ANALYSIS OF THE SEASONAL MIGRATIONS OF MONGOLIAN GAZELLE, USING MODIS DATA

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ABSTRACT:

Conservation and management for Mongolian gazelles (*Procapra gutturosa*), which inhabits steppes in Mongolia, northern China, and southern Russia, are urgently required. The Mongolian gazelle migrates hundreds or thousands of kilometers seasonally, however details of the migration routes are still unknown, because of difficulty in continuous tracking. The objectives in the present study are to describe the migration routes of Mongolian gazelles using satellite tracking, and to examine whether their seasonal migrations are influenced by change in normalized difference vegetation index (NDVI) in their habitat. We captured four gazelles in Omnogobi Province and Dornogobi Province in Mongolia and tracked their location from October 2002 to October 2003. Satellite tracking provided details of their migration routes, and their cumulative moving distances were more than 1000 km. Sift of NDVI values derived from moderate resolution imaging spectrometer (MODIS) satellite image between summer and winter ranges corresponded with seasonal migrations of gazelles in Omnogobi. In Dornogobi, NDVI values of the summer ranges were higher in summer and lower in winter than those of overall average, although NDVI values of the winter ranges were higher than those of the summer ranges almost throughout the year. The gazelles seem to migrate seasonally, depending on the seasonal change of habitat quality between summer and winter ranges. NDVI was an effective indicator for evaluating the gazelle habitat. Therefore, it could explain seasonal migrations of the gazelles. However, the seasonal migrations in some areas were not explained by the NDVI sifts between the ranges. Thus, it is recommended to examine the effective extent and the limitation of NDVI as an indicator.

1. INTRODUCTION

Mongolian gazelles (*Procapra gutturosa*), which inhabit steppes in Mongolia, northern China, and southern Russia, were listed in the Red List of IUCN as Near Threatened (LR/nt) (IUCN 1996), therefore conservation and management for them are urgently required (Jiang et al., 1998; Reading et al., 1998) as total population has decreased from about 1.5 million heads in the 1940's to 300,000-500,000 at present (Lhagvasuren and Milner-Gulland, 1997; Jiang et al., 1998). The Mongolian gazelle migrates hundreds or thousands of kilometers seasonally, however details of the migration routes are still unknown, because of difficulty in continuous tracking.

To conserve the animals that migrate long distances, it is necessary to know their migration routes and reasons why they migrate on such routes. Although it is difficult to know the migration routes of long distances, over the last decade, the advent of reliable satellite tracking technology enabled the study of such long-distance movements (Gillespie, 2001; Akesson, 2002; Webster et al., 2002; Nathan et al., 2003). Besides, Satellite imagery and remote sensing technology have been widely used to assess habitat extent and quality in ungulate studies (e.g. Unsworth et al., 1998; Bowyer et al., 1999).

For ungulates inhabiting grasslands, above ground net primary productivity is strongly correlated with habitat quality (McNaughton, 1985, 1993; Frank and McNaughton, 1992). It is possible to use the normalized difference vegetation index (NDVI; Lillesand and Kiefer, 1999) calculated from satellite image as an index for habitat quality. The NDVI represents the difference in reflection between the near infrared and red parts of the electromagnetic spectrum (Eidenshink and Faundeen, 1994) and works well in measuring plant biomass and productivity because healthy green vegetation reflects strongly in the near infrared but absorbs most light in the red. There are good statistical relationships between the NDVI and biomass and/or productivity (Cihar et al, 1991; Paruelo and Laurenroth, 1995; Paruelo et al., 1997), and NDVI has been used to estimate the quality of the habitat of the Mongolian gazelle (Leimgruber et al., 2001).

Leimgruber et al. (2001) shows that winter and calving grounds had highest NDVI scores during period of use by gazelles in eastern Mongolia, suggesting that gazelle movements track shifts in primary productivity across the steppe. However they just delineated the habitat types within the gazelle range (i.e. winter, summer, and calving grounds) by literatures and expert knowledge, not by actual migration data (Leimgruber et al., 2001), due to lack of data of migration routes and habitat selection of gazelles. If migration routes and habitat selection of

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gazelles are described, analysis between the actual habitat selection of gazelles and NDVI in their habitat is possible. Thus, we started tracking gazelle movement, which is the first trial of satellite tracking on Mongolian gazelles.
The objectives in the present study are to describe the migration routes of Mongolian gazelles by the satellite tracking, and to examine whether their seasonal migrations are influenced by change in NDVI in their habitat.

2. MATERIALS AND METHODS

We captured two gazelles (ID1 and ID2) in Omnogobi Province and another two (ID3 and ID4) in Dornogobi Province in southern Mongolia, in late October 2002 (Figure 1).

Figure 1. Study Area

Each gazelle was collared with a satellite transmitter (also termed platform terminal transmitter, or PTT; model ST-18, Telonics, Inc., Mesa, AZ, USA). The weight of a PTT with collar is 550 g. The PTTs were programmed to transmit radio signals for one 8-h period per week, thus providing weekly location data. The location data was received through computer communications and computer disks sent from the CLS (Collecte Localisation Satellites) Service in France. In this analysis, we used location data of four gazelles from October 2002 to October 2003. Location classes (LC) were categorized from 0 to 3. The higher the LC, the more accurate the location. Less accurate data are also provided as LC A and B. Keating et al. (1991) calculated the accuracy of LC 1, 2, and 3 data from PTTs. Their one-standard-deviation accuracy results, compared to the accuracies reported by Service Argos (1988) were 1188 m versus 1000 m for LC 1, 1903 m versus 350 m for LC 2, and 361 m versus 150 m for LC 3. We obtained location data for the four gazelles every week for a year and selected the best data in each day according to the LC to plot gazelle migration routes. When there were several data from the best LC in a day, the latest data were selected. About 96% of the total number of the best location data in a day fell into LC 1, 2, or 3 (LC 1: 18%, LC 2: 27%, LC 3: 51%), with 4% falling into LC 0.

We defined three categories of their home ranges with location data: annual, summer and winter ranges. These home ranges were calculated by applying the kernel method (Worton, 1989) using Geographic Information Systems (GIS), ArcInfo/ArcView (Environmental System Research Institute Inc.) with the Animal Movement Analyst Extension (Hooge and Eichenlaub, 2000). Annual range in each province was defined as 95% core area with the data from October 2002 to October 2003. Summer and winter ranges of each gazelle were defined as 50% core areas with the data from June to August, and from December to February, respectively.

To analyse the environment condition, we used NDVI derived from moderate resolution imaging spectrometer (MODIS) satellite image. We downloaded vegetation index product (MOD13Q1 Product; 16-day composit NDVI, 250m resolution) in the period that gazelles were tracked, from NASA's Earth Observing System Data Gateway via the Internet (http://redhook.gsfc.nasa.gov/~imswww/pub/imswelcome/plain.html). Mean NDVI of each range was calculated using ERADAS IMAGINE (Leica Geosystems GIS & Mapping, LLC.). To get an index of relative quality in the different ranges within the annual ranges, we subtracted the overall average value from each of the values for the summer and winter ranges.

3. RESULTS

3.1 Migrations of gazelles

The two gazelles (ID1 and ID2) in Omnogobi had moved toward the west along the mountains in southern side since we started to track their locations in October 2002 (Figure 2). ID1 moved to the west approximately 100 km in liner distance, and stayed there from late December 2002 to late March 2003, then went back to the area it had been captured and stayed around there until October 2003. ID2 moved from the captured point to the west approximately 130 km in liner distance, and stayed there from late November to late December 2002, then moved to the west another 130 km and stayed there from January to February 2003. ID2 didn't move after that. We found it had been dead during our field survey in the summer 2003. The cumulative distances moved over a year were 659 km and 383 km and the maximum distances moved during one week were 72 km in late March and 81 km in early January for ID1 and ID2, respectively. The gazelles used the western areas in winter and the eastern area in summer in their annual range (Figure 3).

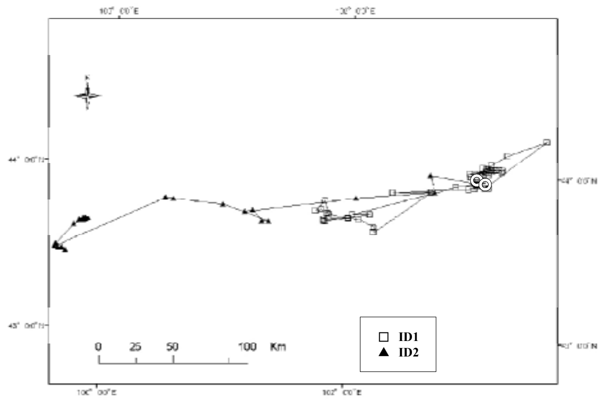

Figure 2. Migration routes of ID1 and ID2 in Omnogobi from October 2002 to October 2003.
The double circle is the site of capture.

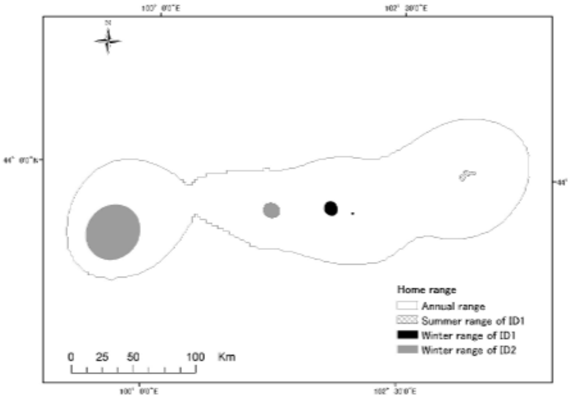

Figure 3. Annual, summer and winter ranges
of tracked gazelles in Omnogobi

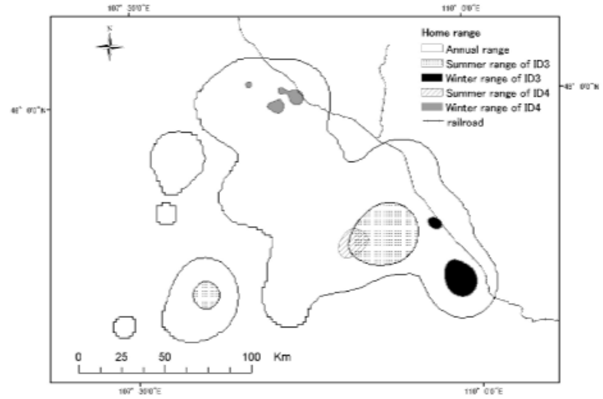

Figure 5. Annual, summer and winter ranges
of tracked gazelles in Dornogobi

In Dornogobi, ID3 used the area alongside a railroad from October 2002 to April 2003, then moved south-westward approximately 140 km in liner distance and stayed around there until July 2003 (Figure 4). ID3 went back to the area where it had been captured by September 2003. ID4 moved northwest approximately 80 km in liner distance along the railroad in late November 2002 and stayed there until mid-April. Then ID4 went south-eastward approximately 100 km in liner distance and stayed there after that. The cumulative distances moved over a year were 1112 km and 1011 km and the maximum distances moved during one week were 80 km in late March and 79 km in late November for ID3 and ID4, respectively. The gazelles used the eastern areas along the railroad in winter and the southern and south-westward areas in summer in their annual range (Figure 5).

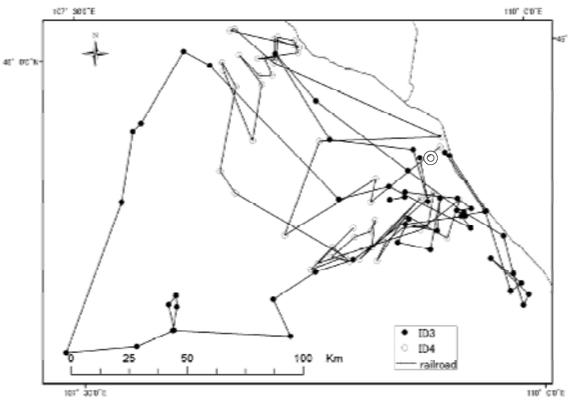

Figure 4. Migration routes of ID3 and ID4 in Dornogobi
from October 2002 to October 2003.
The double circle is the site of capture.

3.2 Seasonal patterns of NDVI in the summer and winter ranges

NDVI values in each range demonstrated seasonal change, with highest values between June and September and the lowest values between December and February in Omnogobi (Figure 6) and Dornogobi (Figure 7). During winter, NDVI of all ranges except winter range of ID4 decreased to nearly or below 0.

In Omnogobi, NDVI of the summer range was higher in summer, while it was lower than that of overall average from October to November (Figure 8). In contrast, NDVI of the winter ranges was lower than that of overall average almost throughout the year. However, it was higher from October to December (Figure 8).

In Dornogobi, NDVI of the winter ranges was higher than that of the summer ranges and overall average almost throughout the year (Figure 9). Seasonal changes of relative NDVI of the summer ranges were slight, however, NDVI values were higher in summer and lower in winter than overall average (Figure 9).

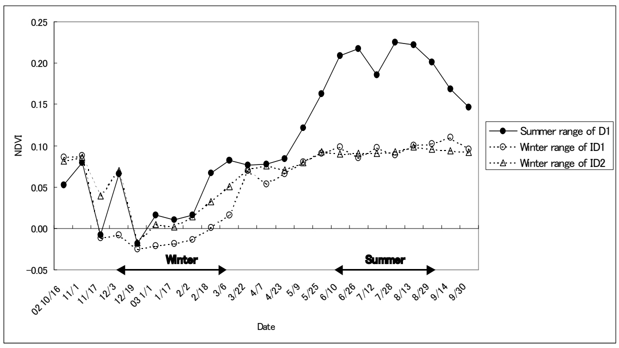

Figure 6. Seasonal changes in NDVI values
of the summer and winter ranges in Omnogobi.

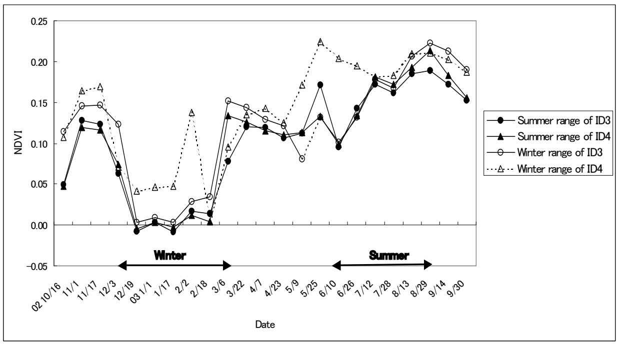

Figure 7. Seasonal changes in NDVI values of the summer and winter ranges in Dornogobi.

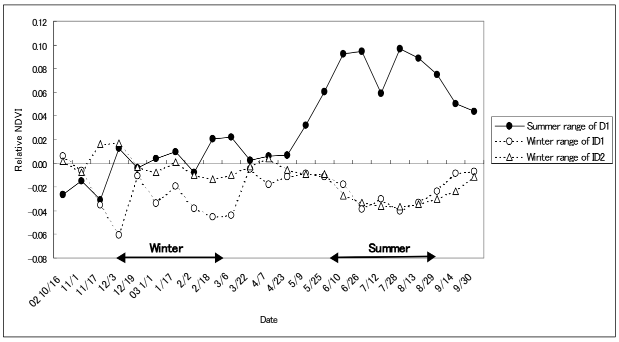

Figure 8. Relative NDVI in the summer and winter ranges, Omnogobi.

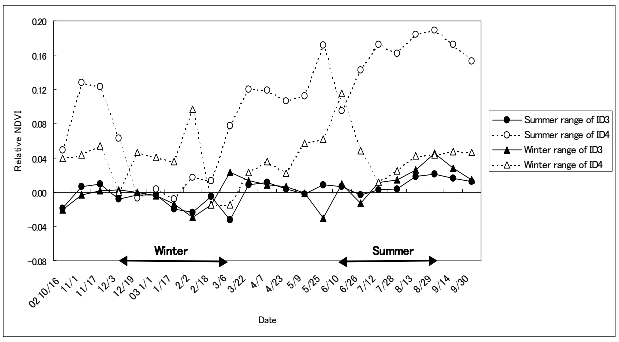

Figure 9. Relative NDVI in the summer and winter ranges, Dornogobi.

4. DISCUSSION

This is the first trial to show the migration routes of Mongolian gazelles by satellite tracking. Their cumulative moving distances were more than 1000 km. Satellite tracking proved their moving ability and provided details of their migration routes with location data. These data can be used to analyse and understand the reasons of their long-distance migrations and for conservation of their habitat. Mongolian gazelles are gregarious and often form large groups, some as large as 80,000 animals, during spring and autumn migrations (Lhagvasuren & Milner-Gulland 1997; Jiang et al. 1998). In fact, the tracked gazelles belonged to large herds of hundreds of animals when they were captured. We also found larger herds in their home range the following summer. Therefore, it is likely that several thousand gazelles moved together with the four gazelles being tracked.

NDVI values changed seasonally. It was high from June to August and sharply declined to around zero from late November in Omnogobi and Dornogobi. It suggests that the plants leaves were dead or grounds were covered by snow in winter. Since migration of gazelles to the winter range also started in late November, gazelles might have moved to avoid deep snow accumulation.

Changes in NDVI values between summer and winter ranges corresponded with seasonal migrations of gazelles in Omnogobi. NDVI values in the summer range were higher than those of annual range in summer, but lower in winter. In contrast, NDVI values in the winter range were lower than those of annual range in summer, but higher from November to December. This sift explains that gazelles selected the area where the vegetation was more abundant and migrated seasonally.

However, the trends of NDVI values between summer and winter ranges were different in Dornogobi. NDVI values were higher in winter range than both in summer and annual ranges thorough the year, although NDVI values in summer range were higher in summer and lower in winter than annual range. This means that there are other factors than NDVI to explain seasonal migrations of gazelles in this area.

Leimgruber et al. (2001) divided gazelle habitat into three categories, winter area, summer area, and calving area, and pointed out the seasonal switching of NDVI values between calving and winter areas in eastern Mongolia. In the present study, however, similar switching of NDVI values was shown without separating calving areas from summer range in Omnogobi. On the other hand, NDVI values were higher in the winter range than in the summer range throughout the year in Dornogobi. To evaluate NDVI as an indicator of the gazelle habitat, it is important to understand what brings these regional differences.

In Mongolia, precipitation increases from southwest to northeast. Omnogobi is located in arider area than Dornogobi and eastern Mongolia, and the vegetation in the winter ranges of gazelles seems very poor in Omnogobi, because NDVI values were around 0.1 even in summer and lower than those in Dornogobi. In such areas, places where plant biomass is greater may be good places for gazelles, and good places could be recognized by higher NDVI value. In more humid areas such as central and eastern Mongolia, however, several vegetation types, for example short grasslands, tall grasslands and shrub lands, occur and NDVI may not directly indicate habitat qualities for gazelles.

NDVI could be one of good indicators of gazelle habitat. However, it is important to evaluate the effective extent and the limitation of NDVI as an indicator. Besides, tracked gazelles sometimes moved along mountains and a railroad. Such topographic and artificial factors might affect their habitat selection. Further researches on migration routes, the vegetation survey in the field, and analysis of the habitat selection of gazelles are needed to conserve Mongolian gazelle.

5. CONCLUSIONS

We described the migration routes of Mongolian gazelles throughout a year for the first time, using the satellite tracking. The gazelles seemed to migrate seasonally, depending on the seasonal change of habitat quality between summer and winter ranges. NDVI was an effective indicator for evaluating the gazelle habitat. However, the seasonal migrations in some areas were not explained by the NDVI sift between the ranges. So it is recommended to examine the effective extent and the limitation of NDVI as an indicator.

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