

Breeding Behavior of Red Fox (*Vulpes vulpes*) in an Outdoor Breeding Facility^{1a}

Dong-Ju Song², Byeong-Cheol Song^{2*}, Jun-Hyeok Kwon², Pyeong-Kang Shin²

실외 번식시설에서 여우의 번식 행동^{1a}

송동주^{2*} · 송병철² · 권준혁² · 신평강²

ABSTRACT

This study examined the behavior of red fox (*Vulpes vulpes*) during the estrus period, breeding period, and mating including the estrus period along as well as the effect of environmental factors in an outdoor breeding facility. The average mating duration was 19.95 min (n = 13, range = 1.17 - 35.25 min). The breeding season was mainly early February (56.6%) for foxes aged more than one year and mid-March (60.0%) for foxes aged less than one year. The mating duration was longest when both male and female were more than one year old (24.43 ± 11.08 min), although copulation took place regardless of partner's age. Females that mated twice within two days after estrus started or with two males had 100% pregnancy rate. In addition, the pregnancy rate was highest (87%) when both mating partners were more than one year old. Foxes preferred daytime to nighttime for mating, and thus mating usually took place on sunny days or between 10:00 and 12:00 on partly cloudy days. A male mated with different females for a maximum of five times, and the higher the mating frequency of a male, the longer the mating duration. Interest in mating decreased after three copulations in the case of males and after two copulations in the case of females. Males required at least 4 hours and 46 minutes between the first and second copulation. For this study, we collected reference data that might be applied to breeding programs for the red fox to secure the restoration of individuals of this important species.

KEY WORDS: *Vulpes vulpes*, PREGNANCY RATE, COPULATION, MATING

요 약

발정기, 교배 기간 및 발정기를 포함하는 교미 중 붉은 여우 (*Vulpes vulpes*)의 행동을 실외 번식시설에서 환경 요인과 함께 조사하였다. 여우의 평균 교배 지속시간은 19.95분(n = 13, 범위 = 1.17-35.25분)이었다. 번식기는 1년 미만 여우의 경우, 3월 중순(60.0%)이었고, 1년 이상 여우는 2월 초순(56.6%)으로 나타났다. 교미 지속시간은 암·수컷 모두가 1세 이상 일 때 가장 길었고(24.43 ± 11.08분), 교배는 나이와는 관계없이 이루어졌다. 여우는 발정기를 시작한 후 2일 이내에 두 번 교배하고 두 마리의 수컷과 교배한 암컷의 임신율이 100%였다. 또한, 짝짓기 개체 간 연령이 1년 이상 된 경우 임신율이 87%로 가장 높았다. 여우는 야간보다는

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2 국립공원관리공단종복원기술원 Species Restoration Technology Institute, Korea National Park Service, Gurye 57616, Korea

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* 교신저자 Corresponding author: sdjoo317@gmail.com

주간 교미를 선호했고 대체로 맑은 날과 부분적으로 흐린 날의 10시부터 12시 사이에 교미를 했다. 수컷 여우는 다른 암컷과 최대 5번 교미했으며, 수컷의 교미 빈도가 높아질수록 교미 지속시간이 늘어났다. 교미에 대한 관심은 수컷은 3회, 암컷은 2회 교미 후 줄어들었다. 수컷은 첫 번째와 두 번째의 교미 사이에 최소 4시간 46분의 휴식이 필요했다. 이 연구에서 우리는 여우의 복원에 있어 개체 확보를 위한 번식 프로그램에 적용 가능한 기본적인 자료를 수집하였다.

주요어: 여우, 임신율, 교미, 교배

INTRODUCTION

The Red fox, *Vulpes vulpes* (Linnaeus, 1758, order Carnivora, family Canidae), comprises 45 subspecies. Foxes distributed in Korea belong to *V. v. peculiosa* Kishida, 1924 (Korean National Park Service, 2010). As foxes have excellent adaptability, they are found in diverse regions, including Eurasia, Africa, and Central Asia, excluding the tropical zone. As omnivores, they feed on rodents, small mammals, birds, and fruits (Lanszki, 2005). Foxes are monoestrous and their copulation occurs in February/March; following a 51-days pregnancy period, three to six young foxes are born (Jung *et al.*, 2013). In the Korean Peninsula, foxes were distributed throughout the country during the Japanese colonial period (1940s) but their population decreased in the 1970s. Only 47 foxes were reported in a survey by the Ministry of Environment, and the last fox was caught on Mt. Jiri in 1978. Since then, foxes have been reported as extinct in the Korean Peninsula. The major causes of decline in the fox population were indiscriminate poaching, habitat destruction, and mass extermination by secondary and tertiary poisoning via toxic substances during the ‘Rat-killing’ campaign staged in the 1960s (Lee *et al.*, 2014).

Although foxes might still inhabit North Korea, their trace almost disappeared in South Korea and therefore, the Ministry of Environment has been restoring their habitat at Sobaeksan National Park since 2012 (Lee *et al.*, 2014). Conservation programs are being developed at present for fox species; however, such programs have various problems including high cost and long captivity periods. Therefore, fox breeding through self-propagation is important to increase populations and genetic diversity but also to accurately understand estrus time and mating features contributing to foxes’ successful copulation. However, only

few data for silver fox breeding have been presented overseas and, in South Korea, research data on fox breeding is almost non-existent, except for some data on fox behavior during breast feeding (Jung *et al.*, 2014).

Therefore, in the present study, we analyzed the mating date, time, and pregnancy rate of 23 foxes introduced into Sobaeksan National Park, aiming to contribute to the information for restoration of the Korean fox, which is a Class 1 endangered species, by providing ecological data concerning its mating and breeding features.

MATERIALS AND METHODS

This study was performed on 23 foxes (14 females, nine males) aged 1–10 years old, weighing 4–7 kg, and mated in January–March, 2017 at the Sobaeksan National Park Central Restoration Center (Taejang-ri, Soonheung-myeon, Youngjoo City, Gyeongbuk; latitude, 36°54′ 36″; longitude: 128°33′ 36″) (Table 1).

Mating was performed in an outdoor breeding facility divided into 10 zones (2.0 × 2.5 × 1.8 m), and furnished with a concealed wooden box (Fig. 1). Vaginal smear tests, for identifying optimal mating time, were performed 2–3 days after placing each female into each zone. At estrus, each female was mated with a male, and, if copulation occurred, the male was immediately removed and replaced by another male for observing additional copulation.

By installing 10 closed-circuit television (CCTV) sets (DS-2CE16F7T-IT1, HIKVISION, South Korea) in the outdoor breeding facility, copulation time and the behavior of male and female were extensively observed for 24 h (Fig. 2). Pregnancy was confirmed 25 days after copulation by the 5.0 MHz Linear Ibex® Pro probe (E.I. Medical Imaging, USA). Pregnant female foxes were relocated and managed separately until delivery.

Table 1. Information for the 23 Red fox individuals studied

Label	Sex	DOB	Origin	Remarks
Red fox 1	F	2007. 4	China	Can not check mating time
Red fox 2	F	2012. 4	China	
Red fox 3	F	2016. 4	China	
Red fox 4	F	2016. 4	China	
Red fox 5	F	2016. 4	China	
Red fox 6	F	2016. 4	China	
Red fox 7	F	2014. 4	China	
Red fox 8	F	2014. 4	China	
Red fox 9	F	2014. 4	China	
Red fox 10	F	2015. 4	China	
Red fox 11	F	2015. 4	China	
Red fox 12	F	2015. 4	China	
Red fox 13	F	2015. 4	China	
Red fox 14	F	2016. 4	Korea	
Red fox 15	M	2016. 4	China	
Red fox 16	M	2016. 4	China	
Red fox 17	M	2016. 4	China	
Red fox 18	M	2016. 4	China	
Red fox 19	M	2015. 4	China	
Red fox 20	M	2015. 4	China	
Red fox 21	M	2015. 4	China	
Red fox 22	M	2013. 4	Korea	
Red fox 23	M	2015. 4	Korea	

F, Female; M, Male
DOB, Date of birth

To analyze the influence of environmental factors on mating behavior, irradiation, temperature, humidity, and wind speed for the region of Taejang-ri, Soonheung-myeon, Youngjoo City, where the breeding ground was installed, were obtained from the National Weather Data Center of the Korean Meteorological Administration (<http://www.kma.go.kr>).

[//www.kma.go.kr](http://www.kma.go.kr)).

Mating data were collected for all females, except one, for which mating was not confirmed. Average and standard deviation (*SD*) data were calculated for each studied feature and significant differences were analyzed by *t*-tests, considering $p < 0.05$ as significant.



Fig 1. Interior of the outdoor breeding facility furnished with a wooden box



Fig 2. Monitoring system installed to observe fox mating in the outdoor breeding facility

RESULTS AND DISCUSSION

1. Breeding season and copulation time

Observing the behavior of the 23 foxes (14 females, nine males) revealed that mating occurred from the end of January to mid-March (Fig. 3). Although female foxes aged one year old or less mainly mated in mid-March (60.0%), mating of females aged over one year old occurred mostly in early February (55.6%).

Considering ecological features such as food and habitat condition, foxes' adaptability is excellent and natural propagation potential is high (Jung *et al.*, 2013). Foxes reach sexual maturity 9–12 months after birth, and the breeding season generally starts in early February or March (Kim, 1998). According to Seo *et al.* (1996) February 12 is the average mating date for foxes, which is approximately one week later than that of the foxes used in the present study. Because of late sexual maturity, Red fox aged less than one year old is late in estrus by about

a month (Kim, 1987). This was displayed in Red foxes aged less than one year old inhabiting Sobaeksan (Fig. 3), as their mating period was approximately a month later than that of Red foxes aged one year old or more.

2. Mating duration and pregnancy rate

Fox mating behavior can be divided into three stages: penis insertion; piston motion and ejaculation (mounting posture); and tie posture (Seo *et al.*, 1996). Mating duration in the artificial breeding facility was analyzed considering the time of each of these stages. Mounting time was 26.39 ± 9.52 s and tie time was 19.51 ± 9.37 min. Average mating duration was 19.95 ± 9.36 min (Table 2). Mating duration in Red fox introduced to Sobaeksan National Park was therefore slightly longer than that reported for Canidae (15 min, on average) in the study developed by the Ministry of Environment (2009), but shorter than the average mating duration reported for Silver fox (26.94 ± 10.58 min.; Seo *et al.*, 1996).

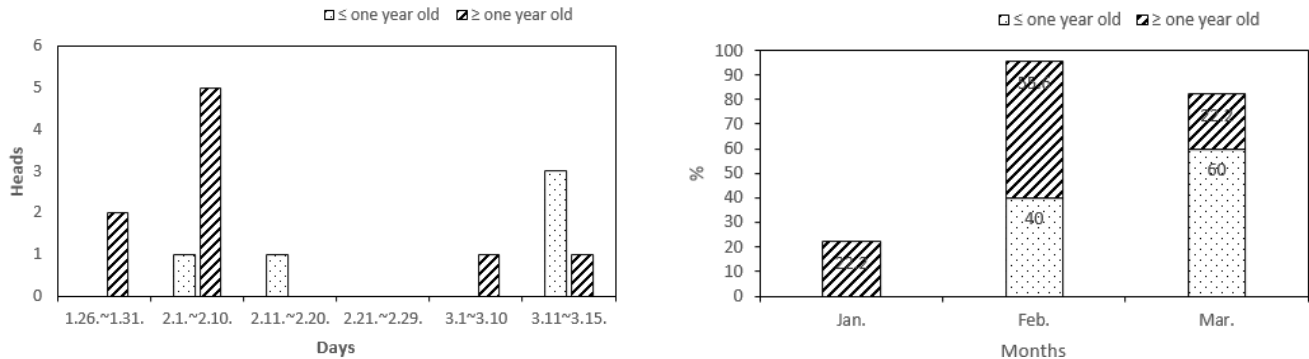


Fig 3. Weekly and monthly matings of the 14 female Red foxes in Sobaeksan National Park. Nine females were one year old or more and five females were less than one year old.

Table 2. Average mating duration (\pm standard deviation) and pregnancy rate considering Red fox sex and age

Sex	Age (n)*	Frequency	Mounting time (s)	Tie time (min)	Mating time (min)	Pregnancy rate (%)
Females	< 1 year old (5)	10	27.70 ± 8.14	17.68 ± 5.88	18.14 ± 5.80	60 (3/5)
	> 1 year old (8)	13	25.38 ± 10.68	20.92 ± 11.41	21.35 ± 11.43	75 (6/8)
Males	< 1 year old (4)	9	24.89 ± 6.51	20.86 ± 6.07	21.28 ± 6.08	50 (2/4)
	> 1 year old (5)	14	27.36 ± 11.17	18.64 ± 11.13	19.10 ± 11.11	60 (3/5)
Average			26.39 ± 9.52	19.51 ± 9.37	19.95 ± 9.36	69.5

* Number of Red fox individuals

The analysis of the effect of sexual experience on mating duration (Table 3) revealed that mating was longest when both mating partners were more than one year old (24.43 ± 11.08). This finding agrees with Seo *et al.* (1996)'s premise that mating duration in foxes is determined by males' sexual experience.

Analysis of the pregnancy rate according to the time allowed for mating (Table 4), revealed that this was highest (54%, 7 females) when only one day was allowed, followed by two (31%, 4 females) and three days (15%, 2 females). However, 54 % of the females that mated twice became pregnant, which was a higher rate than that of females mated once (38%) or three times (0.08%). When only one male was presented, 54% of females became pregnant, and this rate lowered when two (38%) or three males (0.08%) were presented. Fox estrus lasts for one to five days, generally two to three days (Seo *et al.*, 1996; Kim, 1998). Mating

is related with pregnancy rate, and this was reported highest in females mated on the second day after allowing males (85%); moreover, 100% of the females mated on the second day of estrus were pregnant (Kim, 1998). Female foxes introduced in Sobaeksan National Park also presented 100% pregnancy rate if mated on the second day of estrus, mated twice, or mated with two males. When mating females and males were more than one year old, pregnancy rate was the highest (86%, Table 3).

3. Re-mating and copulation frequency

Re-mating periods after the first mating are shown in Table 5. Females required about 14 h 09 min after the first mating for initiating a second mating, but for initiating a third mating they required less time (10 h 3 min). Males started the second mating 4 h 46 min after the first mating,

Table 3. Mating duration (\pm standard deviation) and pregnancy rate of Red fox according to the age of the mating pairs.

Cross (n)*	Mating frequency	Mounting time (s)	Tie time (min)	Mating time (min)	Pregnancy rate (%)
Female > 1 year old (4) × Male < 1 year old (4)	4	25.50 \pm 1.00	18.50 \pm 8.66	18.93 \pm 8.68	67
Female < 1 year old (3) × Male < 1 year old (4)	5	22.00 \pm 6.04	21.76 \pm 4.10	22.12 \pm 4.13	75
Female > 1 year old (7) × Male > 1 year old (5)	8	25.75 \pm 11.91	24.00 \pm 11.11	24.43 \pm 11.08	86
Female < 1 year old (2) × Male > 1 year old (5)	5	33.40 \pm 5.59	13.60 \pm 4.39	14.16 \pm 4.36	50

* Number of Red fox individuals

Table 4. Red fox pregnancy rate according to female's mating frequency, mating day, and number of counterpart males

	Mating times (number)			Mating period (days)			Counterpart males (number)		
	One	Two	Three	One	Two	Three	One	Two	Three
Number of mating females (%)	5 (38%)	7 (54%)	1 (0.08%)	7 (54%)	4 (31%)	2 (15%)	7 (54%)	5 (38%)	1 (0.08%)
Number of pregnant females	2	7	0	3	4	1	3	5	1
Pregnancy rate (%)	40	100	0	42	100	50	43	100	100

Table 5. Resting times before re-mating

	Female		Male	
	Second mating	Third mating	Second mating	Third mating
Resting time required for re-mating	14 h 09 min	10 h 03 min	4 h 46 min	12 h. 07 min

but required longer for initiating a third mating (12 h 7 min). During the reproductive period, males can mate several times; about 15% of the males ejaculate five to six times and 20–25% ejaculate 18–20 times (Seo *et al.*, 1996). However, males mating in the outdoor breeding facility set for the present study only mated twice per day, and the highest the mating frequency the more resting time was provided.

As shown in Figs. 4 and 5, the male fox mounted on the back of the female fox, inserted its penis, ejaculated, and copulation finished after the tie posture. The duration of each mating as mating frequency increases is shown in Table 6. Average mating duration decreased in females as copulation frequency increased, but, in males mating duration increased with increasing copulation frequency after the third mating. In addition, it was confirmed that female and male foxes mated with same partner copulated four times and that a male mated with three different

females was able to copulate for a fifth time. However, males used in breeding programs are not mated more than three times per month and the male: female ratio is maintained at 1:3 (Kim, 1987). As mating frequency and sex ratio used for mating in Sobaeksan-introduced foxes were similar to these, results obtained here can help establishing a breeding plan for Red fox.

4. Irradiation and mating duration

Mating duration in relation to irradiation conditions is shown in Table 7. Foxes in the outdoor breeding facility did not mate on cloudy and rainy days; they mated only on sunny and partly cloudy days. On partly cloudy days mating duration was 19.12 ± 8.13 min, and it was slightly longer on sunny days (20.49 ± 10.34 min.). Although not statistically different, mounting time was slightly shorter on sunny than on partly cloudy days (25.79 ± 10.18 s vs.



Fig 4. Male fox in mounting posture at the first step of mating. Fig 5. Tie posture, a typical mating behavior of Canidae

Table 6. Duration of each mating time according to sex

Sex	Mating				
	First	Second	Third	Fourth	Fifth
Female	20.34 min	18.04 min	15.00 min	11.70 min	-
Male	19.73 min	15.09 min	22.64 min	25.45 min	25.70 min

Table 7. Mating duration according to irradiation conditions

Condition	Mating frequency	Mounting time (s)	Tie time (min)	Mating time (min)
Partly cloudy days	9	27.33 ± 8.90 (min. 15.00 ~ max. 42.00)	18.67 ± 8.20 (min. 11.00 ~ max. 35.00)	19.12 ± 8.13 (min. 11.35 ~ max. 35.25)
Sunny days	14	25.79 ± 10.18 (min. 10.00 ~ max. 42.00)	20.06 ± 10.31 (min. 1.00 ~ max. 39.00)	20.49 ± 10.34 (min. 1.17 ~ max. 39.18)

27.33 ± 8.90 s, respectively). Surveys performed when mating was most frequent (Fig. 6) revealed it generally occurred at 10–12 h and at 14–16 and 18–20 h on sunny days and at 8–12 h on partly cloudy days. In the study conducted by the Ministry of Environment (2009), foxes were reported to mate mostly at night, but Sobaeksan-introduced foxes it seems to mainly take place at daytime, regardless of irradiation conditions. This might be due to first presenting males to females during the estrus period between 10 and 14 h, but additional research is required to examine this difference.

5. Mating environment

Temperature, humidity, and wind speed registered during outdoor mating (Table 8), revealed that average temperature and wind speed were higher on partly cloudy than on sunny days (0.90°C and 2.52 m/s vs. -0.19°C and 2.01 m/s, respectively), but relative humidity was higher on sunny than on cloudy days (48.36% vs. 46.11% , respectively). Average outdoor environmental conditions were $0.24 \pm 5.03^{\circ}\text{C}$, $47.48 \pm 17.39\%$ relative humidity, and 2.21 ± 1.50 m/s wind speed.

CONCLUSION

The present study evaluated the mating behavior of Red fox in an outdoor facility according to mating days, frequency, number of males, and environmental conditions. Although the number of females used and breeding environment were limited, females mated two times, for two days in the mating period or with two males presented the highest pregnancy rate. However, further studies using more individuals and wild-released foxes should be conducted to fully understand the Red fox mating behavior.

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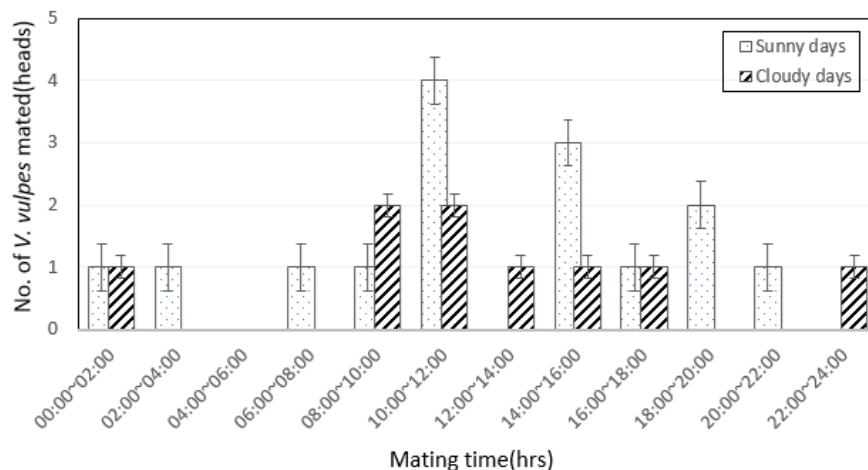


Fig 6. Mating time depending on irradiation conditions.

Table 8. Environmental conditions at the outdoor breeding facility

Condition	Mating frequency	Temperature ($^{\circ}\text{C}$)	Humidity (%)	Wind speed (m/s)
Average	23	0.24 ± 5.03	47.48 ± 17.39	2.21 ± 1.50
Partly cloudy days	9	0.90 ± 0.56	46.11 ± 12.17	2.52 ± 1.73
Sunny days	14	-0.19 ± 3.98	48.36 ± 20.46	2.01 ± 1.36

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