NOTE *Theriogenology*

Difference in Age at First Conception between Early and Late Litters of Feral Raccoon (*Procyon lotor*) in Kanagawa Prefecture

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ABSTRACT. Due to the long parturition period of raccoons, we assumed that age at first conception of late born females was later than that of early born females. From March 2005 to September 2008, 201 females estimated to be younger than 24 months were separated into early- and late-born groups on the basis of their estimated birth month (to the nearest 2 months), and parous status and body mass index (BMI) were examined. Age at first conception of late-born females (over 18 months old) was estimated to be later than that of early-born females (over 12 months old). The average BMI in early-born individuals at 12 months old might have affected their ability to conceive because of body fat deposition.

KEY WORDS: age at first conception, late litters, parturition period, *Procyon lotor*, raccoon.

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The raccoon (*Procyon lotor*) is an invasive alien species in Japan and individuals have been mainly imported as pets from North America since the 1970s [10]. In recent years, the raccoon has naturalized and expanded its distribution to include numerous prefectures in Japan, which is of concern as feral raccoons are considered to have a negative impact on native ecosystems and agriculture and are also known to damage houses by both invading and pollution of excreta [10, 11]. Furthermore, studies on captured feral raccoons have identified harmful pathogens including viruses [9], bacteria [17], and parasites [22]. As feral raccoon distribution has expanded rapidly, these issues have become serious in many areas of Japan. Therefore, to eradicate feral raccoons in Japan, it is necessary to develop a scientifically-based pest-control program which takes reproductive characteristics into account.

In the northern areas of raccoon distribution in North America, the mating season is typically in February and March, with most parturition occurring in spring [23]. On the other hand, reports of late litters produced from August to October are common at lower latitudes including West Virginia, southwestern Georgia, northwestern Florida, and southern Texas [3, 8, 19]. These late litters are conceived in a second mating period, which involves coming into a second estrus after losing a previous litter or failing to produce a litter from the first mating period [8].

Generally, juvenile female raccoons are considered to mate during their first winter and conceive litters as yearlings, while other juveniles cannot do so [7]. There are no studies on when late-born raccoons mate and conceive for the first time. If age at first parturition does not differ between early and late born raccoons, the late born raccoons may develop sufficiently during the following summer. On the other hand, it may not be possible to mate until the following year because breeding is seasonal and regulated by photoperiod fluctuation [4]. To evaluate pregnancy rate as an aspect of population dynamics, it is important to determine whether late born raccoons produce litters in the same year as early born raccoons, or 1 year later.

In Kamakura City, Kanagawa Prefecture (N35° E139°), reproductive potential such as parturition period, pregnancy rate, and litter size of feral raccoons were similar to those in North America, and reports have suggested births during the late parturition periods in the relevant feral raccoon populations [15]. The purpose of the present study was thus to elucidate the age at first parturition of early and late born raccoons and to analyze the differences in growth patterns in relation to age at first conception.

The study was conducted from March 2005 to September 2008 in Kamakura City. In this area, the climate is temperate with dry winters and humid summers, and the mean annual temperature and sunshine duration are 15.5°C and 1920.6 hr, respectively. Raccoon specimens were collected during pest control activities or by the Kanagawa Raccoon Control Program under the initiative of the Invasive Alien Species Act. Raccoons were captured using box traps (Havahart Live Animal Cage Trap Model 1089; Woodstream, Lititz, PA, U.S.A.) and were euthanized by CO_2 inhalation according to the Guidelines for the Management of Invasive Alien Species [1, 12].

Sex was determined by identifying reproductive organs. Body weight (BW; g) and body length (BL; mm) of females was measured, and the uterus and skinned head

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Table 1. Reproductive status, including pregnant or placental scars, of female raccoons younger than 24 months in Kamakura, 2005–2008

Estimated age in months[a)]	Early born raccoon[b)]			Late born raccoon[b)]		
	N	Pregnant	Scars	N	Pregnant	Scars
2	21	0	0	5	0	0
4	31	0	0	16	0	0
6	17	0	0	3	0	0
8	12	0	0	3	0	0
10	7	0	0	6	0	0
12	14	4	4	9	0	0
14	8	2	4	2	0	0
16	8	0	4	3	0	0
18	3	0	1	3	2	1
20	3	0	1	7	1	3
22	5	0	4	15	2	11
Total	129	6	18	72	5	15

a) Age was determined using tooth eruption (Montgomery, 1964) and cranial suture obliteration (Junge and Hoffmeister, 1980) techniques.
b) Birth before May was considered early born, and birth from June was considered late born, according to parturition distribution in Kamakura (Kato *et al*., 2009).

were removed. After heads were processed into skulls, we estimated the age in months of each raccoon by the cranial sutures obliteration method [13]. To analyze the reproductive status of juveniles and yearlings, we used raccoons younger than 24 months. In total, the age of 201 female raccoons younger than 24 months was estimated to the nearest 2 months on the basis of tooth eruption [20] and cranial sutures obliteration [13].

To estimate the birth month of individuals, we subtracted age at capture from the capture date. In Kamakura, feral raccoons are estimated to be born from February to October, and their parturition periods are suggested to have bimodal distribution, as in for example southern Texas [15]. Therefore, in order to evaluate differences in reproductive status between early and late born raccoons, we assumed that the birth months of the early born ranged from February to May and those of the late born ranged from June to October.

Placental scars in the uterus were considered to indicate implantation in the most recent breeding season [14]. Judging from uterus conditions, reproductive status was classified as pregnant females, parous females, or nulliparous females [2, 15]. Due to the small sample size, we could not evaluate the pregnancy rate or litter size in each age class. Additionally, we evaluated body mass index (BMI; BMI=BW (kg)/ BL $(m)^2$) as a relative index of body fat deposition according to previous studies [16, 24]. The BW of pregnant females was calculated by excluding fetal weight.

Of the 201 females, 129 were classified as early born and 72 as late born (Table 1). In the early born group, less than 12 months old females did not conceive (0/88), but pregnant females were found at 12 months old (4/14) and 14 months old (2/8). We confirmed that 4 females in the early born group, captured in March (n=3) and April (n=1), first conceived at 12 months old. On the other hand, both pregnant females and parous females in the late born group did not conceive until 16 months old (0/47). Pregnant females were found at 18 months old (2/3), 20 months old (1/7), and 22 months old (2/15) in the late born group. The youngest pregnant females (18 months old, n=2) in the late born group were captured in March. In the results of observation of placental scars, 18 parous females were over 12 months old in the early born group; however, 15 parous females were over 18 months old in the late born group.

BMI seemed to vary among the early and late born groups (Fig. 1). The average BMI in the early born group was statistically lower than that in the late born group at 4 months old (Mann-Whitney U test, U=143.000, $P<0.05$) and 6 months old (Mann-Whitney U test, U=3.000, $P<0.05$). Conversely, the average BMI in the early born group was statistically higher than that in the late born group at 10 months old (Mann-Whitney U test, U=0.001, $P<0.01$) and 22 months old (Mann-Whitney U test, U=8.000, $P<0.01$). There were no significant differences in the average BMI between early and late born groups in 2, 8, 12, and 16 months old. We could not evaluate the average BMI between early- and late-born groups in 14, 18, and 20 months old using statistical analysis due to small sample size. However, the average BMI in the early born group tended to be lower than that in the late born group in individuals of 14 to 18 months old, and average BMI in the early born group tended to be higher than that in the late born group at 20 months old.

Our study suggests that 4 pregnant females in the early born group mated in their first winter because they conceived in March, similar to the trend in North America [23]. However, late born females did not conceive until 16 months old, when early born females were pregnant or already had placental scars.

The present study is the first to report that age at first conception in late born raccoons is later than that of rac-

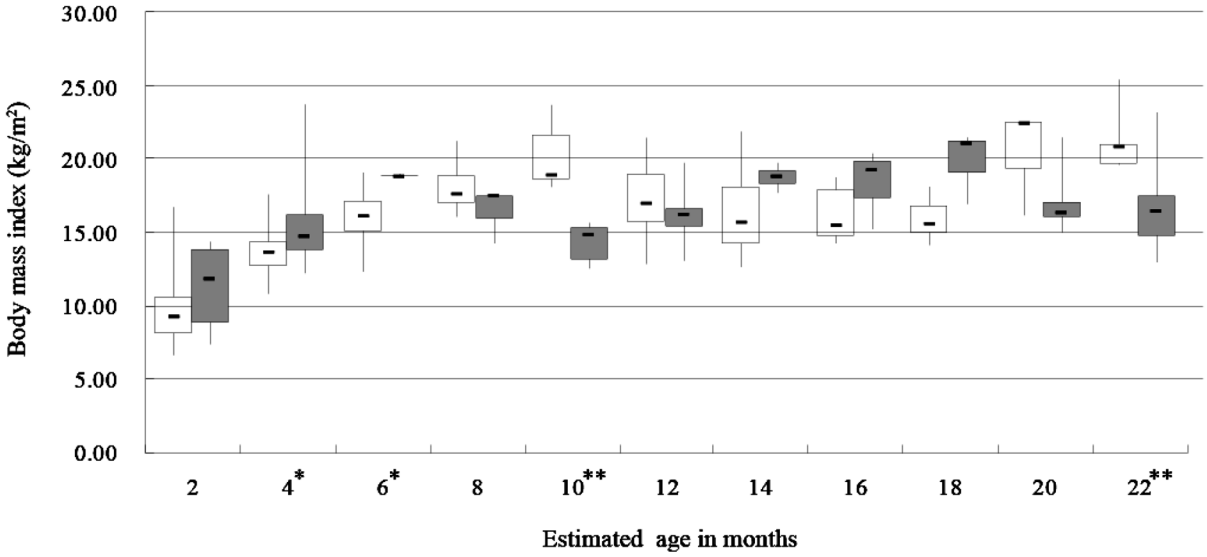

Fig. 1. Fluctuation of body mass index by estimated age in female raccoons younger than 24 months in Kamakura, 2005–2008. Open bars indicate early born litters with an estimated parturition period until May. Closed bars indicate late born litters with an estimated parturition period from June (Kato *et al.*, 2009). Statistical analyses were not performed at 14, 18, and 20 months old due to small sample size.
*: Significant difference at $P<0.05$ between early and late litters.
**: Significant difference at $P<0.01$ between early and late litters (Mann-Whitney U test).

coons in the early born group and occurs the following spring. Additionally, both early and late born raccoons were conceived in March or April. Therefore, we consider that a late born raccoon is not always a mother of late litters and that producing late litters is the result of other factors such as second mating period.

In wild mammals, a good body condition during the mating season is vital for achieving early first conception. For example, in black tailed deer (*Odocoileus bemionus columbianus*), the first individuals to reach the BW threshold for mating, conceive early in the breeding season [21]. In addition, yearling sika deer (*Cervus nippon yesoensis*) females in good body condition are estimated to have earlier than normal parturition periods [25]. In captive raccoons, onset of the first mating period is reported to be stimulated by the lengthening photoperiod and sufficient nutrition [4]. In this study, the high average BMI in the early born group at 10 and 22 months old might mean that these females improved their body condition to conceive during winter. Hence, we propose that age at first conception in feral raccoons is related to good body condition during the mating season.

Late born juvenile raccoons are believed to have a low survival rate in winter [6, 18]. Lehman [18] suggested that late born raccoons could not accumulate sufficient body fat in autumn to survive winter. However, the mild winter in Kamakura City may be convenient for late born juveniles to develop and survive. We consider that the growth rates of late born juveniles are not lower than those of the early born group judging from the difference in average BMI between early and late born females at 4 and 6 months old. Bunnell [5] reported that the growth rates of European hedgehog (*Erinaceus europaeus*) born late in the season were higher than those of litters born at normal times and explained that late born juveniles must reach good body condition in a timely manner. In feral raccoons in Kamakura, the average BMI in adults fluctuates seasonally (Kato *et al.*, in press). The BMI of juvenile and yearling females may have fluctuated as a result of not only growth but also season, although we did not examine the factors which have the greatest affect on fluctuation of BMI.

Finally, the ratio of early born to late born was 129/72, which indicates that late born raccoons are not rare, although our study did not analyze the survival rate in early and late born raccoons. If the survival rate of late born raccoons is high due to the mild winter in Kamakura, the first conception of late born raccoons might affect population dynamics. Therefore, the age at first conception of late born females should be evaluated for development of a raccoon control program. In addition, it is necessary to clarify the growth and mortality rates between early and late born raccoons to determine the proportion of raccoons joining the breeding population by suitable monitoring methods.

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