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Home range study of the Korean water deer (*Hydropotes inermis agyropus*) using radio and GPS tracking in South Korea: comparison of daily and seasonal habitat use pattern

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Abstract

The water deer (*Hydropotes inermis*) is one of the most primitive extant deer of the family Cervidae. Unlike Chinese water deer, Korean water deer have rarely been studied, even though they have relatively well remained in Korea. In particular, the home range of the Korean water deer has not yet been studied. Here we estimated the home range of the Korean water deer using two different methods (GPS and radio tracking) and analyzed the home range according to sex, time, and season. The mean home range size of four individuals was 2.77 km^2 and 0.34 km^2 under the 95% minimum convex polygon (MCP) and the 50% kernel (K) method, respectively. There seemed to be a difference in home range size between males (3.30 km^2) and females (2.25 km^2) under the 95% MCP method. We also found a difference in home range size between day (1.90 km^2) and night (2.43 km^2) by 95% MCP method. In addition, a home range size difference was observed between summer (4.65 km^2) and spring (0.48 km^2) or fall (0.85 km^2) using the 95% MCP method. Water deer seemed to have a larger home range in night than in day, and males also have a larger home range. We presumed that the GPS tracking method of the code division multiple access system could be a very useful tool for understanding the ecology of the water deer using the radio tracking method. Using these tracking methods and through future research, we can better understand the habitat use pattern of these water deer.

Key words: daily pattern, GPS collar, home range size, radio collar, season, sex differences, water deer

INTRODUCTION

The water deer (*Hydropotes inermis*) is one of the most primitive extant deer of the family Cervidae. Males of these animals have large canine teeth, and neither males nor females have antlers (Cooke and Farrell 1998). Two subspecies of the water deer currently exist: the Chinese subspecies (*H. inermis inermis* Swinhoe, 1870), and the Korean subspecies (*H. inermis argyropus* Heude, 1884) (see Geist 1998). Some of the Chinese subspecies were introduced into England and France in the late nineteenth century (Cooke and Farrell 1998, Geist 1998). The Chinese subspecies has been seriously restricted in distribution and population size in China (Wang 1998). In contrast, the Korean subspecies has mostly remained in Korea (Won and Smith 1999). However, a clear survey has

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not yet been conducted. The Chinese subspecies have recently been continuously studied (Xu et al. 1996, Wang 1998, Zhu et al. 2004, Hu et al. 2006, 2007, Koh et al. 2009), but the ecology and genetics of Korean water deer have rarely been studied (Lee 2003, Kim 2007, Koh et al. 2009). Water deer have preferred Asteraceas family followed by Fagaceae and Polygonaceae (Kim et al. 2011). Diets in the lowland and mountainous areas are different. We need to estimate the home range of wildlife in general to better understand habitat use patterns. In Korea, other wildlife species such raccoon dogs (*Nyctereutes procyonoides*) (see Choi and Park 2006, Kim et al. 2008), wild boars (*Sus scrofa*) (see Choi et al. 2006), and Asiatic black bear (*Ursus thibetanus*) (see Yang et al. 2008) have been studied, but only limited amounts of data were gathered.

An individual's home range, the area used by an animal in its normal activities of food collection, mating, and raising its young (Burt 1943), is a fundamental piece of its ecology. To estimate home range size, both minimum convex polygons (MCP) and kernel (K) methods have been commonly used because they are easily compared among studies (Harris et al. 1990, White and Garrott 1990). The K method usually allows for the determination of the center of activity (Worton 1989, 1995, Seaman and Rowell 1996).

Home range sizes of the water deer have been reported in a few studies (Cooke and Farrell 1998). In China, mean seasonal home ranges varied from 18 (1.8 km^2) to 46 ha (4.6 km^2) in a population. Females established feeding sites and set up small territories of about half a hectare. In England, the mean annual home range size was 21 ha (2.1 km^2) at Whipsnade. However, home range studies have not yet been conducted in Korea. Therefore, such studies are essential to understanding the ecology of the Korean water deer. The aim of the present study was to estimate home range sizes. Sex, time (6 AM-6 PM, day and night), and season were considered in the home range comparison.

MATERIALS AND METHODS

Study sites

Two different study sites were targeted in the present study (Fig. 1): one is Daebu Island, Ansan of Gyeonggi Province (126°34'30"-126°39'0" E, 37°15'0"-37°16'30" N), and the other is a rural area of Chuncheon, Gangwon Province (127°46'04"-127°45'23" E, 37°48'28"-37°47'50" N) in the central parts of the Korean peninsula. In the former site, two different types of habitats were found, including a reclaimed area (lowland) and a mountainous area (highland). Dominant species in the reclaimed area included halophytes (e.g., *Salicornia europaea* and *Suaeda japonica*) and reeds (e.g., *Miscanthus sinensis*, *Phragmites communis*, and *Arundinella hirta*). In contrast, shrubs and trees were dominant in mountainous areas. A variety of herbs were commonly found in both areas. In general, the mountainous area consisted of mixed forests dominated by oaks (*Quercus* spp.) and pines (*Pinus* spp.). Various types of herbs were commonly found in the mountainous area.

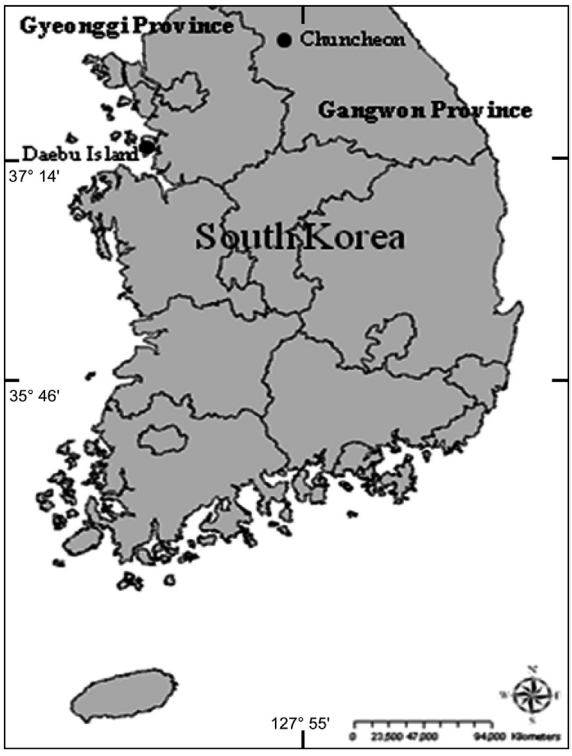

Fig. 1. Map of the study sites: Shihwa reclaimed area, Ansan, Gyeonggi Province, and Chuncheon, Gangwon Province.

Tracking

In Ansan, a total of five individuals were captured using an anaesthetizing gun (N = 2, succicholine injection 200 mg) or rescued from injury (N = 3). Among them, the three individuals rescued from injury were banded on the neck and released into the Shihwa reclaimed land. Despite the injury, no movement problems were observed. Only one female individual could be radio-tracked, and the other two individuals died within one month after release. Two individuals captured using the anaesthetizing gun were killed before release. In a rural area of Chuncheon, two

males and one female were rescued from injury ($N = 3$) by the wildlife medicine center of Gangwon National University. The three individuals were banded on the neck and released into their original habitats. Two males and one female could be tracked after release. All of the released individuals were handled after anaesthetizing. The animals from Ansan were sexed, weighed, aged, and banded before release. One female was continuously tracked for two sequential days with about 1-h gaps using a radio collar (July and November, 2009), and two males and one female were intensively tracked for 2-15 days with about 1-h gaps using a GPS collar (August and September, 2009). We could not detect the radio-tracked female after December 2009 due to signal loss. No signal could be detected on the GPS-tracked male after 15 days due to battery consumption. One male and one female were killed by passing traffic after 2-3 days. The ground homing method was used to radio-track the female (Mech and Barber 2002, Kim et al. 2008). The radio tracking was generally done from a truck using a VHF antenna (Wildsystem, Gurye, Korea) and a R20 radio receiver (ICOM Inc., Tokyo, Japan). We followed the strongest signal to close in on the individual and tried to reduce bias by tracking as carefully as possible using radio tracking (White and Garrott 1990). For GPS tracking, which provides scientists with the ability to track an animal's position and status in real time, we collected GPS coordinates from our homes and offices without any field work. The GPS coordinate data were obtained using a cell phone via Short Message Service (SMS) during the survey periods.

Home range analysis

ArcGIS9.3 computer software (ESRI Inc., San Diego, CA, USA) was used for the home range analyses. All data collected were analyzed to estimate the home range of the Korean water deer using the Home Range Tools (HRT) for ArcGIS9.x. For topographic maps, 1:5,000 maps from the National Geographic Information Institute (NGI, Seoul, Korea) were used. Both the 95% fixed MCP and the 50% fixed K methods were used to calculate home range sizes of the Korean water deer (Worton 1989, Harris et al. 1990, White and Garrott 1990, Worton 1995, Seaman and Rowell 1996). Tracking data of the four individuals were used to estimate home range sizes based on sex, time, or season.

RESULTS

In this study, we analyzed home range sizes of four individuals (the number of fixes for subject 2, 6, 7, and 8 were 96, 217, 42, and 15 GPS points, respectively) of the Korean water deer. The mean home range size of the four individuals was 2.77 km^2 by 95% MCP and 0.34 km^2 by 50% K (Table 1). There seemed to be a clear difference of home range size between the male (3.30 km^2) and female (2.25 km^2) using the MCP method but little difference of home range size between the male (0.23 km^2) and female (0.45 km^2) using the K method (Table 2). For the 95% MCP method, we found a meaningful difference in home range size between day (6 AM-6 PM, 1.99 km^2) and night

Table 1. Information on the Korean water deer ($N = 8$) captured in the present study

ID	Sex	Weight (kg)	Period of tracking (months)	Real tracking days	No. of collected coordinates	Capturing method	Tracking data
Daebu island, Ansan, Gyeonggi Province ($N = 5$)							
1	Male	13	N/A (0)	N/A (0)	N/A (0)	Anaesthetizing gun	Killed by shock
2	Female	15	4	6	96	Rescue from injury	Loss of signal from December, 2009
3	Female	20	N/A (0)	N/A (0)	N/A (0)	Anaesthetizing gun	Killed by shock
4	Male	17	N/A (1)	N/A (2)	N/A (4)	Rescue from injury	Killed before tracking
5	Male	12	N/A (1)	N/A (1)	N/A (3)	Rescue from injury	Killed before tracking
Chuncheon, Gangwon Province ($N = 3$)							
6	Male	N/A	2	15	217	Rescue from injury	Loss of signal
7	Male	N/A	1	3	42	Rescue from injury	Killed by road-kill
8	Female	N/A	1	2	15	Rescue from injury	Killed by road-kill

All individuals were adults. Number in parenthesis is sample size.
N/A, not applicable.

(2.43km^2) (Table 2). Also, a great difference in home range size of the Korean water deer was observed between summer (June-August, 4.65 km^2) and spring (March-May, 0.48 km^2) or fall (September-November, 0.85 km^2) (Table 2). For the 50% K method, little difference in home range size was found between day (0.32 km^2) and night (0.26 km^2) or between summer (0.57 km^2) and spring (0.14 km^2) or fall (0.21 km^2) (Table 2).

DISCUSSION

The home range size of the Korean water deer has been unavailable until now. All of the current studies used a radio collar to track each animal. GPS tracking using a cell phone collar has recently been used to track wild mammals worldwide. However, such a method has not yet been used in Korea. Therefore, it is necessary to apply such a method using a GPS collar and a code division multiple access (CDMA) system for Korean wildlife tracking. Here we mentioned our results using both radio and GPS tracking.

Based on our results, the Korean water deer showed a mean home range size similar to that of the Chinese water deer in China and England. In the present study, mean home range size (N = 4) was approximately 2.8 km^2 for 95% MCP during the study periods. There have been few studies on home range size of the Chinese water deer. At Whipsnade in England, the mean annual home range size was 21 ha (2.1 km^2; 1.2-2.5 km^2) (Cooke and Farrell 1998). In China, it was also reported that mean home range sizes of a population varied between 18 (1.8 km^2) and 46 ha (4.6 km^2) (Cooke and Farrell 1998). Based on the information about home range sizes provided above, those of the Korean water deer (0.2-6.4 km^2) seem to be similar to those of the water deer in England (1.2-2.5 km^2) and China (1.8-4.6 km^2).

In the wild, feeding activity of nocturnal mammals tends to be higher at night than during the day. For example, raccoon dog feeding areas differed largely between daytime (0.01 km^2) and nighttime (0.35 km^2 for 95% MCP) hours (Kim et al. 2008). The Korean water deer in the present study showed the same pattern. However, the Korean water deer moved somewhat more to feed during the daytime (1.90 km^2), even though it moved much move actively at night (2.43 km^2 for 95% MCP). In fact, it seemed to spend its night-time hours mainly feeding by ruminating, whereas it spent its day-time hours both ruminating and resting. Based on our observations, the Korean water deer tended to move actively after dawn (500-700) and before

Table 2. Home range sizes (km^2) of the Korean water deer by individual, sex, time and season

Method	Individual					Sex			Time			Season				
	Radio No. 2 (female)	GPS No. 6 (male)	GPS No. 7 (male)	GPS No. 8 (female)	Mean (SD)	Male (N = 2)	Female (N = 2)	Mean (SD)	Day (N = 4)	Night (N = 4)	Mean (SD)	Spring (N = 2)	Summer (N = 2)	Fall (N = 1)	Mean (SD)
95% MCP	3.69	6.43	0.16	0.80	**2.77 (2.88)**	3.30 (4.43)	2.25 (2.04)	**2.77 (2.88)**	1.90 (2.16)	2.43 (2.88)	**2.17 (2.38)**	0.48 (2.88)	4.65 (4.43)	0.85 (2.04)	**2.77 (2.56)**
50% K	0.67	0.40	0.05	0.22	**0.34 (0.27)**	0.23 (0.25)	0.45 (0.32)	**0.34 (0.27)**	0.32 (0.19)	0.26 (0.16)	**0.29 (0.17)**	0.14 (0.12)	0.57 (0.23)	0.21	**0.32 (0.26)**

SD, standard deviation; MCP, minimum convex polygon method; K, kernel method.

sunset (1,700-1,900). The water deer usually moved to its feeding site(s) or its resting site(s) during those hours. Cooke and Farrell (1998) reported that Chinese water deer spend about half of their daytime hours feeding. The water deer also fed at night, but details of quantity have not yet been determined (Cooke and Farrell 1998). The feeding peaks occurred in the early morning and in the evening as seen in the present study.

To investigate the seasonal differences in home range sizes, we analyzed home range sizes using both radio tracking ($N = 1$) and GPS tracking ($N = 1$) in summer, using GPS tracking ($N = 2$) in spring, and using radio tracking ($N = 1$) in fall (Table 2). We found a large difference in home range sizes between summer and spring or fall. Home range sizes were much more extensive in summer (4.65 km^2) than in spring (0.48 km^2) or fall (0.85 km^2 for 95% MCP) in our tracking. Such seasonal variations of home range size have not yet been analyzed in detail. Cooke and Farrell (1998), however, reported that mean seasonal home ranges were found to vary between 10 ha (1 km^2) and 46 ha (4.6 km^2) depending on season. Presumably, water deer use larger areas and actively move to feed on plants under good conditions during the summer and use smaller areas and move in a more restricted manner feed on plants under relatively poor habitat conditions during the spring, fall, and winter.

Finally, we analyzed the differences in home range size between females and males (Table 2). Based on our study, the female (2.25 km^2 for 95% MCP) showed a smaller home range than the male (3.30 km^2 for 95% MCP). Cooke and Farrell (1998) mentioned that home range size was largest for older females (about 1 km^2) and second-year deer (about 1.5 km^2) from late spring (May) to mid-summer (July), whereas home range size was < 0.5 km^2 for older males (> 2 years). Our results showed that the mean home range size of adult males (≥ 2 years) was larger than that of adult females (≥ 2 years), even though it is difficult to compare with previous results.

In conclusion, we first estimated home range size of the water deer using radio and GPS tracking in Korea. The Korean water deer appeared to have a home range of 0.2-6.4 km^2, which is similar to that of the Chinese water deer in China and England. There were variations between day, night, seasons, and sexes seen in the present study. However, further extensive studies should be conducted to evaluate detailed home range sizes due to our limited data (e.g., the small number of individuals tracked and no tracking in the winter). We suspect that GPS tracking based on the CDMA system could be a very useful tool for understanding the ecology of the water deer using the radio tracking method.

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