

Timing and synchrony of parturition in Alpine musk deer (*Moschus sifanicus*)

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Abstract. Between 1997 and 2001, the birth dates of free living and captive Alpine musk deer were examined to determine fawning patterns, and discuss potential influencing factors. In the wild, parturition shows strong seasonality, and occurred in three months from May to July, most of the births (75%) occurring within a 27 day period. Environmental seasonality, including the climate and forage availability, plays the major role in determining the timing of births in wild musk deer. Similarly, fawning in captivity shows constancy between years and seasonality, although with later initiation and a longer season than in the wild, influenced by an environmental seasonality of relatively lower intensity. More detailed differences in fawning patterns were observed in different rows of enclosures, resulting from differences in human care, and intensified by the social interaction among individuals within a row of enclosures. Although the fawning pattern is not strongly related to age of the captives, an individual's reproductive history seemed to influence fawning timing and synchrony, and the birth date is not strongly related to the survival of the newborn.

Key words: Alpine musk deer (*Moschus sifanicus*), parturition, captive, wild

Introduction

Many mammals breed seasonally, particularly where the environment shows pronounced seasonal variation (Green & Rothstein 1993, Sadleir 1973). Synchrony of parturition, resulting in the birth of offspring within a short time frame, occurs among numerous mammals (Rutberg 1987, Ims 1990), which may be influenced by environmental, ecological and physiological factors (Bronson 1989, Berger 1992). Under captive conditions, animals must endure substantial capture stress (Hafez 1962), which also may influence the timing and synchrony of the captive animals (Porter 2001, Laska 1990).

Published researches on the temporal patterns of birth in ungulates are abundant, but most is limited to gregarious species, such as *Ovis canadensis* (Festa-Bianchet 1988a, Rubin 2000, Shackleton 1984), *Ovis dalli* (Rachlow 1991), *Bison bison* (Rutberg 1984, Green & Rothstein 1993), *Odocoileus hemionus fuliginatus* (Bower 1991) etc. The timing and synchrony of fawning in more solitary animals has received little study, either in the wild or in captivity.

The Alpine musk deer is presently endangered owing to over-harvesting for its valuable musk, listed into Appendix II of the Convention on International Trade in Endangered

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Species of Wild Fauna and Flora (CITES), and protected under the *Wild Animal Protection Law* 1988 as a Category II key species in China. This species of musk deer is sparsely distributed in the mountainous region of western China including Xizang (Tibet), Sichuan and Gansu, where it inhabits coniferous forests and deciduous forests at an altitude of 3000–5000 m. Because of its cryptic and solitary nature and high vigilance, the fawning pattern of the Alpine musk deer remains poorly understood, especially the timing and synchrony of birth. Some studies have reported that female musk deer come into estrus in late November and give birth from May to September with a gestation of 175–185 days (Z h e n g 1979, J i a n g , 1998); these researches, however, are descriptive and based on observations with small sample-size.

Here, we quantified the births of female musk deer and examined the differences in general fawning patterns between captive and wild animals. Furthermore, for the captive does, we examined the effects on the synchrony of parturition from potential factors such as year, rows of enclosures, age classes, origins of a female, reproductive history, and previous reproduction costs of females.

Material and Methods

The study was conducted in Xinglongshan National Nature Reserve (XNNR), where the Breeding Center of Alpine musk deer (BCAMD) was located at an elevation of 2000–2100 m. The reserve has a continental mountain climate with short, cool summers and long, harsh winters. January is the coldest month with temperatures averaging 9 °C, and the temperature minimum is -28 °C. The warmest month is July, averaging 14 °C. Rainfall is mainly in July, August and September, with annual precipitation of 48–62.2 mm (W a n g 1996).

In our collected fawning dates of both wild and captive musk deer, the earliest birth occurred on 20 May, so we call this date the standard date (zero value), and calculated the days from 21 May to each fawning date. The length of the fawning season was defined as the minimum period in which over 75% of births occurred.

Our captive subjects (93 does) were either wild-caught captive deer (WC, 58 does) or first-generation offspring from captive individuals (OC, 35 does). Five to seven musk deer were kept in an enclosure which consisted of an outdoor yard measuring 10 × 10m square and 7 cells with the ceiling 2 m above the floor. Five to eight enclosures were linked in a row and an iron-mesh fence separated the enclosures to prevent subjects from contacting deer in neighboring enclosures, although they could hear and smell them. Between the rows of enclosures, there was a line of building and an area 50 m wide, which could effectively prevent communication among individuals in the two adjoining rows. Animals in each row of enclosures were maintained by a different deer-keeper and were fed twice a day, at dawn and dusk, mainly with fresh leaves (in summer and autumn) or dried leaves (in winter and spring) which were collected from the natural habitats of wild musk deer. Furthermore, the deer were provided with supplemental artificial food (mainly consisting of flour, wheat bran and some vegetables in season) and water *ad libitum*.

Females were artificially separated from males from February to late September but, in later September or early October, one sexually experienced male musk deer was introduced into each enclosure to mate with the females until February when the females went out of

estrus (Jiang 1998). In the parturition season, fawns were artificially weaned on 1 October, prior to the males being introduced to the female enclosures (Jiang 1998).

The fawning dates of the wild musk deer (WI) was collected in the surrounding mountainous region of BCAMD in 2000. We searched for newborn fawns from March to September, the period in which all the published fawning seasons (Zheng 1979, Ohtashi 1993) were included. When a newborn fawn was captured, its weight, the state of standing, locomotion, fur and dental status etc., were recorded, to help to determine its birth date.

The daily body mass growth of 10 newborn fawns of the captive colony was recorded in their early life (20 days), and a regression equation ($Y=3.075E-02X-14.299$, $P<0.01$, where “Y” was the days from 20 May, “X” was the grams of body mass) was calculated in order to express the relations between the growth in body mass and the age in days of captive newborn fawns. Yang (1989) found that the growth in body mass in the early life of the newborn fawn was not significantly different between the wild and captivity, so the established regression equation was used to estimate the birthing dates of the wild young in 2000.

For statistical analysis, the data were classified according to the following characteristics of females: Origin (wild-caught captive deer, WC; first-generation of the captive, OC); Age (females aged 1.5 years; 2.5; 3.5; 4.5; ≥ 5.5 years); Reproductive experience (primiparous or multiparous); Reproductive success in previous year (barren, or bred the previous year); Rows of enclosures (Row 1; Row 2; Row 5; Row 5 and Row 6).

Before statistical analysis, the data were normalized by square-root transformation (Shackleton et al. 1984, Festa-Bianchet 1988). To compare fawning dates between females classified by Origin, we performed a fixed model analysis of variance (ANOVA) and if the difference is significant, a LSD or Games-Howell post-hoc test was used to make pairwise comparisons among the categorized groups (dependent on the significance of Levene’s variance test). A 2-way ANOVA was used to determine the difference of parturition dates in females classified by years and the rows, and to examine potential interaction between these two dependent variables. To determine the influence of Row of enclosures alone on the timing of fawning, which may be a result of the differences in quality of deer keeper care, an ANOVA was again used to analyze the data classified by Row. The factors such as Year, Origin and Row were arranged as covariates, then a CoANOVA was used to test the differences among age-classes. We also employed the same method to examine the differences between the females classed by reproductive history and reproductive success in the previous year. By use of an independent T-test, we examined the potential relation between the birth date of a newborn fawn and its survival to 1 October.

Analyses were conducted with square-root transformed data, but the data listed in the following tables are the raw data. Statistical analyses were completed using SPSS8.0 (SPSS Inc., Chicago, Illinois) and all reported statistical probabilities are 2-tailed at $P=0.05$.

Results

Fawning dates of females of different origin

In 2000, 55 births were recorded, of which 35 were from WI, 5 from WC and 15 OC. Fawns were born in 4 months from May through August (Fig. 1). Although the distribution

of births tended to be skewed toward the beginning of the fawning season, for each of the three groups of females the fawning times all coincided with the peak of temperature and rainfall.

After square-root transformation, the data approximated normal distribution (Kolmogorov-Smirnov test: $Z=0.486$, $n=55$, $P=0.972$). Among the three categories, the temporal parturition patterns were highly significantly different ($F_{2,52} = 10.128$; $df=2, 52$; $P<0.001$). Because the variance was equal (Levene's test: $P=0.958$; $df=2, 52$), according to LSD multiple-comparison, females of WI gave birth earlier than both OC and WC (for OC: $P<0.01$, for WC: $P=0.007$), but the difference between OC and WC was not significant ($P=0.849$). In WI, 75% of births occurred in 27 days, and 88.6% were in May and June, although more than 50 days were needed to get the same cumulative parturition and only 60% gave birth in May and June in WC and OC (Table 1). In a word, the fawning of WI occurred earlier and the fawning season lasted for a shorter period than those of the captives (WC and OC).

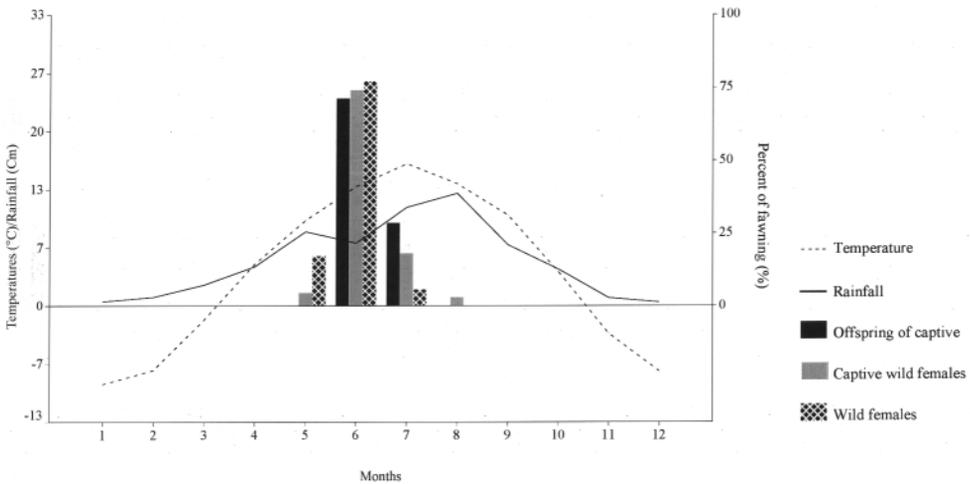


Fig.1. The fawning season of Alpine musk deer and the climate patterns in Xinglongshan National Nature Reserve of China.

Table. 1 Summary of fawning season characteristics among groups with different sources.

	Wild females (WI)	Captive wild females (WC)	Offspring of captive wild females (OC)
Number of sample	35	15	5
Initiation of fawning	20 May	6 June	11 June
Mean \pm 1S.E	11 June \pm 1.85	27 June \pm 3.55	29 June \pm 6.45
Number of days	75% 27	53	54
from the first birth to:	100% 47	60	59

Fawning dates of captive females classified by year and row of enclosures

The birth dates of the captive does from 1997 to 2001 were examined, which showed that the fawning dates were not normally distributed but biased to the beginning of the birth period with skewness of 1.07 ± 0.25 ($n=93$). The square-root transformed data were normally distributed ($Z=0.786$, $n=93$, $P=0.567$). ANOVA showed that the differences of fawning dates were not pronouncedly between 1997 to 2001 ($F=1.184$; $df=4,80$; $P=0.324$), although there were some insignificant differences among years, and no interaction existed between Year and Row ($F=1.633$, $df=4$, $P=0.174$) (Table 2).

Table 2. Summary of fawning season characteristics among five years.

Years	1997	1998	1999	2000	2001	Total
Number of sample	6	10	14	20	43	93
Initiation of fawning	2 June	6 June	30 May	22 May	26 May	22 May
Mean \pm 1 S.E	14 June \pm 3.51	17 June \pm 3.16	26 June \pm 4.99	28 June \pm 3.03	18 June \pm 2.15	21 June \pm 1.52
Number of days	75% 32	40	48	52	34	40
from the first birth to:	100% 37	44	80	60	81	81

The differences of birth dates in captive females among rows was highly significant ($F=3.270$, $df=4,80$, $P=0.043$). When only the factor of Year was analyzed, the difference was more pronounced ($F=4.630$; $df=4,88$; $P=0.002$). Multi-comparison by the Games-Howell test (Levene's test: $F=1.951$; $df=12, 80$; $P=0.04$) found that the differences were mainly between Row 2 and Rows 4, 5, 6 ($P=0.019$, 0.016 , 0.003 respectively). The initiation of birthing and mean birth date in Rows 2 were all later than those of the others except Row 1, because each row had its own keeper, which suggested that the significant differences among rows partially resulted from different patterns of animal husbandry (Table 3).

Table 3. Summary of fawning season characteristics among rows.

	Row of Enclosures				
	1	2	4	5	6
Number of births	8	22	3	50	10
Initiation of fawning	12 June	13 June	16 June	31 May	26 May
Mean \pm 1 S.E	26 June \pm 4.44	30 June \pm 3.23	18 June \pm 1.15	19 June \pm 2.03	11 June \pm 2.55
Number of days	75% 45	53	31	39	29
from the first birth to:	100% 59	81	31	80	32

Fawning dates of female age classes

Among age classes, although the mean birth date seemed to vary slightly (Table 4), the difference was insignificant ($F=21.509$, $df=5$, $P=0.198$). The data for females older than 2

Table 4. Summary of fawning season characteristics among age groups.

Age classes	Number of birth	Initiation of fawning	Mean \pm 1S.E	Number of days from the first birth to:	
				75%	100%
2 years old	20	31 May	29 June \pm 4.29	51	81
Older than 2 years	72	26 May	19 June \pm 1.47	39	60

years were pooled, then compared with those of yearlings by use of the same analysis (Levene's test: $F=1.662$, $df=1,90$, $P=0.201$), which showed that there existed a significant difference between the 2 year olds and those older than 2 years ($F=6.177$, $df=1,75$, $P=0.015$) (Table 4).

Fawning dates of females classified by reproductive history and success

There were 48 captive does with a reproductive history of more than 2 years. Comparison of fawning dates was made between the females that bred one year and were and barren the next, and the difference was not significant ($F=1.506$; $df=1,43$; $P=0.226$), indicating that the females were not likely to give birth later in the year before they were barren than in the year before they were bred. Although the fawns surviving to 1 October seemed to be those that had been born earlier (16 June ± 2.87) than those which did not survive (23 June ± 3.27), and the fawning season of the former (34 days) was shorter than that of the latter by 8 days, the variance of birthing dates was not significantly different ($T=1.328$, $df=23$, $P=0.197$), which indicated that those fawns which survived to 1 October were not likely to be born significantly earlier than those which died before this time.

Discussion

Timing and synchrony of parturition in wild female musk deer

Synchronous parturition is common among ungulates in seasonal environments, and a number of factors have been implicated in affecting the timing and synchrony of parturition (Bowyer 1991, Rutberg 1987), in which the seasonality of the environment is particularly important. In strongly seasonal regions, the period of months with mild climate and abundant forage is limited, which is very important for the survival of both newborn offspring and adult females (Bunnell 1980). Because of the timing and synchrony of parturition, which results in most of the fawns being born during mild months, the newborn develops adequately and attains sufficient body mass to survive resource scarcity in winter (Festa-Bianchet 1988b); consequently the environmental or energetic stresses on newborn offspring are minimized (Sadleir 1973). Furthermore, the birth timing and synchrony are related to the females, as Bowyer (1991) found in mule deer (*Odocoileus hemionus*) which are influenced by energy availability before and during gestation, lactation, and the period when the young are becoming independent from

their parents. So, in a seasonal environment, the timing of birth of ungulates depends largely on the temporal variation in the quantity and quality of food, and so ultimately on environmental seasonality (Leuthold & Leuthold 1975).

In XNNR, the environment is highly seasonal (Wang 1996); the mildest months are from May to September, when the temperatures are relatively high and there is more rainfall, but from October, the temperature drops to below zero and the minimum can reach -30 °C, besides which the rainfall will be sparse. The vegetation changes with climate (Wang 1996), in which the vegetation is dry and of low quality over a period of 7 months (From October to April), while from April the vegetation grows again and is fostered by the more mild climate till September. So for wild musk deer living in XNNR, the best growing season should be from May to September.

In our study, the parturition of wild female musk deer was clustered into three months from May to July, and the birth season is from May to June by which time most of the fawning (88.6%) has occurred. As Rutberg (1987) found in other ungulates, the fawning season of wild musk deer in XNNR coincides with the peak of temperature and rainfall, and the best forage availability coincided with the fawning and lactating season.

Lactation in wild musk deer lasts for 2 months (Zheng 1979). Our data showed that birth in XNNR occurs from May to July in this research, so the period of lactation is from the beginning of the birth season (in May) to September, during which time there are the most abundant forage and mildest climate, and the lactating females can produce adequate milk for the newborn. In addition, newborn musk deer begin browsing at the age of 20 days, and forage more and more thereafter (Zheng 1979). By timing births in a mild period, by the end of the period of lactation when the young are becoming independent the forage is still abundant. The timing of the season of birth is important for the females also. When the fawn is weaned, abundant forage is still available to enable the females to recover their body reserves, lost in gestation and lactation (Clutton-Brock et al. 1989), to survive the coming harsh winter and experience a subsequent successful estrus, which begins in Nov. in XNNR (Jiang 1998).

In addition to the factors of the climate and energy, in some ungulates the intensity and nature of predation also may affect the timing and synchrony of fawning seasons. Predators may be more effectively swamped, confused, or repelled if group members breed synchronously (Bergerud 1974). Births are synchronous to reduce predation on the vulnerable newborn either by satiating or confusing predators (Daphine & McClure 1974). For the musk deer in XNNR, predators such as *Canis lupus* and *Felis bengalensis* have declined steeply over recent years (Wang 1996), so predation does not play an important role in shaping the birth patterns of musk deer there, at least at the present time.

In summary, the fawning of the wild Alpine musk deer in XNNR shows strong seasonality, and the births cluster in a short period from the end of May to June. As in bison (Rutberg 1984), it is the seasonality of climate and forage availability, rather than predation, which is responsible for the timing and synchronizing of births in wild musk deer, through which the survival fitness of both newborn and adult female is maximized.

Timing and synchrony of parturition in captive female musk deer

In many species of ungulates, the timing of births is related to environmental seasonality, and shows an increase in length of birth season with decreasing seasonality (Rutberg

1987), H a s s (1997) and K r a u s m a n et al. (1989), for example, have suggested that bighorn sheep in less seasonal environments have a longer breeding season.

The pattern of parturition of captive animals is not the same as that in their natural environment probably for the same reason. L a s k a (1990) reported that the captive *Carollia perspicillata* in an environment lacking seasonal cues exhibit less birth synchrony than those in the wild. In addition, the age at first reproduction of wild gregarious ungulates is related to mating opportunity, thus influencing the fawning pattern.. The wild musk deer is solitary and territorial, and does aged 2 years can breed for the first time like older does (Z h e n g 1979, Y a n g 1989), so a comparison of fawning dates can be made between the wild and the captive.

In XNNR, BCAMD was built in the natural habitat of the wild population, moreover there is no temperature regulation in the enclosures, so in the captive environment such factors as ambient temperature coincide with the natural pattern. Furthermore, the animals are mainly provided with leaves picked from the natural habitat, and these are fresh in summer and early autumn but drier in winter and spring, so that the food availability for captives also coincided with their natural forage. In a word, the captive musk deer lived in an environment very similar to that of wild Alpine musk deer, not lacking in seasonal cues, and face the same range of environmental factors such as thermal stress, forage availability and quality etc. On the other hand, considering that provisions are more abundant, and that they nonetheless live enclosed, the seasonality of the captive environment is not as strong as that in the wild. So the fawning of the captive musk deer should also show synchrony, but with a longer season than in the wild. This prediction is supported by the finding that decreasing seasonality has indeed relaxed selection upon timing of parturition, so that the birth season is longer (cf. B u n n e l l 1982, F e s t a - B i a n c h e t 1988b). In addition, the birthing patterns were not significantly different between WC and OC , indicating that the fawning shows no strong relation with the origins of the captive females.

The interannual variance of the climate is not significant in XNNR (W a n g 1996), so the climate in BCAMD remains constant between years, and the temperature and forage availability are constant from year to year also. Our data showed that the temporal birth patterns were not strongly different between years, which indicates that the fawning of the captive does seems to be constant interannually, as occurred in captive *Phyllostomus hastatu* (P o r t e r 2001).

Captive animals are subject to the stress of captivity, which may influence their growth (H a f e z 1962), and this in turn may influence the fawning pattern because the physical condition of female deer is known to affect the timing of parturition , those in better condition giving birth earlier (R a c h l o w 1991).

This study showed that the variances of fawning dates among the rows of enclosures were pronounced. Although the general animal keeping pattern is the same among rows in BCAMD, the patterns in different rows show special features, presumably according to the characteristics of different keepers, as each keeper is responsible for deer keeping in one row of enclosures and this appeared to be the only uncontrolled variable. The different maintenance patterns may impose different influences upon the animals' bodily condition, and this might then result in the different fawning patterns among rows of enclosures.

In many animals, the pattern of parturition may be adjusted influenced by the behavioral interaction among individuals (B o i n s k i 1987). Some behaviors such as ano-genital investigation and mutual grooming function to influence the birth process. P o r t e r (2001) transferred female bats between different captive groups and found that the transferred females gave birth in synchrony with their new group and out of schedule with their original group, and that this related to grooming between individuals. Furthermore, the airborne or other passively exchanged chemical cues also seem likely to drive parturition synchrony (H a n d e l m a n n et al. 1980).

At the BCAMD, 5–7 females of different ages were in each enclosure and animals can contact each other within and between enclosures in a row. Furthermore, the females possess abundant glands, such as caudal and interdigital glands, which may serve as means of chemical communication (O h t a i s h i 1993). Importantly, none of the above factors are age-specific. Consequently, through behavioral interaction and volatile chemicals, the birth process was socially modulated in each row of enclosures, as in hamsters (H a n d e l m a n n et al. 1980), and there is no pronounced variance among age groups.

Previous studies on ungulates have suggested that the timing of parturition may be influenced by female age (B u n n e l l 1980, C l u t t o n - B r o c k et al. 1982, F i s t a - B i a n c h e t 1988a, 1988c). In some ungulates, younger females are characterised by later parturition (M i t c h e l l et al. 1973, V e r m e 1985). In our study, there existed differences of birth timing and synchrony among age classes, but not to a pronounced extent. Similarly, R u b i n (2000) found that the age of female desert bighorn sheep imposed no influence upon parturition.

However, the exposure to males can influence reproductive timing, and this influence may be different dependent on the females' ages. F i s h e r (1990, 1995) reported that the presence of a male before breeding starts may enhance the timing of reproduction in female red deer (*Cervus elaphus*), and late parturition may be the result of delayed socially induced estrus (F e s t a - B i a n c h e t 1988c). In BCAND, although the time that the male was introduced was same, the required stimulation to initiate estrus was different among females, because the yearling, especially the primiparous females, required additional stimulation to ovulate and they may enter estrus later than the older females (C o b l e n t z 1986). Moreover, because only one male was available to 5–7 females in each enclosure and the opportunity to mate with the male is limited, primiparous deer may lose mating opportunities owing to their relatively lower (age-dependent) dominance, as was evident in our observations. In addition, primiparous deer were inexperienced in using behavioral cues to adjust the timing of gestation and parturition. Thus, although the variance of birthing patterns among age groups is not pronounced in our research, the birth timing and synchrony did show significantly differences between primiparous and multiparous females. The former drop their fawns later and have a longer fawning season than the latter.

Most life-history models assume that reproduction has a cost (C a l o w 1979, W i l l i a m s 1986) which varies with population or environmental condition (C l u t t o n - B r o c k et al. 1996, F e s t a - B i a n c h e t 1989, 1998), and this can influence subsequent reproduction. The females must recover body reserves lost during gestation and lactation (C l u t t o n - B r o c k et al. 1989, G u i n n e s s et al. 1978,

Mitchell et al. 1976), and this results in different physical condition among individuals. The females without fawns tend to be in better condition (Cottrane et al. 1987) and give birth earlier (McClough 1979) than those with them.

In our work, the musk deer were provided with supplementary food in BCAMD, and the fawns born later in the season can be artificially supplemented with milk from sheep and cows, so a female which bred later was less likely to lose more energy compared to those which fawned earlier. Consequently, the physical condition was not pronouncedly different between the two categories of females, which should not impose any pronounced effect upon the temporal fawning patterns. So, in our data, the female musk deer were less likely to give birth later in the year before they were barren than in the year before they were bred.

Birth date is important for wild animals for their survival, and the young born out of season have a higher mortality than those born earlier (Guinness et al. 1978, Clutton-Brock et al. 1982, Festa-Bianchet 1988a). In our study, the fawns which survived to 1 October were born earlier and over a shorter span than those which died before 1 October, but the difference was not of statistical significance. The above results may be attributed to the following two possibilities: The first is that the survival of fawns is not correlated with their birth date at all in captivity, because the supplementary feeding and the enclosures may relax the energetic and thermal stress. The second is that a relation does exist between the survival and birth dates of fawns, but the difference can not be tested because our research design can not differentiate deaths subjected to other factors.

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