
<td>M4</td>
<td>5.93</td>
<td>0.13</td>
<td>2.15</td>
<td>0.00</td>
<td>0.94</td>
<td>1.62</td>
<td>0.17</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>M5</td>
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<td>0.00</td>
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<td>0.00</td>
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</tr>
<tr>
<td>F1</td>
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<td>4.65</td>
<td>3.26</td>
<td>1.37</td>
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<td>0.00</td>
</tr>
<tr>
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<td>7.20</td>
<td>1.62</td>
<td>0.00</td>
<td>4.65</td>
<td>4.93</td>
<td>2.37</td>
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<tr>
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<td>6.79</td>
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<td>3.26</td>
<td>4.93</td>
<td>3.99</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
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<td>2.37</td>
<td>3.99</td>
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</tr>
<tr>
<td>F5</td>
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<td>3.54</td>
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<td>0.00</td>
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</tr>
</tbody>
</table>

Fig.5.14: Spatial overlaps in MCPs of three male Rhinoceros in the study area.
Fig. 5.15: Showing overlapping areas of four female Rhinoceros in the study area of Sauraha sector.

5.3.3 Core areas

The point of inflection at 65% contour level (Fig. 5.16) and represented the core area of individual rhinoceros in Table 5.3. I have calculated the variation of annual core areas between male and female. There was no significant difference in core areas between males and females (in one way ANOVA, $F_{1,8} = 5.07, p = 0.0544$).
Table 5.3: Fixed Kernel Density, FKD (km²) in different percentage contour volumes (95% - 40%) of ten rhinoceros.

<table>
<thead>
<tr>
<th>Rhino Isopleth</th>
<th>95%</th>
<th>90%</th>
<th>85%</th>
<th>80%</th>
<th>75%</th>
<th>70%</th>
<th>65%</th>
<th>60%</th>
<th>55%</th>
<th>50%</th>
<th>45%</th>
<th>40%</th>
</tr>
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<tbody>
<tr>
<td>M1</td>
<td>17.57</td>
<td>14.34</td>
<td>12.39</td>
<td>10.72</td>
<td>9.46</td>
<td>8.48</td>
<td>6.92</td>
<td>5.97</td>
<td>5.19</td>
<td>4.29</td>
<td>3.65</td>
<td>3.03</td>
</tr>
<tr>
<td>M2</td>
<td>13.68</td>
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<td>8.23</td>
<td>7.80</td>
<td>6.58</td>
<td>5.82</td>
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<td>3.76</td>
<td>3.14</td>
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<td>M3</td>
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<td>7.93</td>
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<td>1.91</td>
<td>1.56</td>
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</tr>
<tr>
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<td>5.35</td>
<td>4.59</td>
<td>3.95</td>
<td>3.49</td>
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<td>1.59</td>
<td>1.39</td>
</tr>
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<td>3.89</td>
<td>3.36</td>
<td>2.93</td>
<td>2.55</td>
<td>2.19</td>
<td>1.82</td>
<td>1.60</td>
<td>1.38</td>
<td>1.15</td>
<td>1.00</td>
<td>0.83</td>
</tr>
<tr>
<td>F2</td>
<td>8.69</td>
<td>7.27</td>
<td>6.28</td>
<td>5.40</td>
<td>4.78</td>
<td>4.09</td>
<td>3.59</td>
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<td>F3</td>
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<td>6.56</td>
<td>5.24</td>
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<td>1.69</td>
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<td>1.78</td>
<td>1.52</td>
<td>1.32</td>
<td>1.12</td>
<td>0.93</td>
</tr>
</tbody>
</table>

![Graph showing average area in sq. km. for different percentage levels of Fixed Kernel Density Isopleths](image)

Fig.5.16: Average Fixed Kernel Density Isopleths area of ten rhinoceros showing point of inflection (arrow) in different percentage (95%-40%) contour level.
5.3.4 Habitat utilization pattern

In order to test whether the identified rhinoceros were using habitat types in proportion to their availability, I used a Chi-square test following Neu et al., (1974). It was found that the various habitat types used by rhinoceros differed significantly from the available habitat types.

In **hot season**, rhinoceros used tall grassland habitat, short grassland and water body more extensively in comparison to the other habitat. They avoided or less preferred wooded grassland/scrub, river bed and Sal forest ($\chi^2 = 76.32$, d.f. = 6, $p< 0.0001$). During **monsoon season**, rhinoceros most utilized tall grassland, riverine forest, short grassland and water body than the availability, and less utilized wooded grassland/scrub, river bed and Sal forest ($\chi^2 = 20.70$, d.f. = 6, $p < 0.01$). Likewise, in **winter season**, they mostly utilized riverine forest, short grassland and tall grassland and less utilized wooded grassland/scrub, water body, Sal forest and river bed ($\chi^2 = 71.39$, d.f. = 6, $p< 0.0001$).

On cumulative terms, rhinoceros mostly utilized riverine forest, tall grassland and short grassland in comparison to other habitats and less utilized water body, wooded grassland/scrub, Sal forest and river bed ($\chi^2 = 54.42$, d.f. = 6, $p < 0.0001$).

5.3.5 Habitat preference

The classified habitat map of intensive study area of Sauraha sector covering an area of 77.1 Km² was categorized in seven different habitat types which were
utilized by 10 identified rhinoceros. Out of which tall grassland covers the largest area (30.47%) followed by Sal forest (20.10%), riverine forest (19.76%), short grassland (12.39%), wooded grassland/scrub (9.61%), water body (3.85%) and river bed (3.82%) (Table 5.4).

Table 5.4: Area (km²) and percentage of habitat types in the study area of Sauraha sector in CNP.

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Habitat Type</th>
<th>Square Kilometer</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>River Bed</td>
<td>2.94</td>
<td>3.82</td>
</tr>
<tr>
<td>2</td>
<td>Wooded GL/Scrub</td>
<td>7.41</td>
<td>9.61</td>
</tr>
<tr>
<td>3</td>
<td>Water Body</td>
<td>2.97</td>
<td>3.85</td>
</tr>
<tr>
<td>4</td>
<td>Sal Forest</td>
<td>15.50</td>
<td>20.10</td>
</tr>
<tr>
<td>5</td>
<td>Short Grassland</td>
<td>9.56</td>
<td>12.39</td>
</tr>
<tr>
<td>6</td>
<td>Riverine Forest</td>
<td>15.24</td>
<td>19.76</td>
</tr>
<tr>
<td>7</td>
<td>Tall Grassland</td>
<td>23.49</td>
<td>30.47</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>77.10</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Result of compositional analysis showed that the rhinoceros exhibited preferences for certain habitats ($\chi^2 = 36.58$, d.f. = 6, $P < 0.0001$). The order of annual habitat preference in the intensive study area being riverine forest > short grassland > tall grassland > water body > wooded grassland/scrub > Sal forest > river bed.

During the hot season rhinoceros were found to have a preference for tall grassland ($\chi^2 = 19.43$, d.f. = 6, $P < 0.05$). The order of habitat preference being tall grassland > short grassland > riverine forest > water body > wooded grassland/scrub > river bed > Sal forest.
The order of habitat preference by rhinoceros during monsoon season in the study area ($\chi^2 = 32.41$, d.f. = 6, $P < 0.0001$) was tall grassland > riverine forest > short grassland > water body > wooded grassland/scrub > river bed > Sal forest.

Habitat preference order for rhinoceros for winter season ($\chi^2 = 22.68$, d.f. = 6, $P < 0.001$) was riverine forest > short grassland > tall grassland > wooded grassland/scrub > water body > river bed > Sal forest.

The Ivlev’s Electivity Index analysis presented in Fig. 5.17 conferred identical results of habitat preferences as determined by compositional analysis for the intensive study area.

![Ivlev Electivity Index](image-url)

**Fig.5.17**: Ivlev Electivity Index for annual and seasonal habitat preference and avoidance in different habitat types.
5.3.6 Movement pattern

Average male rhinoceros moved 3.55 ± 0.48 km/day (in 12 hours day time) in hot season, 3.74 ± 0.57 km/day in monsoon season and 3.97 ± 0.51 km/day in winter season. Female rhinoceros moved 2.16 ± 0.25 km/day in hot season, 2.47 ± 0.39 km/day in monsoon season and 2.88 ± 0.43 km/day in winter season. Male rhinoceros covered larger distance than females. Both males and females walked longer distance in winter season in comparison to other two seasons.

The annual average hourly displacements of male and female rhinoceros were 212.70 ± 9.90 m and 152.22 ± 6.36 m respectively. The average hourly displacements of male rhinoceros were 193.67 ± 9.35 m in hot season, 203.61 ± 10.68 m in monsoon season and 240.83 ± 9.67 m in winter season. The average hourly displacements of female rhinoceros were 137.83 ± 5.11 m in hot season, 149.33 ± 6.98 m in monsoon season and 169.50 ± 7.01 m in winter season. Hourly displacements of male rhinoceros were longer than females. Both males and females’ hourly displacement were longer in winter season than in other seasons (Fig. 5.18 and Fig. 5.19). Diurnal displacement of male rhinoceros was higher than female (in two way ANOVA test; $F_{1, 70} = 38.19$, $p < 0.0001$) but there was no seasonal variations for both males and females (in two way ANOVA test; $F_{2, 69} = 2.05$, $p = 0.1365$).
Fig. 5.18 Annual and seasonal hourly displacement of male rhinoceros in Sauraha sector, CNP. Error bars are standard errors.

Fig. 5.19 Annual and seasonal hourly displacement of female rhinoceros in Sauraha sector, CNP. Error bars are standard errors.
5.4 Discussion

Our finding of home range sizes is consistent with the previous studies (Laurie, 1978; Jnawali, 1995; Dinerstein, 2003; Subedi, 2012) where males have been reported to occupy larger home ranges than the females. While working on rhino population in Chitwan National Park, Jnawali (1995) and Dinerstein (2003) reported near equal annual home range sizes of male (3.30 km$^2$) and 2.90 km$^2$ for females. The annual home ranges estimated for males (10.67 km$^2$) and females (5.46 km$^2$) found in the present study were much larger than what had been reported by Jnawali (1995) and Dinerstein (2003). The home range sizes studied by Subedi (2012) through radio-collared data also revealed larger in sizes for males (19.27 km$^2$) and females (10.20 km$^2$) in comparison to the present study. The finding of larger home ranges both for males and females though compared close with the studies of Subedi (2012) but appeared much larger than what has been reported by earlier worker in the park. When I looked into the occupancies of rhinoceros in terms of densities in Sauraha sector, it was found that earlier densities reported by Dinerstein (2003) 13 rhinos/km$^2$ was much higher than the present density i.e. 0.83 rhino/km$^2$. As Jnawali (1995) and Dinerstein (2003) studies were between 1984 to 1995 and the reintroduction program started concurrently from 1986 to 2003 wherein 91 rhinoceros were translocated from Sauraha sector. Reduction in rhinoceros densities in Sauraha sector as a result of transloctions might have influence over occupying larger ranges both by males and females. Other important aspects of high density of rhinoceros during Jnawali (1995) and Dinerstein (2003) study period were due to
availability of smaller grassland in Sauraha sector that became large by adding additional areas through village relocation in this sector. It is presumed that as the population of rhinoceros will grow in Sauraha sector, home range sizes will be squeezed further to accommodate more population of rhinoceros with decreasing home range sizes both for males and females.

The size of the annual home ranges varied for both males (10.67 km$^2$) and females (5.46 km$^2$) in the present study however, on seasonal context the variations within individual males and females were not significant ($F_{2,27} = 1.315; p = 0.2849$). The home range size recorded maximum during hot season in both males and females, moderate during rainy season and least in winter (Table 4.1). The finding of Dinerstein (2003) for home range size was larger in hot season though have a similar agreement with the present study but differ for the monsoon season when he reported to be contracted with availability of abundant forage. The core area utilization estimated by Dinerstein (2003) at 50% of all locations ranged from 22 - 28 ha which was much lower than the present study i.e. 1.82 – 6.92 km$^2$ at 65% of all locations. The core area utilization within males and females did not show any significant differences ($F_{1,8} = 5.07, p = 0.0544$) in the present study.

In the present study female ranges overlapped some male territories with an area overlap of (1.28 km$^2$). The one dominating male, M1 occupied spatially distinctively larger home range. However, considerable spatial overlaps among three male territories (5.40 km2) were recognized in the Sauraha sector. Occupancy of distinctive home ranges by dominant males either temporally or
spatially have also been reported by Dinerstein (2003) and is in concurrence with the finding of the present study. He further reported that two males overlapped in their home ranges but maintained dominance at different time.

The habitat utilization and habitat preference by rhinoceros showed a similar pattern in the present study in Sauraha sector as pointed out by Subedi (2012) in their findings while working on the same area. The preference of order was riverine forest followed by tall grassland and short grassland (Fig. 5.17). Presence of large number of natural and artificial water holes in riverine forest and tall grassland habitat also facilitate the animal to access these water bodies for thermoregulation through wallowing and dissipating heat stresses. The preference of tall grassland in hot and monsoon season might be due to availability of newly sprouted grasses following annual burning and rains. On contrary, during winter season preference shifts to riverine forest as more browse are available than other habitats. During this period, the riverine forest also acts as a better place to avoid cool winters and frost bites. Hazarika et al. (2011) reported that the rhinoceros in Orang National Park preferred wet grassland and water bodies throughout the year which was not the case in the present study.

The present study recorded the highest movement rate 3.97 km/day for male and 2.88 km/day for female in 12 hours diurnal period in winter season. The same pattern of finding was recorded by Dinerstein (2003) in 24 hours period. He further reported the highest movement in cool season 7.17 km/day for male and 3.58 km/day for female.