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Research Article

Preliminary findings of behavioral patterns in captive alpine musk deer (*Moschus sifanicus*) and prospects for future conservation

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Abstract: Captive farming of alpine musk deer (*Moschus sifanicus*) in China has been used for conservation and harvesting of musk since the mid 1950s. Despite this long history, management practices and captive breeding have been primarily based on trial and error due to lack of behavioral and ecological information about this vulnerable species. Understanding behavioral patterns plays a vital part in determining appropriate management systems; hence the aim of this study was to determine the effect of captivity on behavioral patterns of alpine musk deer by comparing wild-caught and the captive-born alpine musk deer. From August 2002 to January 2003, the behavioral patterns of 30 wild-caught (WC) and 15 captive-bred (CB) adult alpine musk deer were recorded at Xinglongshan Musk Deer Farm (XMDF), located in Xinglongshan National Nature Reserve, Gansu province, China. Focal sampling was used to observe the frequencies of 12 behavior categories. The behavioral patterns of WC and CB musk deer were found to be similar; however, when gender was considered, male WC deer showed a significantly higher frequency of agonistic interaction. These preliminary results suggest that captivity has had no immediate impact on the behavioral patterns of captive alpine musk deer despite 10 generations of captivity. Therefore, the alpine musk deer is not suited for domestication and further investigation into the effectiveness of musk deer farming for the purpose of harvesting musk should be undertaken.

Key words: Alpine musk deer (*Moschus sifanicus*), captivity, wild-caught, captive-born, domestication

Introduction

Musk deer (*Moschus* spp.) are typical small solitary forest ruminants, well known for the production of musk, which is secreted by the adult males (1). Spread throughout the mountainous regions of western China and Russia, the population of musk deer is in decline as a result of habitat loss and intensive illegal hunting for musk (2). With the rapid loss of species worldwide, long-term maintenance of captive populations has become a common approach to species conservation (3). Musk deer farming is considered one of the most important ex situ options available to conserve this species and utilize the musk deer resources sustainably (4). While

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some attempts have been made in India and Russia (2), musk deer farming is most commonly practiced in China, where approximately 2000 individuals are currently held in captivity (5). Early musk deer farming in China suffered a high mortality rate of 60-70% of all wild-caught animals and the animals died from gastroenteritis and poor husbandry (6). Although experience has been gained in managing, breeding and musk extracting techniques, the behavior of alpine musk deer is poorly documented because of the current farming practices primarily based on trial and error. Furthermore, the economic viability of musk deer farms is yet to be studied in detail due to the high maintenance costs and management difficulties, suggesting that musk deer farming, to date, has largely been unsuccessful (2,4).

The alpine musk deer (*Moschus sifanicus*) is endemic to the Qinghai-Xizang Plateau, inhabiting mainly plateaus and mountainous regions in western China. The species is currently listed as vulnerable under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and protected as a Category I key species in China, with a population estimated at less than 100,000 individuals (7). In order to conserve the wild populations and extract musk from the live animal, the Xinglongshan Musk Deer Farm (XMDF) was established in 1990 at Xinglongshan National Nature Reserve, Gansu province in the northwest. Successful captive breeding has occurred within XMDF; wild bred musk deer are caught in accordance with the permits to requisitions and regularly introduced to the captive breeding stock. Currently, 250 alpine musk deer are housed at XMDF, comprising both the captive-born (CB) and wild individuals obtained from the adjoining Xinglongshan National Nature Reserve.

Many efforts have been made to domesticate musk deer, defined as a process whereby a population of animals is adapted to man and to captive environment (8). During domestication, animals adapt to man and captive environment in terms of behavior and an array of other traits, giving rise to a specific domestication phenotype (9). Currently the domestication of musk deer is attempted through enclosed farming practices, in which many deer are housed together in an artificial environment. Captive alpine musk deer, therefore, provide an opportunity to determine the behavioral changes resulting from captivity and to assess the level of domestication within this species. Behavioral analysis may also assist in understanding the relations between behavior and production and to predict possible side-effects of breeding programs. Moreover, such information is essential in developing appropriate captive husbandry techniques for musk deer species.

Materials and methods

Animals, housing and managing

This study was conducted in Xinglongshan Musk Deer Farm (XMDF), at Xinglongshan National Nature Reserve, in Gansu province, China. 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 an average temperature of 9 °C and a minimum temperature of -28 °C. The warmest month is July, averaging 14 °C. Rainfall is mainly in July, August, and September, with an annual precipitation of 48-62.2 mm.

A total of 45 captive adult alpine musk deer were studied. Among them, 30 individuals were captured as wild fawns (1-2 months old) (wild-caught, WC) (13 males, 17 females) and housed at XMDF for a minimum of 2 years prior to this study, and 15 adult musk deer were born, raised and 6 males were born, reared and housed in captivity for 10 generations (captive-bred, CB) (9 males, 6 females).

Animals were housed in outdoor enclosures (10 m × 10 m), in groups ranging from 5 to 7 individuals. Each enclosure contained a central yard with 7 adjoining indoor cells (4 m^2). Wire mesh separated enclosures enabled animals to see, hear, and smell each other. Human interaction was limited to 5 min at dawn and dusk during which animals were fed and husbandry duties were conducted. A diet of fresh leaves (May to November) or dried leaves (December to April) was provided to each enclosure during the experiment. Leaves of the preferred forage species, predominantly *Crataegus kansuensis* and *Acer tetramerum*, were collected from the Xinglongshan National Nature Reserve, a habitat for wild musk deer. The diet was supplemented with on-site mixed artificial feed containing approximately 40% corn, 25% wheat, and 25% bean. In addition, seasonal vegetables were occasionally provided and water was provided ad libitum. Diet manipulation was not possible in this study, as all experiments were conducted at a commercially operating deer farm; food provisions, however, remained consistent within each season.

During the study, males and females were housed separately from March to October; both CB and WB individuals, however, were housed in the same enclosures. From November to February, one male was introduced into each of the female enclosures and the males introduced into the female enclosure were both CB and WB, as with commercial breeding practices. All animals were individually identified by the plastic ear tags with numbers.

The ethogram and the behaviour sampling

Based on the published behavioral patterns of the musk deer (1,6,7), preliminary behavior observation was conducted to establish the ethogram of captive alpine musk deer at XMDF (Table 1).

Data collection and statistical analyses

Due to lighting limitations, behavioral observations were recorded during daylight hours with the assistance of binoculars (10 × 42°) to confirm individual ear tag numbers. To measure the behavioral frequency, a focal animal was selected at random from a group and its behaviors recorded continuously for 5 min. A researcher observed the animals in the building, which lay between the rows of enclosures, and the behavior sampling did not

Table 1. The ethogram and behavioral definition of captive alpine musk deer.

Behavior	Definition
Resting, RE	Animal is lying on the ground and in inactive or relaxed state.
Standing-alert, SA	Animal is still, alert and gazing at stimuli or potential stimuli.
Locomotion, LO	Animal is obviously moving without any accompanying behaviors.
Feeding/Drinking, FD	Animal is feeding or drinking.
Ruminating, RU	Animal expresses typical behavioral series of rumination, i.e. regurgitating, chewing and swallowing.
Tail-pasting, TP	Animal is rubbing its tail and scent-marking on the surface of the wall or doorframe.
Urinating/Defecating, UD	Animal fully or partially exhibits a series of activities such as earth-scratching, urinating and pellet covering.
Environmental sniffing, ES	Animal explores the wall or ground with its nose.
Self-directed behavior, SD	Animal expresses activities directed to itself, including self-grooming with mouth, self-scratching and other self-directed behaviors.
Ano-genital sniffing, AS	Animal sniffs or licks the ano-genital region of another musk deer
Affinitive interaction, AI	Direct body-touching activities without obvious conflict among individuals, including mutual grooming, nursing and licking.
Agonistic interaction, CI	Obvious agonistic behaviors with or without direct body touching.
Miscellaneous behavior, MB	All other behaviors.

influence the normal activity of the animal. A single researcher conducted these observations 10 times a day, 3 days a week and for 4 weeks over a 6-month period.

Average monthly frequency was calculated for each behavior and individual. Miscellaneous behavior (MB) and behavior samples whose recorded duration was less than 5 min were excluded from the analysis. The Mann-Whitney U test was used to test the potential differences between the WC and the CB musk deer for both males and females. Statistical analysis was conducted with the SPSS 11.0 (SPSS Inc., Chicago, Illinois, USA), using 2-tailed probability, with a significance level of $P = 0.05$.

Results

The behavioral comparison of the WC and the CB male musk deer

As shown in Figure 1, WC males had significantly more agonistic interaction (0.51 ± 0.19) than the CB males (0.08 ± 0.03) ($P < 0.05$). In general, the WC males tended to exhibit more resting, standing-alert, locomotor, feeding/drinking, ruminating, self-directed behavior and ano-genital sniffing behavior than the CB males did. Conversely, the CB males had a higher frequency of environmental sniffing and affinitive interaction as compared to the WC musk deer; however, these differences were not statistically significant ($P > 0.05$).

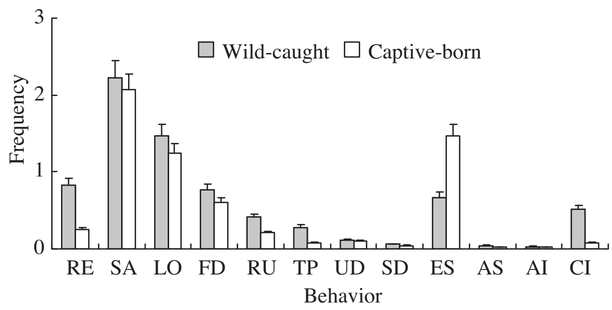

Figure 1. Average behavioral frequency for the wild-caught (WC, N = 13) and the captive-bred (CB, N = 9) male musk deer.
Behaviors include: Resting (RE), Standing-alert (SA), Locomotion (LO), Feeding/Drinking (FD), Ruminating (RU), Tail-pasting (TP), Urinating/Defecating (UD), Self-directed behavior (SD), Environmental sniffing (ES), Ano-genital sniffing (AS), Affinitive interaction (AI), Agonistic interaction (CI).

The behavioral comparison of the WC and the CB female musk deer

The behavioral differences between the WC and the CB female musk deer are shown in Table 2. There was no significant difference between any of the behaviors exhibited ($P > 0.05$); however, in general, the WC female musk deer performed resting, feeding/drinking, ruminating, environmental sniffing, affinitive interaction, and agonistic interaction more frequently than the CB female musk

Table 2. Average Behavioral frequency for the wild-caught (WC, N=17) and the captive-born female (CB, N = 6) musk deer.

Behavior	Wild-caught	Captive-born	P
Resting, RE	1.27 ± 0.76	0.40 ± 0.12	0.223
Standing-alert, SA	2.03 ± 0.34	2.36 ± 0.47	0.449
Locomotion, LO	1.23 ± 0.31	1.41 ± 0.38	0.430
Feeding/Drinking, FD	1.08 ± 0.23	0.60 ± 0.24	0.168
Ruminating, RU	0.64 ± 0.15	0.25 ± 0.12	0.422
Tail-pasting, TP	---	---	---
Urinating/Defecating, UD	0.13 ± 0.04	0.15 ± 0.08	0.573
Self-directed behavior, SD	0.05 ± 0.02	0.08 ± 0.04	0.354
Environmental sniffing, ES	0.71 ± 0.25	0.66 ± 0.16	0.372
Ano-genital sniffing, AS	0.05 ± 0.02	0.05 ± 0.03	0.610
Affinitive interaction, AI	0.08 ± 0.05	0.03 ± 0.02	0.808
Agonistic interaction, CI	0.28 ± 0.10	0.23 ± 0.11	0.709

deer, but fewer standing-alert, urinating/defecating, self-directed and locomotion behaviors.

The behavioral comparison of the WC and the CB musk deer

Combining sexes, the behavioral patterns of the WC and the CB musk deer are shown in Figure 2. Trends indicated a higher incidence of resting, feeding/drinking, ruminating, and tail-pasting behaviors in the WC deer as compared to the CB deer. Moreover, the WC musk deer exhibited social behaviors such as affinitive interaction and agonistic interaction more frequently than the CB. However, no significant differences were found for any behavior categories (Mann-Whitney U test, P > 0.05).

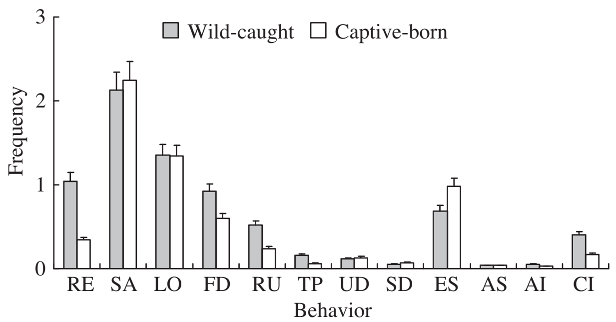

Figure 2. Behavioral comparison between the wild-caught (N = 30) and the captive-born (N = 15) musk deer. Behaviors include: Resting (RE), Standing-alert (SA), Locomotion (LO), Feeding/Drinking (FD), Ruminating (RU), Tail-pasting (TP), Urinating/Defecating (UD), Self-directed behavior (SD), Environmental sniffing (ES), Ano-genital sniffing (AS), Affinitive interaction (AI), Agonistic interaction (CI).

Discussion

Animal farming may promote the modifications of behavior or genetic adaptations of behavior to the adaptive environment (10), resulting in a captivity-based phenotype. The transfer of wild animals to artificial environments may lead to different selection pressures and environmental constraints such as accessibility to resources like food, water and mating partners and to an increased proximity to perceived dangers, i.e. increased human contact. In regard to the behavioral adaptations, domesticated animals show little evidence of loss of behavioral traits from the repertoire of the species, rather the addition of new behaviors was observed. Andersen et al. (11), however, argue that differences between wild and domestic stocks are quantitative in character and are best explained by response thresholds or behavioral frequency.

Our results indicated that across the range of 12 behavioral categories recorded, no significant difference was found in the average frequency of behaviors between the captive-born and the wild-born individuals, for either male or female musk deer. These results may be a consequence of the artificial enclosures whereby both the WC and the CB musk deer were housed in identical enclosures, in which individuals had no control over the number of co-inhabitants, where resources were limited, and there was no or little option to leave or modify the environment. Håkansson et al. (12) suggested that the social environment has a major impact on the social behaviors of animals. Whilst this factor needs to be considered, our preliminary results, namely the variation in aggressive behavior in males, suggest that the social environment is not the sole factor affecting captive behavior.

In the wild, musk deer occupy home ranges of 15-32 ha. Males are highly territorial, and maintain exclusive home ranges; however, they overlap with several female home ranges (6,13). Border disputes between the males occupying adjacent territories have been recorded, with the likelihood reduced by the dense nature of forest or scrub habitat (13). Whilst the musk deer do not have antlers, males possess elongated upper canine teeth that project far below the lower lip and are used for fighting between rivals (1). In the artificial captive environment at XMDF, the musk deer, particularly the wild-born musk deer, which are confined within a narrow enclosure, lacking environmental richness and shelter, are predicted to engage in a high frequency of interaction and fighting with other musk deer. This hypothesis was supported by our results indicating that the WB deer engaged in significantly more aggressive interactions as compared to the CB. Similarly, Håkansson et al. (12) found significant differences in social behaviors in red jungle fowl (*Gallus gallus*) with different origins, despite being raised under identical conditions.

For wild animals, fear-related behaviors relating to genetic background and evolution are critical for survival. Animals in captivity are influenced by relaxed natural selection pressures, i.e. reduced protection against predators, which can be considered as an early step in domestication (12). Furthermore, close contact with humans can be expected to cause a modification of behaviors, specifically fear-related behaviors, where selection pressure may change from avoidance to the acceptance of daily encounters with humans (9). Wallace (14) suggested that, over only a few generations, the lack of natural selective pressures may change the genetics of important behavioral traits. As solitary small forest ruminants, musk deer have evolved behavioral responses relying on vigilance and flight response to avoid predators (6).

In this study, caretakers had daily contact with the deer at dawn and dusk during feeding and enclosure cleaning. Despite the lack of statistical support, anecdotal observations indicated that the response of the WC deer to human interaction was markedly different from those of the captive-born deer, in that the WC deer were nervous and alert, exhibiting more flight response to humans, whereas the CB deer were more explorative and feed oriented. Such findings are supported by Zhang (1), who provided preliminary reports as to the domestication of forest and musk deer.

The interaction of the developing animals with their captive environment could cause group differences in a given generation (15); for example, captive ocelots (*Leopardus pardalis*) were less active than wild ocelots (16). Zhang (1) reported that the young musk deer are easier to tame than the adult animals, and the female musk deer are easier to tame than the males. In this study, although no significant differences existed between the general behavioral patterns of the females and the males, the differences in social behavior (affinitive and agonistic interaction) between the WC and the CB males were greater than those of the WC and the CB females. Due to the sample size no age effect could be analyzed in this study.

Modification of behavior was important in the adaptation of wildlife to the new environment, and this ability to change behavior may have made the animal amenable to domestication (17). Domestically tame animals have developed through thousands of generations of human interaction. The degree of domestication of an animal, however, is difficult to estimate because the animal's phenotype depends not only on its genetic make-up but also on its experiences during ontogeny. Captive foxes selected for domestication started eating in the presence of a human and took food from their keepers (18). Zhang (1) reported that musk deer were easily adapted to the captive condition based on normal feeding and reproduction soon after capture. Notwithstanding the factors, our preliminary results suggest that the behavior modes of the captive musk deer have not been modified to adapt to the captive condition, even after 10 generations in captivity. As such musk deer do not indicate any major signs of domestication. Furthermore, due to the behavioral adaptations it is unlikely that a domestic animal would survive in wild situations, and it would be quickly destroyed if significant predator pressure were present. At XMDF and at other musk deer farms in China, intentionally or inadvertently released captive musk deer, which were born and raised in captivity for over 10 years, were recorded to survive for a long time. This indicated that the captive musk deer are not limited in responding in an adaptive manner to the natural environment.

With the economic viability of current farming practices in question (1,4), other conservation methods should be considered to protect this vulnerable species. Long-term maintenance of captive populations followed by release of captive animals into the wild is one of the various approaches to the conservation of the endangered species. Ex situ conservation of the threatened species may lead to behavioral adaptation, which can affect the success of reintroduction attempts, ultimately affecting the outcome of reintroductions (12). McPhee (3) reported that the more generations of a *Peromyscus polionotus* population has been in captivity, the less likely an individual is to take cover after seeing a predator. Several reintroduction programs have shown that the survival rates of the captive-born animals are lower than those of their wild-born offspring (19). In general, the captive-born animals were deficient in locomotion and foraging skills when compared with their wild-born offspring, and some of these deficiencies persisted after 2 years in the wild. Our results, however, indicated little evidence of domestication, and small behavioral differences between the wild-born and the captive animals. These findings highlight the potential use of reintroduction conservation strategies for captive musk deer, particularly in view of the success of current captive breeding.

Considering the numerous factors that affect domestication, biological, and ecological characteristics, and enclosure and managing system, musk deer domestication is a complicated process, involving the development of a complex relationship with humans. Our preliminary study indicates little evidence to suggest that musk deer are suitable for domestication. Further studies are necessary to explore the potential differences in physiological stress levels between the wild-caught and the captive-born animals, and to explore appropriate management practices for captive populations.

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