Reproductive Rhythm of Captive Forest Musk Deer (Moschus berezovskii): Parturition Timing and Post-Synchronization Imprinting

Authors: Sun Junping, Cai Yonghua, Yang Ying, Wang Jing, Fu Wenlong, Cheng Jianguo, Meng Xiuxiang

Date: 2017-03-22T00:00:00+00:00

Abstract

A study was conducted from March to October 2013 at the Maerkang Musk Deer Farm in Sichuan Province, during which 178 cases of parturition in captive forest musk deer (Moschus berezovskii) were recorded to analyze parturition timing, synchronization, and key influencing factors. Results indicated that parturition occurred between May and July, with a parturition period extending 66 days. The mean parturition date was May 25 (17.60±0.98, n=178), and the parturition season (duration for 75% of deliveries to complete) spanned 22 days (i.e., May 7 to May 28). The strong seasonality of parturition in Maerkang forest musk deer represents an adaptation to local seasonal hydrothermal conditions and food resources. The correlation between parturition timing and age was not significant (r=-0.121, P=0.106>0.05). Although subadult females (2-3 years) exhibited later parturition timing (May 26, 18.81±1.47, n=75) compared to adult females ((4-9 years) (May 24, 16.97±1.41, n=95) and aged females (10 years) (May 21, 13.63±2.24, n=8), differences did not reach statistical significance (P > 0.05). Furthermore, no significant differences in parturition timing patterns were detected among different breeding areas within the farm (P> 0.05). Parturition in females housed in modified enclosures with mud flooring (May 22, 15.31±1.48, n=62) occurred slightly earlier than in those housed in original enclosures with brick flooring (May 26, 18.82±1.27, n=116), but this difference was not statistically significant (P> 0.05).

Full Text

Reproductive Rhythm of Captive Forest Musk Deer (*Moschus berezovskii*) at Maerkang Musk Deer Farm: Parturition Timing and Synchrony

SUN Junping[1], CAI Yonghua[2], YANG Jing[1], FU Wenlong[2], CHENG Jianguo[2], MENG Xiuxiang[1]

[1]School of Environment and Natural Resources, Renmin University of China, Beijing 100872, China
[2]Sichuan Institute of Musk Deer Breeding, Dujiangyan 611830, China

Abstract: This study was conducted from March to October 2013 at the Maerkang Musk Deer Farm (MMDF) in Sichuan Province. The birth dates of 178 captive forest musk deer were recorded and analyzed to determine the temporal fawning patterns, parturition timing, synchrony, and potential influencing factors. The results showed a strong seasonality in the parturition patterns of captive forest musk deer, with all parturitions occurring within a 66-day range from May to July. The average fawning date was 25 May (n = 178), and the majority of births (75%) happened within 22 days from 7 to 28 May. The parturition seasonality of captive forest musk deer at MMDF was adapted to the local strong seasonal patterns of temperature, precipitation, and food resources in Maerkang. Moreover, although the parturition pattern was not strongly correlated with the age of the captive females ($r = -0.121$, $P = 0.106 > 0.05$), sub-adult females were inclined to fawn later (26 May, n = 75) than adults (24 May, n = 95) and old deer (21 May, n = 8). However, this difference in parturition timing was not significant ($P > 0.05$). Furthermore, no significant difference was observed among the different enclosures ($P > 0.05$), although the females in the original enclosures with a brick surface were inclined to fawn earlier (22 May, n = 62) than those in the refined enclosures with an earth surface (26 May, n = 116).

Keywords: forest musk deer (*Moschus berezovskii*); reproduction rhythm; parturition timing; parturition synchrony; fawning patterns

---

Introduction

In temperate habitats, the extended winter season and associated low temperatures and food scarcity are limiting factors for wildlife population growth, particularly affecting the survival of parturient females and newborn offspring. Wildlife in seasonal environments typically exhibit seasonal reproduction, with periodic estrus, mating, and parturition showing strong timing and synchronization. Through the regulation of cyclical reproduction and synchronized parturition, newborn offspring can better complete their early growth and accumulate sufficient energy reserves for winter, while parturient females can recover from the energetic costs of reproduction. This helps improve their overwinter survival and reproductive success in the following year. Temperate and polar mammals, especially ungulates, commonly display reproductive rhythms. To date, research on parturition timing and synchrony has focused primarily on highly gregarious ungulates such as bighorn sheep (*Ovis canadensis*), Dall' s sheep (*Ovis dalli*), and American bison (*Bison bison*), as well as mule deer (*Odocoileus hemionus*). In contrast, studies on relatively solitary small ungulates are extremely scarce, and research on musk deer (*Moschus* spp.) and similar taxa is lacking.

Musk deer are valuable resource animals whose adult males secrete musk. To protect wild musk deer populations and enable sustainable utilization of musk resources, China began ex-situ conservation, captive breeding, and musk resource development in the 1950s. The primary species in captivity is the forest musk deer (*Moschus berezovskii*), which accounts for over 80% of China' s captive musk deer population. Due to their dense habitat, extreme vigilance, and solitary nature, studying their reproductive rhythms and parturition timing in the wild is extremely difficult. Current research on musk deer reproduction is largely based on captive populations, with scholars investigating estrus and mating, reproductive behavior patterns, parturition, and mother-offspring relationships. Lang et al. studied fecal progesterone changes in captive forest musk deer during the reproductive cycle, while Yang et al. conducted research on synchronized estrus induction using progesterone-releasing devices and pregnant mare serum. Meng et al. performed preliminary studies on the reproductive performance and behavior of captive forest musk deer and alpine musk deer (*M. sifanicus*). However, reports on parturition timing and synchrony in musk deer are limited to captive alpine musk deer. To date, no studies have examined the reproductive rhythm and temporal patterns of the primary captive species, forest musk deer. Quantitative documentation of their parturition timing and synchrony, along with analysis of influencing factors, can contribute to successful captive breeding, ex-situ conservation, and sustainable utilization of this endangered species.

Study Area

This study was conducted from March to October 2013 at the Maerkang Musk Deer Farm, which is affiliated with the Sichuan Institute of Musk Deer Breeding. The farm is located within the natural distribution range of wild forest musk deer in Maerkang County, Aba Prefecture, Sichuan Province, in the Min Mountains region. The area features a high-altitude alpine canyon climate with large diurnal temperature variations. The farm is situated at an elevation of 2600 m, with an average diurnal temperature difference of 12–14°C, average seasonal temperature difference of 21.6–25.3°C, and annual precipitation of 753 mm. The average annual temperature is 12.30°C, with over 2000 hours of annual sunshine and 120 frost-free days.

Sample Animals and Grouping

The Maerkang Musk Deer Farm consists of five breeding areas, each comprising multiple enclosures. Each enclosure houses 2–3 forest musk deer, with a central brick shelter platform in the activity area (100–200 m^2). The farm maintains a captive population of forest musk deer, all of which are captive-born offspring. Each breeding area is managed by dedicated keepers responsible for feeding and daily care. The musk deer diet consists primarily of leaves and ground plants collected locally, supplemented with concentrated feed. Summer feeding occurs at 06:00 and 19:00, with enclosure cleaning taking approximately 5 minutes per enclosure during feeding times. Outside these periods, the musk deer experience minimal disturbance.

All musk deer are ear-tagged from a young age for individual identification. This study involved 178 parturient females (1 year old). Individual age was calculated in full-year units, with females divided into three age classes: sub-adult (1–3 years), adult (4–9 years), and old (10 years). Based on enclosure flooring, breeding areas were classified as either original enclosures with brick-paved surfaces (with moss and weeds growing between bricks) or refined enclosures with compacted earth surfaces.

Data Collection

During the study period, the earliest recorded forest musk deer parturition occurred on 8 May, which was designated as the reference baseline date for Maerkang musk deer births. The number of days from this reference baseline date to each individual's parturition date was calculated. The parturition season was defined as the period during which cumulative births reached 100%. Birth dates were recorded daily by keepers and verified by researchers.

Data Analysis

Parturition data were initially non-normally distributed (Kolmogorov-Smirnov test: $D = 1.913$, $n = 178$, $P = 0.001 < 0.01$). After square root transformation, the data achieved normal distribution (Kolmogorov-Smirnov test: $D = 1.091$, $n = 55$, $P = 0.185 > 0.05$). The effects of female age, enclosure type, and other variables on parturition timing were analyzed using ANOVA. When significant differences were detected, pairwise comparisons were conducted using LSD (least significant difference) or Games-Howell tests based on homogeneity of variance test results. Pearson correlation was used to calculate the relationship between female age and parturition timing. All statistical analyses were performed using SPSS 11.0, with significance set at $= 0.05$.

Results

Seasonality of Parturition A total of 178 captive forest musk deer births were recorded at the Sichuan Maerkang Musk Deer Farm. Parturition occurred from 8 May to 12 July, spanning 66 days, with the average parturition date being 25 May (17.60 ± 0.98 days from the reference date, n = 178). Seventy-five percent of births were concentrated within a 22-day window from 7 to 28 May. The frequency distribution of musk deer births and monthly average temperatures and precipitation are shown in [Figure 1: see original paper]. Maerkang' s annual precipitation is 753 mm, with precipitation from May to September accounting for 79.97% of the annual total (6.41 ± 1.62 cm, n = 12). The average temperature during these months is 12.30°C.

Temporal Distribution of Parturition The distribution of parturition timing is illustrated in [Figure 2: see original paper]. The transformed data showed normal distribution, enabling parametric statistical analysis.

Relationship Between Age Class and Parturition Timing The parturition timing patterns across age classes are shown in [Figure 3: see original paper] and summarized in . Although there was a trend for earlier parturition with increasing age in Maerkang' s captive forest musk deer, the correlation between age and parturition timing was not significant (r = -0.121, n = 178, P = 0.106 > 0.05). No significant differences in parturition timing were found among age classes (F , = 0.850, P = 0.591 > 0.05). The difference between adult and old females was not significant (F , = 0.437, P = 0.647). Sub-adult females gave birth slightly later than adults, but the difference did not reach statistical significance.

Effects of Enclosure Type on Parturition Timing No significant difference in parturition timing was observed among the different breeding areas (F , = 1.987, P = 0.059 > 0.05). Females in original brick-floored enclosures gave birth earlier (15.31 ± 1.48 days, n = 62) than those in earth-floored refined enclosures (18.82 ± 1.27 days, n = 116), but this difference was not significant (F , = 2.948, P = 0.088 > 0.05). The parturition timing patterns across enclosures are shown in [Figure 4: see original paper].

Discussion

The parturition timing patterns of wildlife are directly related to fluctuations in food resource quantity and quality, though the ultimate determining factors are seasonal physical conditions such as water and thermal regimes. Winter low temperatures and food scarcity in seasonal environments are key constraints on wildlife reproductive success and population growth. Animals in strongly seasonal temperate habitats typically show seasonal reproduction with strong parturition timing and synchrony. By timing parturition to coincide with periods of favorable climate, water-thermal conditions, and food resources, offspring can complete nursing, food intake, and early growth under optimal conditions, thereby improving their overwinter survival. Offspring born significantly later experience higher mortality than early-born individuals.

For captive wildlife, in addition to natural seasonal physical factors, comprehensive stressors in artificial environments—including restricted movement, artificial feeding, and high population density—can affect growth patterns, behavior, and reproductive activities, potentially influencing parturition timing and synchrony. The Maerkang Musk Deer Farm in this study was built within the natural habitat of wild forest musk deer, with open-air enclosure designs and no temperature control equipment. Consequently, environmental factors such as enclosure temperature changed synchronously with the natural environment, maintaining strong seasonality.

Compared to wild musk deer, captive forest musk deer at Maerkang receive food consisting of leaves, ground plants, and seasonal fruits and vegetables collected from the natural habitat surrounding the farm. The results indicate that key factors such as water-thermal conditions and food resources in the captive environment at Maerkang remain strongly seasonal and synchronized with natural habitat climate changes. Parturition in Maerkang' s captive forest musk deer occurred from May to July, demonstrating extremely strong parturition seasonality. The musk deer lactation period is generally about 3 months, making May–July the lactation season when Maerkang receives 79.97% of its annual precipitation, with average temperatures of 12.30°C. This overlap between the parturition and lactation season and the period of optimal environmental conditions benefits early fawn growth and energy accumulation, facilitating survival through the winter when water-thermal conditions and food resources are scarce.

At approximately 20 days of age, fawns begin eating leaves, and the gradually changing environmental factors and food resources remain within the fawns' adaptive tolerance range. During the lactation period, abundant food resources enable postpartum females to recover reproductive energy expenditure and fat reserves, while also preparing for the upcoming estrus and mating season, thereby enhancing reproductive success in the following year. For musk deer, female gestation and other reproductive activities require substantial energy and time investment. The period from October to November is both the initiation of the next estrus-mating season and the beginning of winter when food becomes scarce. The excellent water-thermal conditions and food resources during the parturition and lactation season facilitate energy replenishment and reserve accumulation in parturient females, improving their future reproductive success and overwinter survival.

As habitat seasonality decreases, animal reproductive seasonality tends to weaken. For example, bighorn sheep (*Ovis canadensis*) in less seasonal environments show relatively weaker parturition timing and synchrony. Laska' s research also demonstrated that the seasonal breeding bat *Carollia perspicillata* no longer exhibits parturition timing and synchrony in captive environments lacking usable reference cues. In contrast, wild alpine musk deer from Gansu' s Xinglong Mountain still show strong parturition seasonality in captivity, though their parturition season is significantly longer than that of wild individuals. Compared to Xinglong Mountain, although Maerkang is at a lower latitude, the captive forest musk deer at Maerkang showed earlier parturition initiation and a shorter, more strongly seasonal parturition period than the captive alpine musk deer at Xinglong Mountain. These differences may be attributed to variations in local topography and microclimate between the two locations, as well as species-specific characteristics such as the larger body size and longer gestation period of alpine musk deer.

All breeding areas in this study had similar enclosure facilities. Although each area was managed by different keepers, standardized captive management practices ensured no differences in feed formulation, feeding protocols, or other management models. Consequently, breeding area effects on captive forest musk deer were not significant, consistent with findings in other ungulate species.

Social behavior between males and females can affect female estrus, mating, and gestation length, thereby influencing parturition timing. During the estrus-mating period, increased exposure to male red deer (*Cervus elaphus*) can advance female conception and parturition through socially induced estrus. Conversely, delayed parturition in female deer is associated with late male introduction or weak behavioral stimulation. Female sexual maturity, dominance rank, and behavioral-endocrine responses to social interactions with same-sex and opposite-sex individuals also directly affect estrus, mating, and parturition timing. Sub-adult and primiparous females require stronger behavioral stimulation to initiate ovulation and other physiological activities, and their mating opportunities are often lower than those of older females due to age-dependent dominance hierarchies and reproductive opportunity allocation in musk deer. Consequently, their estrus and mating are delayed, resulting in later conception and parturition compared to adult females.

References

[1] Bunnell FL. Factors controlling lambing period of Dall' s sheep. *Canadian Journal of Zoology*, 1980, 58(6): 1027-1031.
[2] Rutberg AT. Adaptive hypotheses of birth synchrony in ruminants: an interspecific test. *The American Naturalist*, 1987, 130(5): 692-710.
[3] Ims RA. The ecology and evolution of reproductive synchrony. *Trends in Ecology & Evolution*, 1990, 5(5): 135-140.
[4] Berger J. Facilitation of reproductive synchrony by gestation adjustment in gregarious mammals: a new hypothesis. *Ecology*, 1992, 73(1): 323-329.
[5] Festa-Bianchet M. Age-specific reproduction of bighorn ewes in Alberta, Canada. *Journal of Mammalogy*, 1988, 69(1): 157-160.
[6] Rachlow JL, Bowyer RT. Interannual variation in timing and synchrony of parturition in Dall' s sheep. *Journal of Mammalogy*, 1991, 72(3): 487-492.
[7] Rutberg AT. Birth synchrony in American bison (*Bison bison*): response to predation or season? *Journal of Mammalogy*, 1984, 65(3): 418-423.
[8] Bowyer RT. Timing of parturition and lactation in southern mule deer. *Journal of Mammalogy*, 1991, 72(1): 138-145.
[9] Zhang BL. *Musk Deer: Their Capture, Domestication and Care According*

to Chinese Experience and Methods. Agricultural Press, 1979.
[10] Zhang BL. Musk deer: their capture, domestication and care according to Chinese experience and methods. *Unasylva*, 1983, 35(139): 16-24.
[11] Sheng HL, Liu Z. *Chinese Musk Deer*. Shanghai Scientific and Technical Publishers, 2007.
[12] Homes V. *On the Scent: Conserving Musk Deer—The Uses of Musk and Europe' s Role in Its Trade*. TRAFFIC Europe, Brussels, 1999.
[13] Meng XX, et al. *Musk Deer Farming in China*. China Forestry Publishing House, 2006.
[14] Lang DM, et al. Changes in fecal progesterone of captive female forest musk deer during estrous cycle. *Southwest China Journal of Agricultural Sciences*, 2011, 24(5): 1783-1788.
[15] Yang Y, et al. Application of CIDR in synchronized estrus of forest musk deer. *Southwest China Journal of Agricultural Sciences*, 2011, 33(4): 40-42, 53-53.
[16] Meng XX, et al. Reproductive physiology and performance of forest musk deer. *Journal of Northwest A&F University (Natural Science Edition)*, 2003, 31(6): 103-106.
[17] Meng XX, Yang QS, Feng ZJ, Xia L, Jiang YW, Wang PM. Timing and synchrony of parturition in alpine musk deer (*Moschus sifanicus*). *Folia Zoologica*, 2003, 52(1): 39-50.
[18] Meng XX, Yang QS, Xia L, Feng ZJ, Jiang YW, Wang PM. The temporal estrous patterns of female alpine musk deer in captivity. *Applied Animal Behaviour Science*, 2003, 82(1): 75-85.
[19] Meng XX, Zhou CQ, Hu JC, Li C, Meng ZB, Feng JC, Zhou YJ, Zhu YJ. The musk deer farming in China. *Animal Science*, 2006, 82(1): 1-6.
[20] Green WCH, Rothstein A. Persistent influences of birth date on dominance, growth and reproductive success in bison. *Journal of Zoology (London)*, 1993, 230(2): 177-186.
[21] Bunnell FL. The lambing period of mountain sheep: synthesis, hypotheses, and tests. *Canadian Journal of Zoology*, 1982, 60(1): 1-14.
[22] Porter TA, Wilkinson GS. Birth synchrony in greater spear-nosed bats (*Phyllostomus hastatus*). *Journal of Zoology (London)*, 2001, 253(3): 383-390.
[23] Laska M. Gestation period and between birth intervals in *Carollia perspicillata* (Phyllostomatidae Chiroptera). *Journal of Zoology (London)*, 1990, 222(4): 697-702.
[24] Coblentz BE. A unique ungulate breeding pattern. *Journal of Wildlife Management*, 1980, 44(4): 929-933.
[25] Cothran EG, Chesser RK, Smith MH, Johns PE. Fat levels in female white-tailed deer during the breeding season and pregnancy. *Journal of Mammalogy*, 1987, 68(1): 111-118.
[26] Krausman PR, Leopold BD, Seegmiller RF, Torres SG. Relationships between desert bighorn sheep and habitat in western Arizona. *Wildlife Monographs*, 1989, 102: 3-66.
[27] Rubin ES, Boyce WM, Bleich VC. Reproductive strategies of desert bighorn sheep. *Journal of Mammalogy*, 2000, 81(3): 769-786.

[28] Fisher MW, Meikle LM, Johnstone PD. The influence of the stag on pubertal development in the red deer hind. *Animal Science*, 1995, 60(3): 503-508.
[29] Meng XX, Sih A, Li HT, Cody N. Quantified analyses of aggression pattern in a captive population of musk deer (*Moschus sifanicus*). *Annals of Animal Science*, 2012, 12(3): 413-421.

Note: Figure translations are in progress. See original paper for figures.