

Postprint: Body Condition and Influencing Factors of Forest Musk Deer (*Moschus berezovskii*) in Ex-situ Conservation

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Abstract

By establishing a quantitative body condition scoring standard based on external morphological traits, body condition scoring was conducted on 586 captive forest musk deer (299 females and 287 males) at the Sichuan Maerkang Musk Deer Farm between July and October 2012, and the effects of relevant variables on body condition scores were analyzed. The results showed: the mean body condition score of captive forest musk deer at Maerkang Musk Deer Farm was $3.49 (\pm 0.02, n=586)$, with the majority of musk deer (59.56%, $n=349$) having body condition scores above the mean. The mean body condition score of female musk deer ($3.50 \pm 0.02, n=299$) was slightly higher than that of males ($3.49 \pm 0.03, n=287$) ($P > 0.05$), the body condition scores of adult musk deer ($3.59 \pm 0.02, n=291$) were extremely significantly higher than those of aged musk deer ($3.38 \pm 0.09, n=27$) and subadult musk deer ($3.35 \pm 0.03, n=184$) ($P < 0.01$). The body condition score of musk deer was not significantly correlated with age ($r=0.07, P > 0.05$); however, the correlation between body condition score and age was extremely significant for subadult and adult musk deer (subadults: $r=0.19, P < 0.01$; adults: $r=-0.16, P < 0.01$), whereas the body condition score of aged musk deer showed a slight negative correlation with age ($r=-0.23, P > 0.05$). The S-model $y=e^{1.2811-0.0885/a}$ ($R^2 \leq 0.051, df=500, F=26.74, P < 0.01$) could approximately fit the relationship between body condition score and age in musk deer. Additionally, the body condition of musk deer in modified enclosures with mud flooring at Maerkang Musk Deer Farm ($3.52 \pm 0.03, n=197$) was significantly better than that of musk deer in original blue-brick enclosures ($3.47 \pm 0.02, n=389$) ($P < 0.05$).

Full Text

Studies on Body Condition Scoring and Influencing Factors in Captive Forest Musk Deer

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Abstract

The forest musk deer (*Moschus berezovskii*) has become endangered due to habitat loss and musk exploitation, and musk deer farming has emerged as an effective measure for conserving wild populations while providing medicinal musk sustainably. In musk deer farming, the health condition of captive individuals is closely related to reproduction and musk production. This study surveyed the body condition of 586 captive forest musk deer (299 females and 287 males) at the Maerkang Musk Deer Farm (MMF) during July–October 2012 using a quantified scoring system, and analyzed the effects of potential influencing factors. The results showed that the average body condition score of captive forest musk deer was $3.49 (\pm 0.02, n = 586)$, with most individuals (59.56%, $n = 349$) scoring above the mean. The body condition of all females (3.50 ± 0.02) was better than that of all males (3.49 ± 0.03), but the difference was not statistically significant ($P > 0.05$). The body condition of adults (4–9 years old) ($3.59 \pm 0.02, n = 291$) was significantly better than that of older deer (older than 10 years) ($3.38 \pm 0.09, n = 27$) and sub-adults (2–3 years old) ($3.35 \pm 0.03, n = 184$). No significant correlation was found between musk deer's body condition and age overall ($r = 0.07, P > 0.05$), but the body condition scores of adults and sub-adults were highly significantly correlated with the animals' age (sub-adults: $r = 0.19, P < 0.01$; adults: $r = -0.16, P < 0.01$). Moreover, a significant negative correlation was observed between older individuals' body condition and their age ($r = -0.23, P > 0.05$). The S model $1.2811 - 0.0885/\text{age}$ ($F = 26.74, P < 0.01$) fitted the relationship between the score of captive deer and its age. Furthermore, the body condition score of musk deer in enclosures with earth-ground ($3.52 \pm 0.03, n = 197$) was significantly higher than those in enclosures with brick-ground ($3.47 \pm 0.02, n = 389$) ($P < 0.05$).

Keywords: forest musk deer (*Moschus berezovskii*); ex-situ conservation; body condition scoring; influencing factors

Introduction

Moschus species are valuable resource animals whose musk is widely used in Asian traditional medicine and the perfume industry. Although China has the richest musk deer resources, wild musk deer have become critically endangered due to habitat loss and historical overexploitation. Ex-situ conservation through captive breeding has become an important approach for protecting and sustainably utilizing musk deer resources. China initiated musk deer ex-situ conservation and breeding in 1958, with the forest musk deer (*M. berezovskii*) being the primary species. While considerable research has been conducted on breeding management, behavioral patterns, and disease prevention and control, challenges persist including slow population growth, low survival rates, and high mortality. These issues are generally associated with poor body condition in captive musk deer, which is also linked to declining reproductive performance and production traits.

In long-term musk deer farming practice, scholars have proposed various methods for assessing captive musk deer body condition. Liu et al. conducted preliminary evaluations of body condition in captive forest musk deer in Shaanxi. However, to date, quantitative scoring-based assessments of captive musk deer body condition and identification of key influencing factors have been lacking. Based on quantitative scoring of body condition in captive forest musk deer at the Maerkang Musk Deer Farm under the Sichuan Institute of Musk Deer Breeding, this study investigated the key factors affecting forest musk deer body condition. The results provide a reference for improving endangered musk deer conservation and farming productivity in China.

1. Study Area

The study was conducted at the Maerkang Musk Deer Farm, affiliated with the Sichuan Institute of Musk Deer Breeding, located in Maerkang County, Aba Prefecture, Sichuan Province, within the natural distribution range of wild forest musk deer in the Min Mountains. The area features a high-altitude mountain canyon climate at 2,600 m elevation. The average temperature ranges from 12–14°C, with seasonal temperature variations of 21.6–25.3°C and daily temperature variations of 2.5–6.4°C. The average daily temperature difference is substantial, with annual precipitation of 753 mm, annual sunshine of 2,000 hours, and a frost-free period of 120 days.

2. Sample Animals and Grouping

The Sichuan Institute of Musk Deer Breeding is one of the first musk deer breeding centers established in China. The Maerkang Musk Deer Farm comprises multiple enclosures, each consisting of several musk deer pens with brick shelter platforms. Each pen houses forest musk deer in activity areas of 100–200 m². The farm currently maintains a captive population of musk deer, all of which are

captive-bred offspring. Individual identification is achieved through plastic ear tags applied since infancy. Each feeding area is managed by dedicated keepers responsible for feeding and daily management.

Musk deer feed consists of concentrate feed and manually collected leaves. Feeding occurs at 06:00 and 19:00, with pen cleaning conducted during feeding, taking approximately 10 minutes per pen. Outside these times, musk deer are seldom disturbed. Based on pen floor substrate, the farm is divided into original enclosure areas (with brick-paved activity floors, a configuration dating from the early stages of musk deer farming, where moss and weeds grow between bricks) and modified enclosure areas (with hardened, compacted mud floors of lower hardness than brick, where grass grows between cracks).

3. Body Condition Scoring and Data Collection

Based on reported ecological and biological characteristics, health and production performance indicators of musk deer, and referencing livestock body condition scoring standards, we developed a body condition scoring standard for captive forest musk deer. The scoring criteria included coat color, mental status, area between rib and hipbone, hip side, spine area, and tuber of coxae and ischium.

Body condition scoring was conducted during July–October 2012. Following standard development, researcher training, and pre-evaluation, three researchers and keepers simultaneously assessed each musk deer individual using the common standard, with the average value taken as the individual's body condition score.

4. Data Analysis Methods

Data normality was tested using the Kolmogorov-Smirnov test, with skewness and kurtosis calculated. Parametric (ANOVA) or non-parametric methods (Mann-Whitney U test, Kruskal-Wallis test) were selected accordingly to examine the effects of gender, age, and enclosure factors on body condition scores. Pearson correlation analysis was performed between these factors and body condition scores. The significance level was set at $P = 0.05$, and the highly significant level at $P = 0.01$. All analyses were conducted in SPSS 11.0.

Results

1. Overview of Body Condition in Captive Musk Deer at Maerkang

The body condition scores of captive forest musk deer at Maerkang Musk Deer Farm exhibited a non-normal distribution, skewed toward higher values. The mean score was $3.49 (\pm 0.02, n = 586)$, ranging from 1.8 to 4.75. Skewness was $-0.706 (\pm 0.101, n = 586)$ and kurtosis was $1.401 (\pm 0.202, n = 586)$. Individuals scoring above the mean accounted for 59.56% ($n = 349$).

2. Gender Differences in Body Condition Scores The mean body condition score of captive female musk deer was $3.50 (\pm 0.02)$, with 62.21% ($n = 186$) of individuals scoring above the mean. The mean score for males was $3.49 (\pm 0.03)$, with 56.79% ($n = 163$) above the mean. No significant difference was found between genders (Mann-Whitney U test, $Z = -0.555$, $P = 0.58 > 0.05$). Therefore, data from both sexes were combined for subsequent analyses.

3. Relationship Between Body Condition and Age Overall, musk deer age was not significantly correlated with body condition score ($r = 0.07$, $P = 0.15 > 0.05$, $n = 502$). However, when analyzed by age class, sub-adult musk deer showed a highly significant positive correlation between age and body condition score ($r = 0.19$, $P = 0.01$, $n = 184$), while adult musk deer showed a highly significant negative correlation ($r = -0.16$, $P < 0.01$, $n = 291$). Older musk deer exhibited a non-significant negative correlation with age ($r = -0.23$, $P = 0.25 > 0.05$, $n = 27$).

The S model $1.2811 - 0.0885/\text{age}$ ($F = 26.74$, $P < 0.01$, $n = 500$) provided a good fit for the relationship between musk deer body condition score and age [Figure 1: see original paper]. Body condition scores differed significantly among age classes (Kruskal-Wallis test, $\chi^2 = 48.25$, $P < 0.01$). Adult musk deer (3.59 ± 0.02 , $n = 291$) had significantly higher scores than both older musk deer (3.38 ± 0.09 , $n = 27$) (Mann-Whitney U test, $Z = -6.85$, $P < 0.01$) and sub-adults (3.35 ± 0.03 , $n = 184$) (Mann-Whitney U test, $Z = -2.408$, $P < 0.01$). No significant difference was found between sub-adults and older musk deer (Mann-Whitney U test, $Z = -0.645$, $P = 0.519 > 0.05$) [Figure 2: see original paper].

4. Relationship Between Body Condition and Enclosure Type The body condition score of musk deer in modified enclosures with mud floors (3.52 ± 0.03 , $n = 197$) was significantly higher than that of deer in original brick-ground enclosures (3.47 ± 0.02 , $n = 389$) (Mann-Whitney U test, $Z = -2.15$, $P = 0.016 < 0.05$) [Figure 3: see original paper].

Discussion

This study demonstrates that the mean body condition score of captive forest musk deer at Maerkang Musk Deer Farm was 3.49, with 59.56% of individuals scoring above the mean, indicating generally good body condition. However, only 10.41% of individuals achieved the highest scores, suggesting considerable room for improvement in farming management and musk deer body condition.

Wild musk deer show no gender differences in ecological requirements for habitat, food, or resting sites, and captive environments affect both sexes similarly in terms of response intensity and pattern. Musk deer also exhibit similar seasonal energy demand patterns. Our findings confirm these observations, showing no significant gender differences in body condition scores. However, the

proportion of females scoring above the mean (62.21%) was higher than males (56.79%). Since male health directly relates to musk secretion and mating behavior, Maerkang farm should implement targeted improvements for male musk deer to enhance musk production and reproductive performance.

Sub-adult musk deer in this study had not yet reached full sexual maturity. Their body condition showed a positive correlation with age, as body reserves gradually increase with age. Musk deer reach full sexual maturity after 3 years of age. The relationship between body condition and age in captive musk deer presents a complex pattern. Adult musk deer showed significantly better body condition (3.59) than sub-adults (3.35), but both adult and older musk deer exhibited negative correlations between body condition and age. As captive musk deer age, particularly in older individuals, accumulated stress from the captive environment affects their condition. The captive environment is artificial, with resource configurations differing markedly from natural habitats, and captive individuals exhibit different spatial and activity patterns from wild musk deer, ultimately affecting their body condition. All Maerkang captive musk deer are captive-bred, so age corresponds to years in captivity; older individuals experience longer and more intense environmental stress, leading to declining body condition over time.

In musk deer farming practice, farms should group musk deer by age and years in captivity to establish targeted management and disease prevention systems that optimize body condition across all age groups. Enclosures are the artificial habitat for captive animals, and their conditions and configurations affect development and growth. Enclosure environment influences musk deer behavior patterns, activity rates, and reproduction. In this study, body condition scores in original brick-ground enclosures were significantly lower than in modified mud-ground enclosures. The original enclosures, with their hard brick floors, cause hoof wear, injuries, and infections during high-activity periods, especially during breeding season fighting and mating. The moss and weed growth on aging brick surfaces hinders thorough disinfection and disease prevention, resulting in higher disease incidence. Modified enclosures with hardened mud floors have relatively softer surfaces, reducing hoof wear and disease, and facilitating thorough cleaning and disinfection, leading to better health and body condition.

Compared with common methods in animal husbandry such as visual assessment or height-weight ratios, the body condition scoring method based on external morphological traits used in this study offers the advantages of simplicity, ease of implementation, and wide applicability without requiring special equipment. It allows rapid assessment and enables both managers and researchers to evaluate using consistent indicators and standards, enhancing comparability of results. This method can be promoted in musk deer ex-situ conservation and farming operations.

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