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A Brief Report of the Short-Term Home Range Study of a Pair of Raccoon Dogs(*Nyctereutes procyonoides koreensis*) in a Rural Area of Gurye, Chonnam Province, South Korea Using Radiotracking Method[1]

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전라남도 구례 농촌지역에서의 단기원격무선추적을 이용한 너구리(*Nyctereutes procyonoides koreensis*) 한 쌍의 행동권에 관한 연구[1]

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ABSTRACT

The primary aim of this study is to estimate the home range of a pair of raccoon dogs(*Nyctereutes procyonoides koreensis*) and to compare with the previous study of raccoon dogs in a rural area of Gurye, the southern part of South Korea. Radiotracking was regularly carried out on 2 raccoon dogs for 2 days every 2 months(in June, August, October and December, 2006). During the 2 days, radiotracking was usually conducted every 1 ~ 3 hours through day and night. The analysis of tracking data with a total of 46~64 bearings showed that the total home range size of the pair was 0.41㎢, and mean home range size was 0.32㎢ by 95% minimum convex polygons(MCP) estimate. The home ranges of the male and female were largely overlapping(about 70~95%), and the sizes were not very much different from each other. However, there was a big difference between day(0.01㎢) and night-time(0.35㎢) home ranges, and it was largest in summer(0.56㎢) and smallest in winter(<0.01㎢). In addition, the home range of the pair included 1 core area and 4 different feeding areas. In conclusion, our raccoon dog home range data using the same individuals but with more frequent bearings per day and more extended tracking intervals still showed very similar results to the previous study with less frequent bearings per day and more extensive tracking days.

KEY WORDS : HOME RANGE OF MALE AND FEMALE, HOME RANGE IN DAY AND NIGHT-TIME, SEASONAL HOME RANGE

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요 약

이 연구의 주된 목적은 구례 농촌지역에 서식하는 1쌍의 너구리(*Nyctereutes procyonoides koreensis*) 행동권을 측정하고 이전 너구리 연구와 비교하는데 있다. 원격무선추적은 2개체의 너구리를 이용하여 2개월 간격(2000년 6, 8, 10, 12월)으로 2일씩 주기적으로 수행되었다. 모니터링 기간 동안, 무선추적은 주간과 야간에 걸쳐 보통 1~3시간 간격으로 실시되었다. 전체 46~64개의 무선추적 자료의 분석 결과는 95% 최소볼록다각형(MCP) 방법에서 1쌍의 너구리의 전체행동권 크기가 0.41㎢, 평균행동권 크기가 0.32㎢임을 보여주었다. 암컷과 수컷의 행동권은 상당 부분 중첩되었고(약 70~95%), 행동권 크기는 서로 유사한 양상을 나타내었다. 그러나 주간(0.01㎢)과 야간(0.35㎢)의 행동권 크기는 매우 큰 차이를 보였고, 여름(0.56㎢)에 가장 컸지만 겨울(<0.01㎢)에 가장 작았다. 추가적으로, 1쌍의 너구리는 1개의 핵심지역과 4개의 서로 다른 섭식지역들을 가지고 있었다. 결론적으로, 동일한 개체들을 이용하여 하루 동안 더 빈번한 추적 수와 더 긴 추적 간격을 이용한 이 너구리 행동권 자료는 하루 동안 덜 빈번한 추적 수와 더 짧은 추적 간격을 이용한 이전의 연구와 매우 유사한 결과를 보여 주었다.

주요어 : 암수의 행동권, 주야간의 행동권, 계절적 행동권

INTRODUCTION

The raccoon dog(*Nyctereutes procyonoides* Gray) is a nocturnal Asian native canid with 6 recognized subspecies (Ellerman and Morrison-Scott, 1951; Ward and Wurster-Hill, 1990; Kauhala and Saeki, 2004). The raccoon dog lineage diverged from other canids probably as early as 7~10 million years ago(Wayne, 1993). This species is a true omnivore and its seasonal food habit shifts as food availability changes(see Kauhala and Saeki, 2004 for references). The species exhibits profound fattening in preparation for winter during the fall(Kauhala, 1992), and spends 4~5 months of midwinter in a burrow or den in a superficial hibernation-like state in Finland(Asikainen *et al.*, 2004). The raccoon dog is strictly monogamous, the male and female forming a permanent pair(Kauhala *et al.*, 1993), or lives in groups at least in some areas(Ikeda *et al.*, 1979; Ward and Wurster-Hill, 1989). It achieves sexual maturity at 9 ~ 11 months and can breed in the first year, and reproduce every year thereafter(Kauhala and Saeki, 2004). Mating occurs in the beginning of spring, usually March in Finland(Helle and Kauhala, 1995). It is widespread in northern and eastern Europe as an introduced species from the former Soviet Union, and in Asia as an endemic species(Ellerman and Morrison-Scott, 1951).

The raccoon dog is one of the most abundant mammals in South Korea(Won *et al.*, 2004). About 35% of the total mammal casualty cases treated in wildlife rescue centers is from this species, which is the highest among mammals in South Korea(Kim, 2006). In addition, Choi and Park (2006a) reported that the incidence of road-kill in this species is second highest among mammals in Jirisan area. On the other hand, it is known as a major vector, either carrier or transmitter, for sylvatic rabies in regions near the Korean demilitarized zone, DMZ(So *et al.*, 2002a; 2002b; Hyun *et al.*, 2005; Kim *et al.*, 2006). Therefore, research on the ecology of raccoon dogs is essential for building effective strategies of managing the population, zoonoses and ecosystem health.

Home range of an animal is the area traversed by the individual in its normal activities of food gathering, mating and caring for its young(Burt, 1943). In raccoon dogs, home range sizes have been reported from various studies in many European countries(see Kauhala and Saeki, 2004 for references) and Japan(see Saeki, 2001 for references). Both minimum convex polygons(MCP) and kernel(K) methods have been used as tools of home range size estimation, because they are easy to compare among studies(Harris *et al.*, 1990; White and Garrott, 1990). Whereas the former methods do not indicate how intensively different parts of an animal's range are used, the latter methods allow determination of center of activity (Worton, 1989; 1995; Seaman and Powell, 1996). These

methods have been previously used for raccoon dogs (Saeki, 2001; Kauhala *et al.*, 2006). In addition, population density, dispersal distance, home range overlap and habitat utilization pattern are required to understand the ecology, and disease transmission in the species(Saeki, 2001; Kauhala *et al.*, 2006). In general, home range size is known to be negatively correlated with population density, and positively correlated with dispersal distance (Macdonald and Bacon, 1982; Harris and Trewhella, 1988; Trewhella *et al.*, 1988). High density increases the risk of disease prevalence(e.g., scabies or sarcoptic mange and rabies) and long dispersal distances usually speed the spread of diseases(Artois and Andral, 1980; David *et al.*, 1982; Macdonald and Sillero-Zubiri, 2004). On the other hand, overlap between home ranges affects the likelihood of intra and inter-species contact. Habitat utilization by raccoon dogs has been also studied in previous experiments(Saeki, 2001; Kauhala *et al.*, 2006).

In research by Choi and Park(2006b), the only known report on home range size of raccoon dogs in South Korea to date, radiotracking of 9 individuals with 1 or 2 bearings was conducted every day for at least 3 months. The report showed that the raccoon dogs in the Gurye area had a very small home range size, usually less than 1㎢. However, the number of bearings(1 or 2) every day in the study was too small to ascertain the mean home range of the raccoon dogs over the year. To extend the previous study, we conducted another radiotracking study of the raccoon dog pair with more bearings(about 9 bearings a day; total 46~64) from early summer through the winter season. The raccoon dog pair tracked in this study was the same individuals that were used in the previous radiotracking study. The aim of the present study was to estimate home range sizes, home range overlap and habitat utilization by the raccoon dogs and to compare with the previous study.

MATERIALS AND METHODS

1. Study site

The study site(about 4×5㎢) is a rural area of Gurye, Chonnam province, in the southern part of South Korea (Figure 1). All raccoon dogs were trapped from open grasslands and bush(usually reeds) habitats near Seosi stream. Surrounding this site, various types of habitat exist, such as rice paddies, dry fields, orchards, grasslands and forest, in which wild raccoon dogs could obtain enough food and cover throughout all seasons. There are several poultry and cattle farms in the study site, and the area is situated in the middle of several small villages and roads. The ground was frequently covered with snow for about 4 months, usually from November to February.

2. Radiotracking

Four raccoon dogs were captured using traps(Havahart live trap and Soft catch spring trap) in 3 areas between October 2004 and July 2006(22 months). Of the 4 raccoon dogs captured, 2(the same individuals, identified as E and F in Choi and Park, 2006b) were anaesthetized by an intramuscular injection of Ketamine(0.15ml/kg) and Rompun(0.1ml/kg) mixture, and the others(newly captured

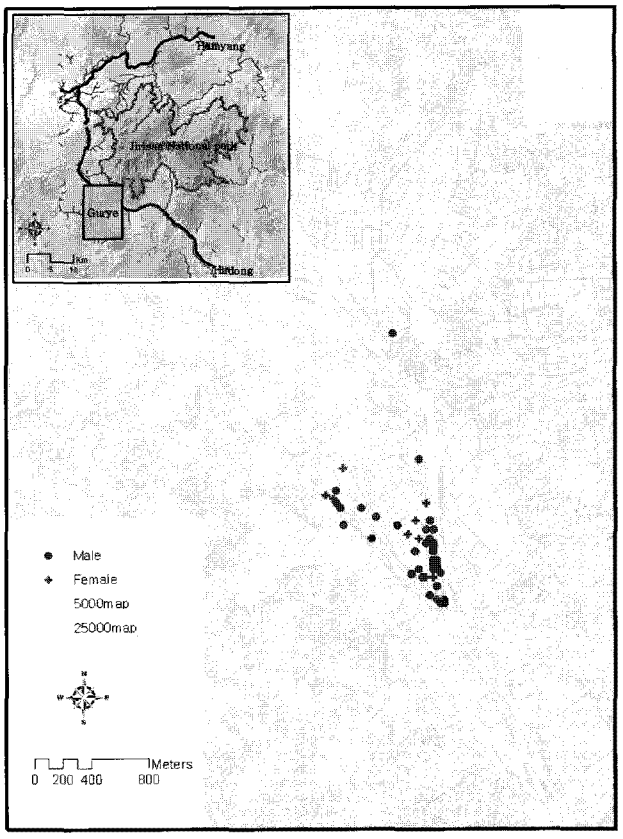

Figure 1. Maps of study site, Gurye, Chonnam Province in the southern part of South Korea. Large: topographic map, 1: 5,000; Small: topographic map, 1: 25,000

Table 1. Information on the raccoon dogs(n = 4) captured in this study

Individual	Sex	Age	Weight (kg)	Duration of tracking(months)	Actual tracking days	No. collected coordinates	Radiotracking data
A	M	Adult	5.6	7	11	64	available during the whole radiotracking period
B	F	Adult	5.8	5	8	46	available between June and October 2006
C	F	Adult	6.0	N/A (2)	N/A (4)	N/A (6)	killed by disease unidentified
D	F	Yearling*	3.0	N/A (2)	N/A (3)	N/A (0)	killed by disease unidentified
Mean			**5.1**	**6**	**9.5**	**55**	

M: male, F: female, *: younger than 1 year old

individuals) were handled without anaesthetizing. The animals were sexed, weighed, banded with a radiocollar (Model ATX150AA, Wildsystem, Rep. Korea), and released as soon as possible(Table 1).

Among the 1 male and 3 females captured, 1 male and 1 female were continuously radiotracked for sequential 2 days every 2 months with about 1~3 hour gaps(Jun., Aug., Oct. and Dec. 2006). In December, we could not get any bearings of the female due to the loss of the signal. The radiotracking was done mainly from a truck with a VHF antenna(Wildsystem, Rep. Korea) and a R20 radioreceiver (ICOM Inc., Japan). Homing by ground method was used for tracking the pair(Mech and Barber, 2002). We followed a signal toward the greatest strength to close in on the individual, and tried to reduce the bias with a greatly careful tracking as much as possible during the radiotracking(White and Garrott, 1990).

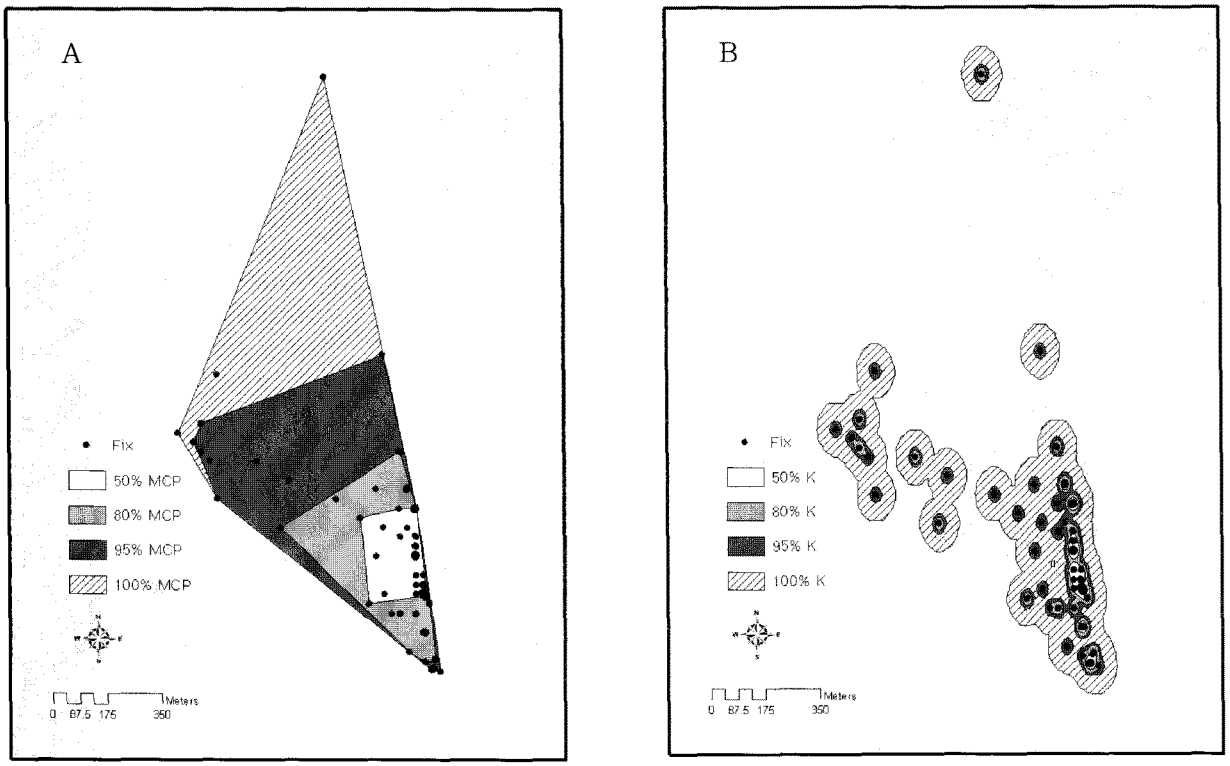

Figure 2. Total home ranges of the 2 raccoon dogs(a pair) for minimum convex polygons(MCP) and kernel(K) methods A. Home ranges by 100, 95, 80 and 50% MCP. B. Home ranges by 100, 95, 80 and 50% K

3. Home range Analysis

ArcGIS9 computer program(ESRI Inc., U.S.A.) was used for editing topographic maps and creating thematic maps. All bearing data collected was analyzed to estimate their home ranges using the Home Range Tools(HRT) for ArcGIS9.x. For topographic maps, 1:5,000 and 1:25,000 maps, and land use maps from National Geographic Information Institute(NGII, Rep. Korea) were utilized. We calculated home range sizes of raccoon dogs using both fixed minimum convex polygons(MCP) and fixed kernel (K) methods for 100%, 95%, 80% and 50%(Worton, 1989; Harries *et al.*, 1990; White and Garrott, 1990; Worton, 1995; Seaman and Powell, 1996). For K, the least squares cross validation was chosen(Worton, 1989; Seaman and Powell, 1996). In addition, we analyzed the fundamental home range overlap and habitat utilization patterns of raccoon dogs(Saeki, 2001). All descriptive data analyses were done using SPSS version 10(SPSS Inc., U.S.A.).

RESULTS

Home range sizes were estimated by MCP and K. Figure 2 shows the total home range sizes for the pair of raccoon dogs in this study. Total home range size was 0.41㎢ by 95% MCP. Mean home range sizes of the raccoon dogs by MCP and K are presented in Table 2; they were smaller than 1㎢ by both MCP and K. There seems to be no big difference between the male and female home range sizes(Table 2). However, large differences in home range sizes between day and night-time were detected(Table 2). By 95% MCP, home range sizes were 0.01㎢ in day-time and 0.35㎢ in night-time. Home range sizes estimated by K presented in Table 2. In addition, we could observe clear differences among seasons in home range sizes by all analyses(Table 2); the biggest in summer(0.56㎢ by 95% MCP) and the smallest in winter(<0.01㎢ by 95% MCP).

The pair showed very large home range overlap during

Table 2. Mean home range sizes of the raccoon dog pair by sex, day and night, and season. MCP(100~50%), fixed minimum convex polygons; K(100~50%), fixed kernel method. The bold numbers indicate the highest values

Method (%)	Individual or Sex			Time			Season				
	A (Male) (n = 1)	B (Female) (n = 1)	Mean (n = 2)	Day (n =2)	Night (n =2)	Mean (n =4)	Early Summer (Jun.) (n = 2)	Summer (Aug.) (n = 2)	Fall (Oct.) (n = 2)	Winter (Dec.) (n = 1)	Mean (n = 7)
MCP(㎢)											
100%	0.685	**0.691**	0.688 ± 0.004	0.010 ± 0.001	**0.684 ± 0.009**	0.347 ± 0.389	0.181 ± 0.066	**0.557 ± 0.048**	0.185 ± 0.001	0.002	0.264 ± 0.213
95%	**0.364**	0.275	0.319 ± 0.063	0.010 ± 0.001	**0.351 ± 0.029**	0.180 ± 0.198	0.164 ± 0.071	**0.557 ± 0.048**	0.185 ± 0.001	0.002	0.259 ± 0.216
80%	0.142	**0.159**	0.151 ± 0.012	0.005 ± 0.001	**0.150 ± 0.014**	0.078 ± 0.084	0.033 ± 0.010	**0.207 ± 0.080**	0.012 ± 0.002	0.001	0.072 ± 0.099
50%	0.028	**0.041**	0.035 ± 0.009	0.002 ± 0.001	**0.047 ± 0.010**	0.024 ± 0.027	0.013 ± 0.009	**0.036 ± 0.028**	0.007 ± 0.004	0.001	0.016 ± 0.019
K(㎢)											
100%	0.326	**0.355**	0.341 ± 0.021	0.012 ± 0.001	**0.524 ± 0.098**	0.268 ± 0.301	0.203 ± 0.046	**0.411 ± 0.072**	0.053 ± 0.005	0.001	0.191 ± 0.173
95%	0.067	**0.084**	0.076 ± 0.012	0.001 ± 0.001	**0.092 ± 0.016**	0.047 ± 0.053	0.025 ± 0.005	**0.088 ± 0.003**	0.035 ± 0.002	0.001	0.043 ± 0.033
80%	0.032	**0.044**	0.038 ± 0.009	0.001 ± 0.001	**0.047 ± 0.011**	0.024 ± 0.027	0.013 ± 0.003	**0.048 ± 0.002**	0.019 ± 0.001	0.001	0.023 ± 0.018
50%	0.010	**0.014**	0.012 ± 0.003	0.001 ± 0.001	**0.015 ± 0.003**	0.008 ± 0.008	0.004 ± 0.001	**0.019 ± 0.001**	0.007 ± 0.001	0.001	0.009 ± 0.008

the radiotracking period. The proportion of overlapping area ranged approximately from 70 to 95%(90, 85, 95 and 70% for 100, 95, 80, 50% MCP, respectively; Figure 3A).

The habitat utilization pattern of the raccoon dogs is shown in Figure 3B. They had 1 core area and 4 different feeding sites(site 1, 2, 3 and 4) in their own home ranges. Among the feeding sites, 2 were very close to the core area but the others were relatively far from the core area. The former sites(site 1, total 17 bearings for the male and female site 2, 14 bearings) were used more frequently than the latter sites(site 3, 5 bearings; site 4, 9 bearings).

DISCUSSION

Home range size is a basic parameter used to study and manage wild animal species and populations. Choi and Park(2006b) previously monitored raccoon dogs(n = 9) with 1 or 2 bearings every day for more than 3 months in the same study site as used in the present study. They recommended that more extensive daily radiotracking would provide better understanding of the home range of raccoon dogs. Although the radiotracking in this study was conducted with only a pair of raccoon dogs, and the number of bearings was still not very large, our study period encompassed the early summer to winter season, and we monitored both in day and night-time. Furthermore, we recorded more bearings per day(normally 8~14 bearings) than the previous study. The bearings were recorded whenever the raccoon dogs moved during the monitoring time. If they remained in the same place, we did not mostly record the bearings to decrease overlapping data.

Home range of raccoon dogs has been extensively studied in Japan(see Saeki, 2001 for references) and European countries(see Kauhala *et al.*, 2006 for references). In South Korea, Choi and Park(2006b) first showed that the mean home range size of raccoon dogs was 0.80㎢(n = 9, 100% MCP; Table 3). This measure is much smaller than those of the reports from Japan(2.78 ~6.10㎢ for 100% MCP; Table 3) and Finland(5.70~7.00

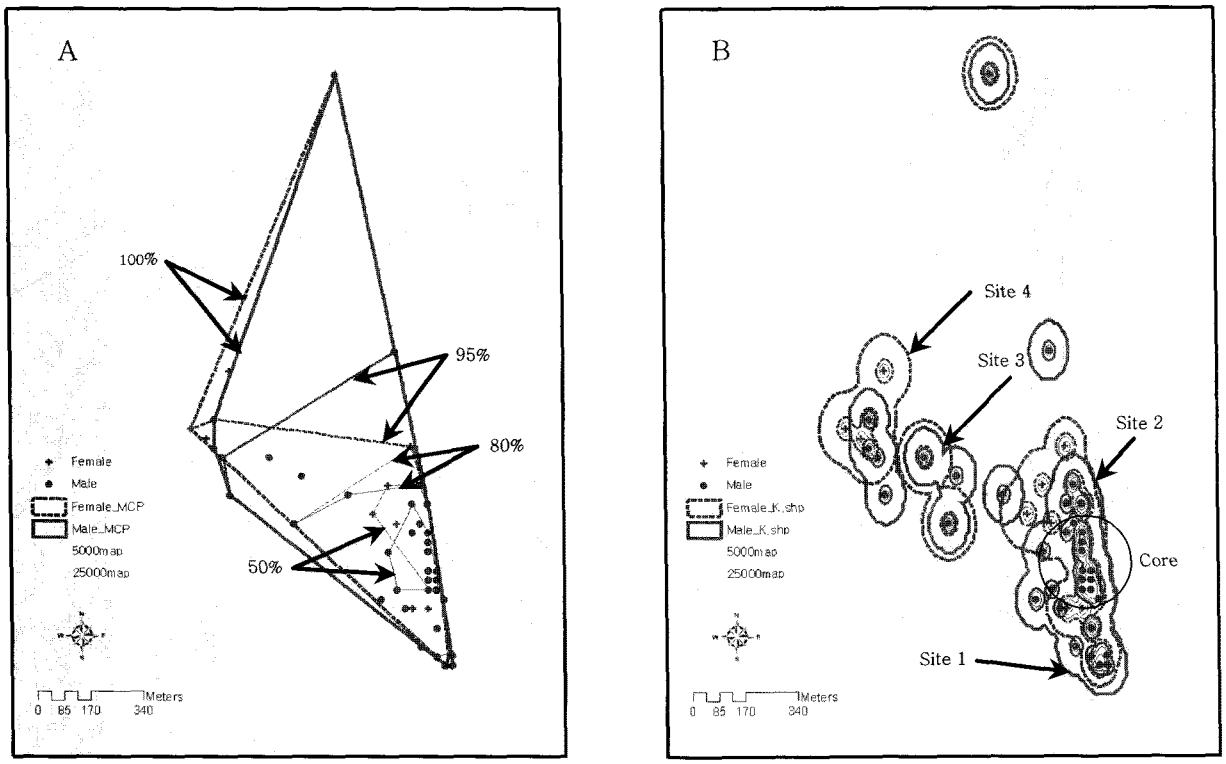

Figure 3. A. The overlapping pattern of home ranges of the 2 raccoon dogs(a pair) by 100, 95, 80 and 50% MCP estimates during the radiotracking period. B. Habitat utilization(100, 95, 80 and 50% K estimates) of the raccoon dogs during the radiotracking period

Table 3. Home range sizes of raccoon dogs in different areas of various countries

Country	Method	Home range size (km^2)	No. animals	Tracking period	Habitat	Reference(s)
Korea	100%MCP	0.69	2	5 ~ 7 months	rural (Gurye)	**this study**
	95%MCP	0.32				
	80%MCP	0.15				
	50%MCP	0.04				
	100%K	0.34				
	95%K	0.08				
	80%K	0.04				
	50%K	0.01				
	100%MCP	0.80	9	90 ~ 401 days	rural (Gurye)	Choi and Park, 2006b
	95%MCP	0.54				
Japan	100%MCP	2.78	18	2 months ~ 2.4 years	countryside	Saeki, 2001
	95%MCP	1.60				
	100%K	2.37				
	95%K	1.11				
	100%MCP	6.095	12	3 ~ 8 months	subalpine	Yamamoto *et al.*, 1994
	100%MCP	0.307	5	9 ~ 37 days	urban	Yamamoto, 1993
	100%MCP	0.069	3	3 ~ 8 months	urban (university camp.)	Fukue, 1991
	100%MCP	0.490	4	5 ~ 20 days	plateau (with garbage sites)	Ward and Wuster-Hill, 1989
	100%MCP	0.103	3	4 ~ 12 days	islet	Ikeda, 1982
	100%MCP	0.300	4	4 ~ 12 days	islet	Ikeda, 1982
	Bait-marking	0.028	N/A	5 times for 17 months	islet	Ikeda, 1979
Finland	100%MCP	7.0	23	2 months ~ 3 years	boreal forest	Kauhala *et al.*, 1993
	100%HM	9.5				
	85%HM	3.4				
	100%MCP	5.7	17	17.0 ± 5.2 months	coniferous forest	Kauhala *et al.*, 2006
	95%K	3.9				
	50%K	0.8				
Germany	100%MCP	1.5				Schwarz *et al.*, 2002
	100%MCP	4.0 - 7.5				Drygala *et al.*, 2000, 2002

㎢ for 100% MCP; Table 3). The mean home range size of the 2 raccoon dogs in our study(0.69㎢ by 100% MCP; Table 2) was a little larger than that found for the same individuals in the previous study(0.51㎢ by 100% MCP). The slightly larger mean home range size might be due to the increased number of bearings a day. By 95% MCP, however, the mean home range size(0.32㎢, Table 2) in our results was very close to the previous study(0.36㎢). In South Korea, carnivores(feline and canine species), feeding on or competing with raccoon dogs, became almost extinct. Therefore, population density of raccoon dogs has been increased greatly resulting in much smaller home range size than that in other regions(Won and Smith, 1999). A review of home range sizes of previous studies in various countries is shown in Table 3.

No large difference in home range sizes for the raccoon dogs was found between the two sexes. This result was previously expected for the monogamous raccoon dogs (Kauhala *et al.*, 2006). Raccoon dog pairs usually share their home range and move around together(Kauhala *et al.*, 1993; Kauhala and Helle,1994). Choi and Park(2006b) showed that the home range sizes were similar between

sexes in the case of 95% MCP. Saeki(2004) also showed that there was little sex difference in raccoon dog home ranges in Japan. Therefore, our results are consistent with the previous studies, although the sample size was very small(n = 1 for each). In addition, we found that proportions of overlapping area of the raccoon dog pair were generally higher than 70%, close to the result of the previous study. The pair usually moved together during the study period. However, we do not know how large the overlapping pattern is between nonpairing individuals. In the previous study, unanalyzed data showed that the proportion of home range overlap between nonpairing individuals ranged approximately from 10% to 30%(Choi and Park, 2006b).

Won(1968) suggested that the raccoon dog is generally more active during the night than during the day in South Korea. Our results showed clear differences between day and night home range sizes, even though we collected relatively fewer bearings for the day than for the night due to the lack of movement. In the field, we frequently observed the raccoon dogs staying near their den(s) during the day with little activity, but moving actively during the night.

There were large seasonal differences in home range sizes of the raccoon dogs; large in summer, medium in early summer and fall, and very small in winter. The small home range during winter appears to be due to their winter sleep, which is different from hibernation. During the winter sleep, raccoon dogs can maintain their body temperature close to normal, and can have occasional periods of arousal, food intake and defecation. This occurs in areas with frequent snows and with the ambient temperature below -5~-10℃ for long periods(Nowak, 1993). Raccoon dogs are known to reduce their movements in fall before winter lethargy(Korhonen, 1987; Kowalczyk *et al.*, 2003). In summer, they increase their movements most likely to get foods for their pups or themselves. The feeding behavior of raccoon dogs is similar to that of badgers, *Meles meles*(Kaulala *et al.*, 2006), but is different from Asiatic black bears, *Ursus thibetanus*(Nowak, 1991; Reid *et al.*, 1991) which increase their nocturnal activity for food intake through fall.

According to our present study and the previous study, raccoon dog population density, at least in Gurye, seems to be higher than that in Japan or Finland. During the study period, we frequently observed individuals crossing over roads among rice paddies or dry fields. We also checked 12 road-kills by collision with vehicles on a local highway near the monitoring site during the study period(T. Y. Choi unpubl. data). In addition, raccoon dogs might share their home ranges with others with a considerable portion of overlap as mentioned above. The high population density and small home range size, and the resultant home range overlap may accelerate dissemination of infectious diseases in raccoon dogs such as rabies and sarcoptic mange. Currently, the rabies cases in South Korea are limited to the regions near the DMZ area(Kim *et al.*, 2006). However, the disease is continuously spreading southward(Kim *et al.*, 2006). This may be related to the high population density of raccoon dogs in South Korea. Even though our study area was limited to a single locality in the southern part of South Korea, the small home range size and the high population density of raccoon dogs seems to be a general phenomenon throughout the whole country(H. Lee pers. comm.). Thus, determining the exact home range size and overlap, population density, and subadult dispersal pattern of raccoon dogs would be critically important in order to understand the spread of rabies in Korea. In European countries, rabies ecology has been extensively studied in relation with population densities of carrier animals(David *et al.*, 1982; Macdonald and Sillero-Zubiri, 2004; Kauhala *et al.*, 2006), and in relation with dispersal distances (Artois and Andral, 1980; Macdonald and Sillero-Zubiri, 2004; Kauhala *et al.*, 2006). For example, Kauhala *et al.*(2006) reported that high population densities and long dispersal distances of medium-sized carnivores(e.g., badgers, red foxes and raccoon dogs) might increase the risk for a rabies epizootic and the travel rate of rabies. We observed 5 raccoon dogs killed by diseases such as sarcoptic mange and acute pneumonia during the monitoring period(T. Y. Choi unpubl. data), but no rabies cases were observed in our site.

The individuals radiotracked had their own den(s) to mate and care for young in a core area where the animals spent 50% of their time(about 0.01㎢). There were 4 different sites for feeding and/or resting. Among them, the site 1 and 2 might be frequently utilized both for feeding and resting, but the site 3 and 4 might be used only for feeding. The former sites(bush habitat near Seosi stream)

were close to the core area and seemed to be safer to feed and rest than the latter sites(near the poultry farm and rice paddies).

In conclusion, our raccoon dog home range data using the same individuals but with more frequent bearings per day and more extended tracking intervals still showed very similar results to the previous study by Choi and Park(2006b) with less frequent bearings per day and more extensive tracking days. This confirms the previous result and suggests that home range data with less frequent tracking intervals of more bearings per day may be useful for certain purposes.

Thus, our results are complementary to the previous study, and there are several new findings from the present study. First, mean home range sizes in night-time were much larger than those in day-time. Second, mean sizes of home range in summer were larger than those in the other seasons. Third, proportion of home range overlap between the pair was quite large. Fourth, the raccoon dog home range consisted of 1 core area and several different feeding/resting areas.

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