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Comparative Characteristics of the Home Ranges of Domestic and Wild Animals in Arid and Semi-Arid Afro-Eurasian Watering Places as Hot Spots for Pasture Degradation

Buho HOSHINO*[1], Hiroshi NAWATA[2], Kenji KAI[3], Hiroshi YASUDA[4], Kenji BABA[1], Sumiya GANZORIG[5], SURIGA[5], Manayeva KARINA[5], Tsedendamba PUREVSUREN[5], Miki HASHIMOTO[5], Kenji KAWASHIMA[5], Jun NODA[6], Katsuro HAGIWARA[6] and Yuka SHIBATA[1]

Abstract: In this study, we investigated home range of wildlife and livestock that graze on pastures in Mongolia, China (Inner Mongolia and Tibet) and Sudan. In order to clarify the animal home range, the daily movement of domestic and wild animals was tracked using GPS (Global Positioning System) collars and ARGOS satellite transmitters. The home range of sheep, goats and horses was investigated in Mongolia and China; those of camels, donkeys and goats in Sudan; migration of Tibetan antelope (Chiru, *Pantholops hodgsoni*) in Tibet; and home range of the Brandt vole (*Microtus brandti*) in Mongolia. The home ranges of sheep and goats in nomadic Mongolian family are simple, elongated in shape and possess almost no track intersections. The daily routes possess the same pattern, but pass in different places and do not overlay the previous. Those of sheep and goats in settled nomad families in Inner Mongolia differ in shape, have multiple overlays and tend to cross previous paths. Grazing inside fenced pasture causes this pattern; grazing velocity and total distances are higher than that of Mongolian livestock. In Mongolia, surroundings of livestock watering sites are heavily degenerated in a range of 1 km radius. Pasture degradation attracts rodent species, *Microtus brandti*, to those sites. Analysis of the habitat selection by this rodent on Maximum Entropy Model showed that habitat most preferred by voles are degraded grasslands along roads, ger (tent-type movable house) and watering sites with percent contribution varying from 5.5 to 47.9, and permutation importance of 25.1; 48.7 and 20.9, respectively. We suggest that in conditions of arid and sub-arid land, the livestock and wild animal's concentration around water sources may cause progressing degradation of pasture and desertification.

Key Words: Arid and semi-arid Afro-Eurasia, Home ranges of domestic and wild animals, Satellite tracking, Watering places

1. Introduction

Both geographically and ecologically, the Afro-Eurasian continental dry land is characterized by arid land with less than 250 mm of annual rainfall, or semi-arid (Gobi) with less than 500 mm of rainfall and represented by deserts, steppes, savanna, and mountain steppes. All these are poor in water resources. In condition of aridity the water is a major driving force for various environmental changes. In such places the people, livestock and wild animals are forced to be concentrated around water sources (rivers, lakes, wells, springs etc.), and their life traces often results in inhibition of the vegetation around that place. Over-exploitation of surroundings of the water source area result in it being devoid of plants and barren. Since water sources are very rare in arid land, their usage is very intense, without rest time and impedes the recovery of vegetation. Places with long term degradation may increase in size, covering the adjoining area and could serve as hot spots for the further degradation or desertification of the pastures. Moreover, due to climate change in recent years, the overgrazing of pastures in Mongolia has lead to the expansion of desertification and degradation of grassland (Batima *et al*., 2005). Newly deserted areas generate a new source of yellow sand storms that affects the neighboring countries and becomes a serious environmental issue. These environmental changes are shaking animal husbandry which is one of the major industries in the country. Also, it has been suggested that yellow dust storms may transfer pathogenic substances like foot-and-mouth disease agents across the borders (Maki *et al*., 2012).

In this study, we investigated home ranges of different livestock and wild ungulate species in arid and semi-arid area of Mongolia, China (Inner Mongolia, Tibet) and Sudan.

* Corresponding Author: aosier@rakuno.ac.jp
582 Midorimachi, Bunkyodai, Ebetsu-shi, Hokkaido 069-8501

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1) Department of Environmental Symbiotic, College of Agriculture, Food and Environmental Science, Rakuno Gakuen University, Japan
2) Faculty of Engineering and Resource Science, Akita University, Japan
3) Graduate School of Environmental Studies, Nagoya University, Japan
4) Arid Land Research Center, Tottori University, Japan
5) Graduate School of Dairy Sciences, Rakuno Gakuen University, Japan
6) Department of Veterinary Medicine, Rakuno Gakuen University, Japan

2. Methodology

To clarify the animal home range, daily movement of domestic and wild animals was tracked using GPS (Global Positioning System) collars and ARGOS satellite transmitters. The home range of sheep, goats and horses was investigated in Mongolia; those of sheep in China (Inner Mongolia); those of camels, donkeys and goats in Sudan; migration of Tibetan antelope (Chiru, *Pantholops hodgsoni*) in Tibet; and home range of the Brandt vole (*Microtus brandti*) in Mongolia.

The domestic animals were fitted with collars that contained a GPS logger. Each animal was tracked for one or two days; the GPS logger was programmed to collect information regarding animal positioning every 10 seconds and location signal was stored during grazing. All of the data were downloaded to PC and included date, time, traveling distance, speed, location (Latitude/Longitude). Using geographic information system (GIS) software (ArcGIS 10, ESRI) coordinates were converted to Universal Transverse Mercator (UTM) form to facilitate algebraic derivation of total distances and total areas.

According to the grazing route of an animal the condition of pastures were investigated on 1 m × 1 m quadrates along a transect from the house with the distance of 100 m, 200 m, 400 m and vegetation coverage, height, species and soil moisture were measured. We also recorded the spectral reflectance of plant species by Hand Held-Field Spec (©ASD). NDVI (Normalized Difference Vegetation Index) data include a 10-day composite SPOT VEGETATION (VGT) data set (with 1 km resolution) from June of 2000 to September of 2011 (ftp://free.vgt.vito.be/home.php) and those from Landsat TM have been used in this study.

The spatial and temporal patterns of the endangered Tibetan antelope have been studied using satellite-based ARGOS platform transmitter terminal (PTT) tracking data. The data were obtained from the satellite tracking of nine female Tibetan antelopes that were collared with satellite transmitters and have been tracked from August 2007 up to September 2012. The PTT were programmed to transmit signals for 24 h period every 3 days and the satellite tracking data was received through computer communications.

The distribution and habitats of the Brandt vole were studied using satellite and fieldwork data, aimed to clarify the influence that the habitation of the Brandt's vole gives on the degenerated pastureland. During fieldwork the geo-botanical studies (such as plant coverage, species richness, plants height and dry matter productivity (DMP)), landscape and habitat observations (such as elevation, land cover, colony sizes, and population density) were conducted. Field and satellite data were analyzed using Maximum Entropy Modeling. Maxent

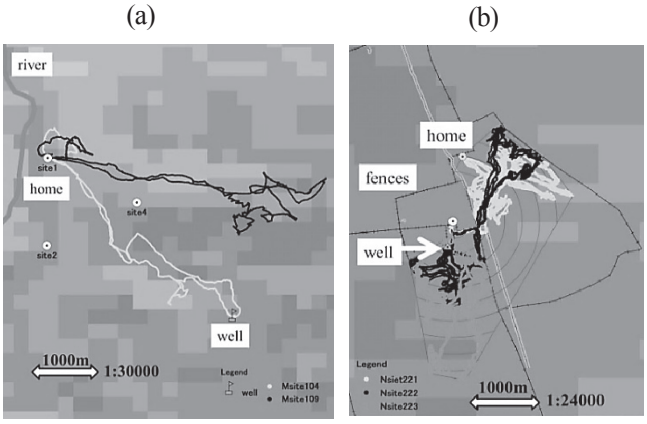

Fig. 1. GPS tracks of livestock where, (a): behavior of grazing sheep in mountain steppes of Harhorin County (Mongolia); (b): behavior of grazing sheep in the settlement in Abaq Xushuu of Inner Mongolia (the animals move around home, their tracks are forming numerous intersections).

Model is based on a machine learning response that is designed to make predictions from incomplete data. This approach estimates the most uniform distribution (maximum entropy) of sampling points compared to background locations given the constraints derived from the data (Phillips *et al*., 2006). The approximation of an unknown probability distribution should satisfy any known constraints, and subject to those constraints, should have maximum entropy (Jaynes, 1957).

3. Result and Discussion

3.1. Home range of livestock of nomadic and settled pastoralists

In conditions of mountain steppe zone of Mongolia (Harhorin County), nomads are located very close to a water source (Orkhon River). All of the sheep (5 sheep/days) and goat tracks (5 goat/days) graphically represented as simple elongated polygon, in which individual animals have moved from household to pasture and go back to home or well **(Fig. 1(a))**. It has been shown that the livestock movement tracked in different household places and during different dates possesses a similar pattern. The daily routes possess the same pattern, but pass in different places, not overlaying the previous.

The sheep tracks in settlements of Inner Mongolia, where livestock breeders use fences to protect their owned pastures, are different in shape with numerous intersections, grazing distance and other characteristics (Fig. 1**(b)**). The fences are largely restricting behavior of the animals that are forced to graze in narrow range inside the fences. Multiple overlays and crosses of previous paths are the characteristic pattern caused by grazing in enclosures. Grazing velocity and total grazing distances were higher than that of Mongolian

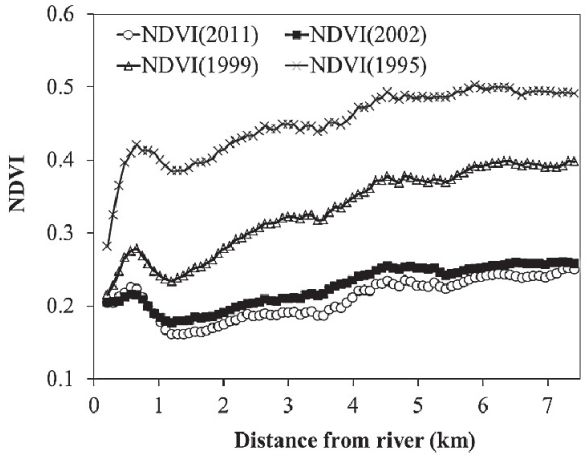

Fig. 2. Distribution of NDVI values in dependence with distance from the water source (Orkhon River, Harhorin County, Mongolia).

livestock.

3.2. Degradation of pastures around water sources

Depending on the frequency of its use by livestock, the water source places can become a hot spot for desertification and degradation of the land. **Figure 2** shows the values of normalized difference vegetation index (NDVI) calculated from Landsat TM satellite data, which were overplayed on the sheep satellite tracking data. During the 16 year period from 1995 to 2011, the vegetation coverage at riverbed and both sides of the Orkhon River was deteriorated in an 1 km distance range from the river due to livestock trampling. The plant height and coverage has gradually decreased with closer to river distances, for except only two species that are of low palatability to livestock (such as *Potentilla bifurca Linnaeus*, and *Elymus chinensis*). Especially after 2002 when the study area was utilized as summer pastures, the vegetation cover in river basin showed significant degradation (Hoshino *et al*., 2009, 2012; Suriga *et al*., 2012).

Plants with a high grazing-resistance, such as species belonging to *Urticaceae* or *Iridaceous*, were dominant in riverbed and places closer to ger; the results of our field survey showed that species belonging to these families were abundant in 1 km range from the river. NDVI values reach peak at the distance of 4.5 km from the ger and river. The places near to ger and water source are characterized by plants with poor palatability, but this varies with distances. In general, plants with low palatability are widely distributed and dominant species are perennial grasses belong to *Poaceae* and annual species belong to *Asteraceae*. It is considered that in this area the grassland degradation is progressing even at 5 km distance from the river.

Because there is a water source in the vicinity of 200 m from the ger, the plant cover is reduced by trampling, and

Table 1. Comparison of livestock home ranges in two study sites in Mongolia and Inner Mongolia.

	Grazing velocity (km/h)		Tracking area (ha)	
	MEAN	SD	MEAN	SD
Inner Mongolia	0.65	0.07	214.88	149.73
Mongolia	0.54	0.3	246.03	197.36

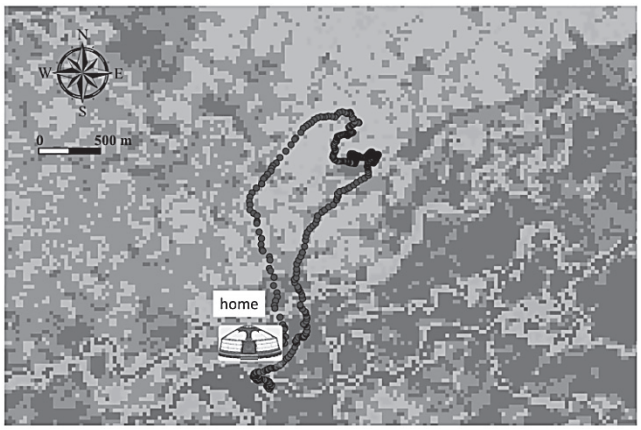

Fig. 3. GPS tracking of the domestic horse in Mongolia (August 28, 2002; Mungunmorit County).

consists mainly of species with low palatability. In comparison with 2011, when precipitation values were only half that of 2012 (208 mm vs 400 mm), the vegetation had overall increased in 2012. However, there was no change in abundance of *Poaceae* and only annuals are benefited from a sudden rainfall.

The pasture use by livestock in settled households in Inner Mongolia and nomadic households in Mongolia is very different. The movements of sheep and goats in Inner Mongolia have been restricted by fences and animals which have to use the same pasture repeatedly; in Mongolian case animal movement has not been restricted by any kind of artificial barriers and their tracks did not overlay in 2 days of field observation.

Comparison of the average distances, home range area and grazing velocity of the livestock on both sites (Inner Mongolia and Mongolia), showed that home range area was larger in Mongolia, but grazing velocity and distances were longer in Inner Mongolia (**Table 1**). It is believed that the home range area in Inner Mongolia was smaller due to the limiting effect of pasture fences.

3.3. Home range of domestic horses in Mongolia

GPS tracks of domestic horses in Mongolia were greatly affected by the hot temperatures and blood-sucking insects that occurred during our study. Graphically these are represented as a simple elongated polygon, without crosses on paths. However the animals spent a lot of time during insect activity

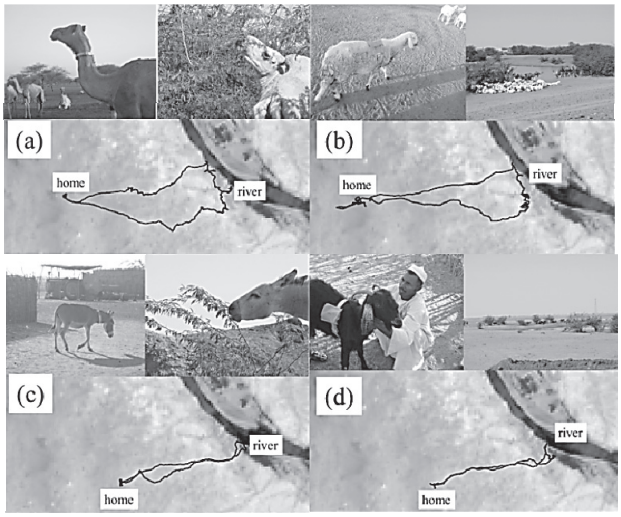

Fig. 4. The home range of livestock at Atbara river, East Kassala State, Sudan Republic (where, (a) is domestic camels; (b) is domestic sheep; (c) is domestic donkeys and (d) is domestic goats (the red color zone along river is dense mesquite forests, black lines shows GPS tracking of behavior of livestock). The background image is provided by Landsat TM 5, the R-G-B color combination is TM bands 4(NIR)-3(Red)-2(green), October 14, 2011.

in waters of Herlen River (**Fig. 3**).

3.4. Home ranges of livestock in Sudan

The life of nomadic peoples of semi-arid Sudan also relies on the condition of pastures and precipitation; they move north in rainy season and migrate south during a dry season. Similar to Mongolia, in Sudan, the livestock (camels, donkeys and goats) home range forms elongated polygons that connect the water source (home) and the grassland with abundant vegetation. The home range of camels is slightly larger than that of donkeys and goats (**Fig. 4**).

3.5. Home range of wildlife (Tibetan antelope (*Pantholops hodgsoni*))

Satellite tracking of the migrating chiru was successful; eight of nine tracked individuals used a breeding site in the surroundings of the lake Huiten (or Zhuonai lake) that is located in the National Reservation of Huh-Xil, China (situated 4900 m - 5100 m above sea level). The satellite data clearly show exact locations of summer (calving), intermediate (transitional during migration) and winter pastures, and also provided data on the Tibetan antelope's temporal distribution pattern (**Figs. 5** and **6**).

During the observation period, only winter pastures were used for the majority of the year (in average 9 months). So called summer calving grounds were used for a short time of 8 to 20 days and temporal pastures were used during migration to and from calving ground. As was found in a previous study, the seasonal migration cycle has been limited to a 3

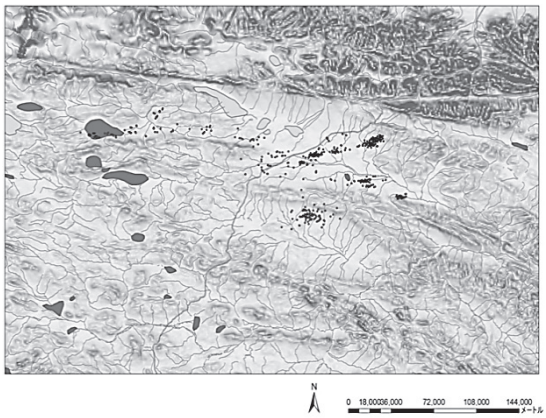

Fig. 5. ARGOS satellite ground signals of tracked chiru (chiru wintering ground are located east from railway; pregnant chiru headed for lake Huiten nur to give birth).

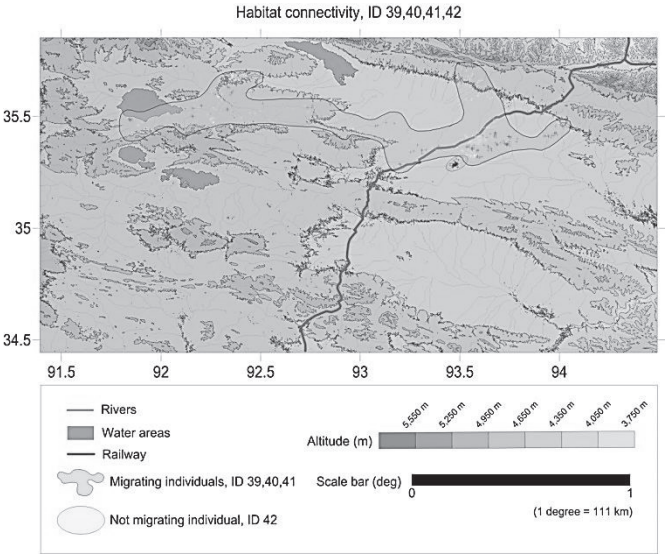

Fig. 6. Home range of chiru in Tibetan high plateau (four individuals of female chiru with ARGOS transmitter ID 39, 40, 41, 42 showing the same migrational pattern from wintering place to breeding ground).

month period beginning from May and ending in August (Hoshino *et al*., 2011; Manayeva *et al*., 2012).

3.6. Home range of the Brandt Vole (*Microtus brandti*) in Mongolia

Heavily overgrazed pastures became suitable habitats for the colonies of the Brandt's vole (*Microtus brandti*). The rodent pest prefers short grass steppe habitat with sparse vegetation and readily colonizes degenerated pastureland.

Analysis of the habitat selection by this rodent on Maximum Entropy Model showed that habitat most preferred by voles are degraded grasslands along roads, "ger" and watering sites with percent contribution varying from 5.5 to 47.9, and permutation importance of 25.1; 48.7 and 20.9, respectively (**Fig. 7** and **Table 2**). At this time, we do not believe that the more dense distribution of voles around water

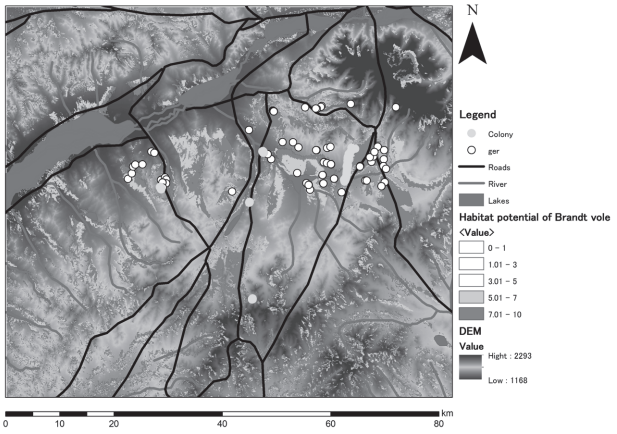

Fig. 7. Distribution of colonies of Brandt vole (white: ○ is ger; green● is vole colony; the vole colonies are concentrated in places with degraded vegetation close to ger, wells, and along roads).

Table 2. Analysis of the variable contribution for the habitat selection by *Microtus brandti*.

Variable	Percent contribution	Permutation importance
Distance from the roads	**47.9**	**25.1**
Distance from the Yurt (home)	**35.4**	**48.7**
Digital elevation	7.3	2.8
Distance from the river (watering places	**5.5**	**20.9**
Effective brightness temperate	2.8	1.2
Heat Load Index	0.7	0.6
Hill shade	0.3	0
Slope	0.2	0.5
NDVI	0	0.2

sources is related to the need for water. The livestock watering sites are trampled and overgrazed at most and became suitable habitat for the voles. Voles are abundant in degraded grassland along rivers, as well as around wells and springs (Batsaikhan *et al*., 2001; Kawashima *et al*., 2012, 2013).

4. Conclusions

The constant movement of nomads with their livestock throughout the year is explained by limited natural resources of water and plants; nomads need to use that in a sustainable way. The nomadic movement range is also limited by the spatial and seasonal distribution of the water resources. In Mongolia, nomadic families are requiring pastures with water sources and the water availability is a major factor that determines livestock distribution and its home range patterns. But, in Inner Mongolia, the pasture size and kind is determined by enclosures, regardless of water source location. So far, the limiting factor in the former case is a water source and in the latter case is an enclosure size. The spatial pattern of the habitat use by sheep and goats are greatly different in the two places due to the availability of water or to the limitation in pasture space. In general, the animals at first quickly move tending to reach previously unused pastures and graze while slowly moving back to home or water source. In restricted environments, grazing behavior is altered to chaotic movement that results in increased trampling effect on pastures inside. In unrestricted environments, trampling and overgrazing occurred around nomads' home and water sources. Such places are attracting the Brandt vole, which benefits from pasture overgrazing, rapidly multiplying in numbers and spreading over entire degraded pastures. Abrupt population increase of the rodents leads to the further deterioration of pastures. The long-term stay around one water source causes a variety of negative outcomes including water depletion, water contamination of the overgrazing at surrounding area, and finally the place becomes a hot spot of degeneration and desertification.

The home range patterns in livestock in Sudan resembled those in Mongolia, but the nomad's home was located away from water source and this has forced the livestock to go rivers for watering and grazing in its surroundings.

Of the study areas, only Tibet has been well secured with water sources. The Tibetan antelope is characterized by distinct female only seasonal migrations, during which the females are migrated to calving grounds and after giving birth go back to wintering places. Causes of such migration are not fully understood and require more detailed investigation that is important for species conservation and protection.

Pasture degradation in the wide area of arid and semi-arid Afro-Eurasian watering places is forced by climate change and overgrazing. It is very difficult to provide assessment, monitoring and management using conventional methods. However, remote sensing, GPS (Global Positioning System) and GIS (Geographic Information System) techniques are very helpful and useful tools for detecting change of habitat and tracking of behavior of animals. We suggest that in conditions of arid and sub-arid land, the livestock and wild animal's concentration around water sources may cause progressing degradation of pasture and desertification.

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