Pertanika J. Sci. & Technol. 30 (1): 527 - 546 (2022)

PERTANIKA JOURNALS

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Comparative Study on the Social Behavior of Sambar Deer (*Rusa Unicolor*) in Three Selected Captive Facilities in Peninsular Malaysia

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ABSTRACT

Sambar deer was up-listed from Least Concern to Vulnerable by the IUCN Red list in 2015. The local government has initiated *Ex-situ* conservation efforts to boost sambar deer numbers in captivity and reintroduce them into the wild. The reproductive success of sambar deer and their welfare management practices in captivity are important components for effective captive breeding programs. However, there has been a lack of study on sambar deer in recent years, especially about their behavior in captivity. This study aimed to identify environmental factors that may influence the behavior of the captive sambar. Three captive sites were selected and observed for an average of 40 days at each site (minimum 37 days to maximum 43 days, 6 hours/day). A Generalized Linear Model was used to determine the correlation between social behavior and extrinsic parameters. 'Captive sites' showed the strongest correlation in behavioral variability environmental settings, such as the size of the enclosure, could force the deer to spend more time in a herd, which increases the frequency in grooming, which was recorded to be highest in Zoo Negara compared to other captive sites. Time of day also significantly influenced certain behavior skewed towards morning slots. It could be due to an adaptive behavior to the feeding time in the captive sites being often in the morning, which caused the deer to rest towards the afternoon. A suggestion would be to create a more erratic feeding schedule to ensure that the deer adapt to behavior variations. An extensive study needs to be done on sambar deer to pinpoint the specifics and better understand these possible influential factors in their behavior.

Keywords: Captivity, *ex-situ* conservation, generalized linear model, sambar deer, social behavior

ARTICLE INFO

Article history:
Received: 25 June 2021
Accepted: 15 September 2021
Published: 10 January 2022

DOI: https://doi.org/10.47836/pjst.30.1.29

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ISSN: 0128-7680
e-ISSN: 2231-8526

INTRODUCTION

Sambar deer (*Rusa unicolor*) are ungulates defined as hoofed placental mammals distributed across Afro-Eurasia and the New World (Hendrix & Vos, 2019). Unfortunately, due to poaching and deforestation, their status moved from being 'Least Concerned' in 1996 to 'Vulnerable' in 2015 (Timmins et al., 2015). In addition, the population of sambar deer in their native range has been declining, resulting in a regional abundance in areas that are well protected (Timmins et al., 2015). In some countries, such as Australia, sambar deer are considered a pest after being introduced (Gormley et al., 2011). In Sabah, the sambar deer population has been instilled to decline in numbers based on interviews carried out in local communities. The decline was based on the increase in licenses issued to hunt the deer (Wong et al., 2012). This trend shows a need to investigate captive populations as an option for conservation efforts, which is at the center of our research.

Sambar deer are nocturnal species whey they are active during the night (e.g., feeding and locomotion) compared to during the day. This behavior was developed as a strategy against predators and to decrease thermoregulatory stress, especially in tropical areas (Semiadi et al., 1993). However, due to the captive environment, they have adapted to grazing more frequently during the day (Couchman, 1978). Other studies have also observed through camera trap data and activity pattern analysis that sambar deer are cathemeral (Tan et al., 2018). In addition, sambar deer have been recorded in the wild to be solitary and rarely in a herd (Wong et al., 2019).

Sambar deer prefer mixed forest habitat as they provide essential shade area, watering holes, and high temperature, especially during daytimes (Chatterjee et al., 2014). Seasonal variation was shown to influence the time budget allocation of female Alpine musk deer to sustain energy lost during pregnancy, lactation, and parturition by increasing its ingestive optimization. It was done by increasing locomotion (standing-gazing and moving) rather than bedding (Meng et al., 2011). The visitor density/frequency was proven to induce higher pacing in jaguars compared to Sellinger and Ha (2005), which showed no association between visitor frequency and pacing. However, they speculated by tying pacing jaguars with other factors (e.g., enclosure size, shrubs/plants) (Vidal et al., 2016).

One of the main threats to sambar deer is poaching. The meat of sambar deer is of high value in Malaysia, contrary to some other species, such as wild boars or tapirs related to superstitious or religious beliefs leading this species towards local extinction due to hunting. In the case of not having sambar deer farms in Peninsular Malaysia, wild sambar meat is sold under the disguise of farmed Javan rusa (*Rusa timorensis*) to escape legal actions (Kawanishi et al., 2014). An interview-based survey across five sites located in Peninsular Malaysia showed that a hunting ban on sambar and muntjac was implemented for the 11-months in 2011, but all studied sites had ignored such restriction, and the hunting was carried out throughout the year (Goldthorpe & Neo, 2011).

Enclosure size and natural substrates (e.g., vegetation, grass, wood chips, water body), which were preferable over concrete flooring, were shown to decrease stereotypic behavior, specifically pacing and increased exploratory behavior (e.g., drinking, grooming, stalking) in tigers (Pitsko, 2003). Shaded areas provide ungulates with a resting place, as they require cooling their bodies in tropical climates, which reduces their foraging activity. The enclosure space should not only fit the functional dimensions of the species housed but, more importantly, permit reactive response and provide a comfortable living situation (Tennessen, 1989). For species with a wide home range, such as carnivores, can influence the frequency of pacing in a captive setting (Clubb & Mason, 2003). Space utilization was observed in leopards in Indian zoos that showed frequent pacing at the edge of the enclosure and high resting towards the back of the enclosure that shied away from the presence of visitors (Mallapur et al., 2002).

Poached species, in particular, tend to be more nocturnal to reduce hunting pressure (Tan et al., 2018). As a comparative, tapirs were found to increase their lip-licking behavior to decrease their internal temperature. It is recommended that the enclosure have a watering pool or mud wallow that allows them to physically reduce their body temperature (Arumugam & Buesching, 2019). Lions in captivity were observed to reduce normal behavior in an environment with minimal facilities compared to lions kept in a larger facility. The receptiveness of female sambar deer was shown to be lower than other ungulates species, and the semen produced by stags varies based on age and health conditions (Muir et al., 1997), which contributes to the difficulty to breed them in captivity. Reproductive success in *ex-situ* environments compared to wild populations could be attributed to poor species-appropriate socio-environmental settings (Lindburg & Fitch-Snyder, 1994).

The research aimed to determine possible extrinsic parameters (captive sites, time of day, temperature, and rain) that may influence the social behavior of sambar deer in the various captive sites in Peninsular Malaysia. An extension of this, an ethogram was updated and modified from a study done by Aun and Rahman (1989) working with the same species.

MATERIALS AND METHODS

Study Site and Field Methods

This study was carried out at (a) Zoo Negara, Selangor (3°12’32.8”N 101°45’29.6”E), (b) Zoo Taiping, Perak (4°51’17.9”N 100°45’05.2”E) and (c) Sungkai Captive Wildlife Centre, Perak (4°01’54.3”N 101°22’09.9”E). These sites were categorized into two, captive (permitted to visit by the public) inclusive (a) and (b) and semi-captive (no visitor, located away from human settlements and the habitat is set up close to mimic sambar deer’s natural environment) referring to (c). These captive sites were based on availability and permission from each zoo and the Department of Wildlife and National Parks (DWNP). Sungkai Captive Wildlife Center was chosen as it has a reintroduction program for sambar deer.

Zoo Negara was officially opened to the public in 1963 and since then has become one of the main attractions for tourists in Malaysia. The zoo hosts up to over 450 species of wildlife. The sambar deer, *Rusa unicolor,* is kept in an enclosure measuring 100.9 meters (length) x 15 meters (width), as depicted in Figure 1. There are 11 individuals of sambar deer consisting of two stags and nine does. Based on records obtained by the zoo, the two stags were transferred from the Wildlife Conservation Centre in Sungkai, Perak, under the management of the Department of Wildlife and National Parks (DWNP) in the year 2014. The enclosure is shared among two other species, hog deer (*Axis porcinus*) and spotted deer (*Axis axis*). Their numbers and size vary among species. In addition, the enclosure has three moat pools with varying sizes located on the left side of the enclosure. The perimeters of these moats are covered in cement. There are two big huts/shelters labeled as night dens, each on opposite ends of the enclosure and a smaller shelter for the feeding area that was newly built.

In addition, there are two big islands for the deer to rest and take shelter as these 'islands' have moderate-sized trees that provide shade. One of these islands was only constructed in the mid of 2018. The enclosure has sandy and muddy grounds, and not much vegetation can be seen. The perimeter is covered with wired fences. There are two viewing docks for visitors to observe the deer. The enclosure has soil and gravel as their flooring, and only certain areas, such as the feeding hut and shelters, are with cemented flooring. There are a couple of puddles created naturally from heavy rainfalls near the main viewing dock. In addition, there are not many natural covers or shade from trees as there are only a few fully-grown trees in the enclosure. Each of these trees is wrapped with wire fencing around its trunk to avoid debarking from the deer. The newly made "island" has been planted with varying species of flora but is currently not opened to the deer to allow the island to settle in fully. The width of the enclosure runs along a housing area with a small gap in between for the keepers to maneuver through. On the right side of the enclosure is a small patch of unused land overgrown with various flora species.

Zoo Taiping is located towards the northern side of Peninsular Malaysia. The town is surrounded by mountainous terrain sheltering from the harshest weather. The enclosure measures 75.3 meters x 29.5 meters (Figure 2). The enclosure consists of one wallowing pool and five sets of night quarters, each measuring 5.4 meters x 5.7 meters. There are several large trees within the enclosure. The tree barks are wrapped with flexible wire fencing to prevent the sambar deer from debarking the trees. The enclosure is described to be surrounded by greenery. The ground is fully-grown with grass, and the trees provide plenty of shady areas for the deer. Moreover, there are several mud puddles (made naturally) that the deer wallow in during hotter days. The enclosure consists of twelve individuals; three stags, six does, and two younger deer. Just a few days before sampling in Zoo Taiping was completed, one of the does has given birth to a newborn fawn making the total number of individuals is fourteen.

The Sungkai Conservation Centre was built by the Malaysian government body for wildlife (DWNP). This center is dedicated to rescuing wildlife in conflict and captive breeding for endangered species. The area hosts various wildlife species, such as the Malayan tiger, Malayan sun bear, and Seladang/Gaur, aside from sambar deer. Other captive facilities across Malaysia have been built for the same purpose. However, Sungkai Conservation Centre was chosen based on logistics, funding, and, more importantly, accessibility. The enclosure measures 212 meters x 68 meters (Figure 3). Over 60 individuals are in an enclosure, making it difficult to differentiate between individuals. The ground is fully grown with grasses and shrubs alongside large trees. The keeper claimed that the enclosure had more trees when it was newly made. However, due to debarking behavior of the deer, most of the trees had fallen over time. As a result, shaded areas are scarce, and not much wallowing pool can be found unless created naturally from heavy rainfall. The whole area is divided into four different paddocks with varying sizes but located just next to each other. These paddocks are well secured with high fences, with gates and corridors between each of the paddocks. There are huts or shelters in each paddock, hung with salt blocks and huge pails filled with water. The terrain of the paddock is quite uneven, with several places with deeper ends creating holes by which the deer take quick dips.

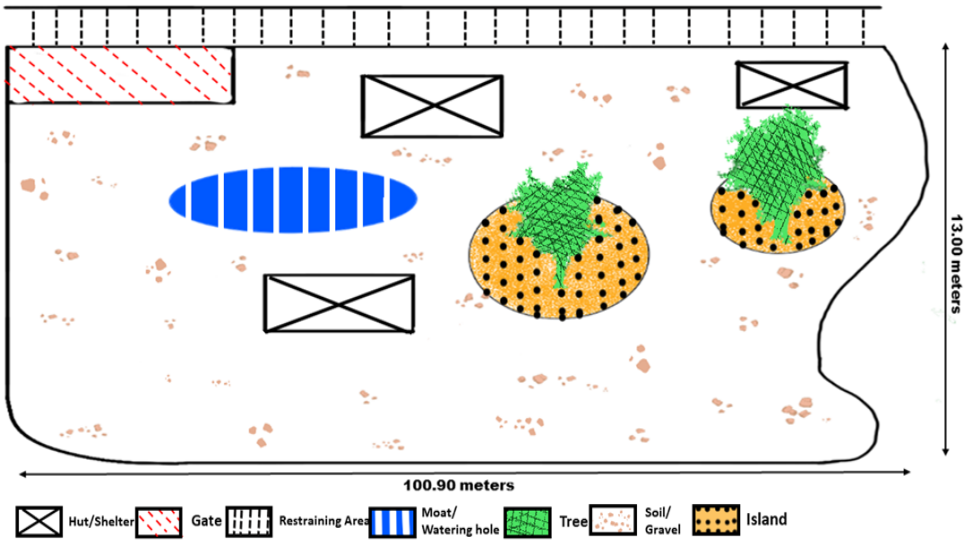

Figure 1. The layout of the sambar deer paddock in Zoo Negara. The layout shows the perimeter of the paddock and the vegetation areas, as well as the moat and feeding area.

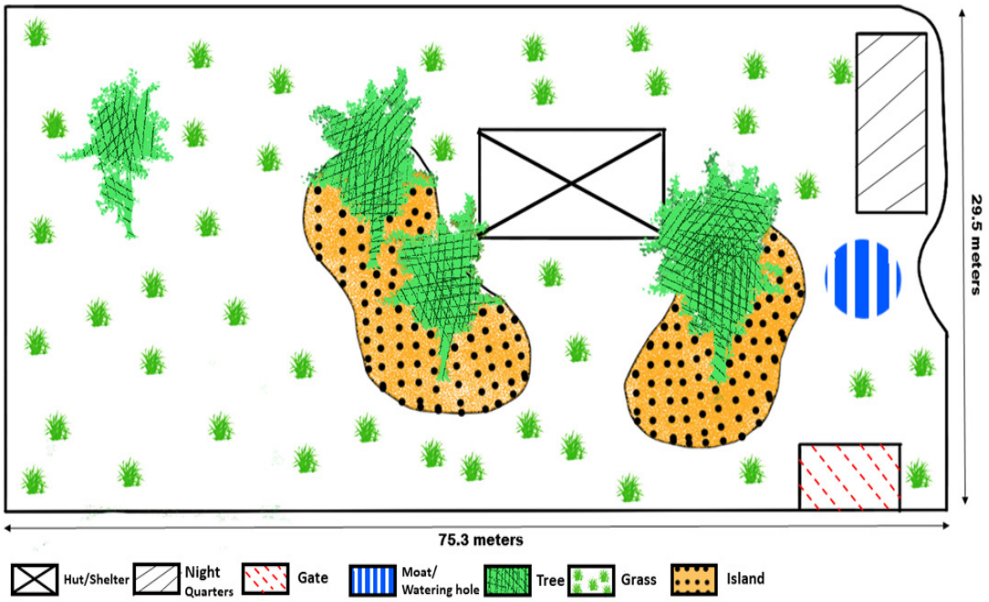

Figure 2. The layout of the sambar deer paddock in Zoo Taiping, Perak. The layout shows the perimeter of the captive area and the feeding hut, as well as vegetation plots.

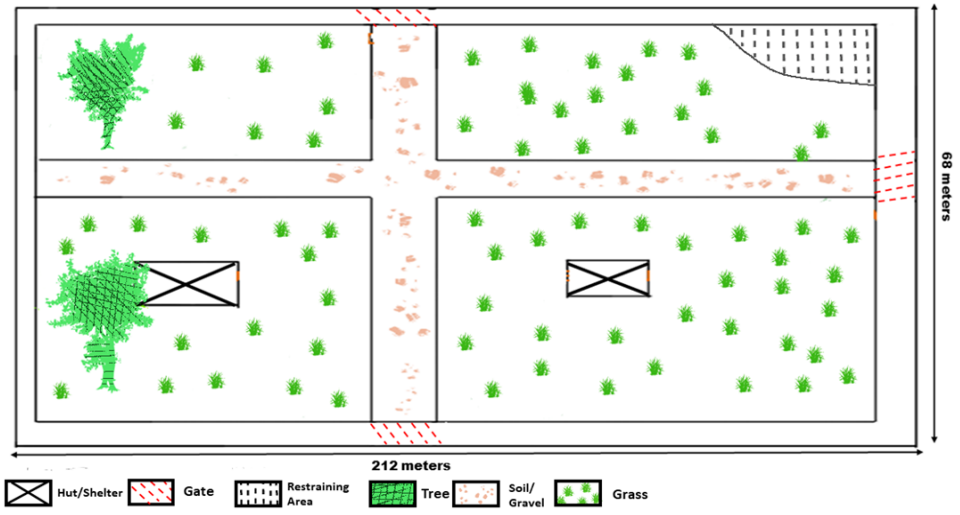

Figure 3. Overview of the Sungkai Conservation Centre managed by the Department of Wildlife and National Parks. There are four separate paddocks where they are rotated from time to time to allow for the vegetation to grow.

Ethogram and Behavioral Observations

The ethogram used in this study was a modified and adapted list of repertoires of behaviors that are common for ungulates studies (Table 1). The main body of the ethogram was adapted from Aun and Rahman (1989), who also worked on sambar deer in Zoo Melaka, Malaysia studying their behavior in captivity. It was the earliest recorded study on sambar deer behavior in Malaysia. The ethogram was further modified and adapted to current progress and understanding in the animal behavior field (Aun & Rahman, 1989; Semiadi et al., 1994; Semiadi et al., 1995; Lu et al., 2009; Xiaofeng et al., 2011; Powell et al., 2013; Razal et al., 2017; Arumugam & Buesching, 2019: Table 1). Institutional Animal Care and Use Committee, Universiti Putra Malaysia, approved all the methodologies involved in behavior observation and recordings (Ethical approval ref.: UPM/IACUC/AUP-R042/2018). The diurnal observation was carried out through direct observation.

Deer were observed in the enclosure divided into two-time slots in one day. The first slot begins at 0900hrs to 1200hrs (Morning), and the second slot begins at 1400hrs to 1700hrs (Afternoon), three hours of observation per slot total of six hours of observation per day. The three hours slots were broken down into observation points that lasted for ten minutes with a five minutes interval in between points (Aun & Rahman, 1989). Observations were not carried out between 1200hrs and 1400hrs as sambar deer have been known to be least active during these periods (Semiadi et al., 1993) and allowed the observer to have a break between observation periods. A scan sampling method was used to collect these behavioral data. Each frequency of behavior observed is taken as one data point (Table 2), which is accumulated at the end of the ten-minutes observation period. At the beginning of each observation slot, the temperature and humidity were recorded once for each ten-minute observation using a handheld digital thermometer and humidity device. Social behavior was recorded and categorized as interactions between two or more individual deer within the group at any given point of time during observations.

The data points were recorded on a spreadsheet focused on the herd behavior of sambar deer, which focuses on their social behavior. The number of individuals observed varied depending on the study sites. Assumptions were made that these observations would not affect the results. Unfortunately, tagging the deer was not permitted in any of the study sites, providing a challenge and obstacle to identifying or differentiating between individuals unless they have natural markings on the body that can be easily seen. An observation point was established at the beginning of each captive site observation period, and this point did not change throughout as not to influence or affect the behavior of the captive sambar deer.

In addition to observation, the enclosure space and area settings and layout were also recorded alongside informal discussion with their caretaker to take note of general ideas of their daily behavior to aid with the finalization process, for example, the average feeding time and their movement in the enclosure.

Table 1

Adapted and modified ethogram applied for this study with specifics to social behavior and alertness behavior with extensive definition and description included for each behavior.

Behavioral Grouping	Behavior Subgroup	Description
Courtship	Low Stretch (LS)	Male approaches female from the rear with head lowered
	Anogenital sniff (AN)	Male approaches female and sniffs and licks vulva
	Follow (FO)	Male follows female after walking away
Receptive	Flehmen (FL)	Head may be raised above horizontal, and lips curled Lips usually opened after smelling dung or urine Lips usually opened after smelling dung or urine
	Urine- Drinking (DU)	Males drink the urine of a female
Pre-mounting	Neck-gripping (NG)	Male anchoring the female by placing the neck on the upper back of the female
	Chin-resting (CR)	Male rest chin/head on the rump of a female
Aggression	Rutting (RU)	Rubbing of antlers (stripping of large areas of barks on trees)
Grooming	Allo-grooming (GR)	Grooming between 2 individuals. One being the groomer and one being the groom.
Defensive	Lookout (LO)	Individuals being attentive to their surrounding Head is usually horizontal or above with eyes open Ears are moving often or aligned with the line of sight Occurs with several positions, including standing and sternal recumbent
	Alarmed (AL)	Tail erected with both eyes and ears towards the direction of a threat

Generalized Linear Model Analysis

A Generalized Linear Model (GLM) analysis was conducted using R- software Version 3.5.1 for the data recorded. The full average intercept was recorded instead of average condition intercepts. The full average includes every model possible, which further narrows down the estimator and is usually used for variables with weaker correlation in accordance with smaller than "subset" estimators. The parameters were averaged, and only those with AICc < 7 were further analyzed and reported.

The data points obtained were analyzed both as individual behaviors and as subgroups. Subgroups were sorted into six major groups; Courtship (Anogenital Sniff, Low Stretch and Follow), Receptive (Flehmen and Urine Drinking), Pre-mounting (Neck Gripping and Chin Resting), Grooming (Grooming), Defensive (Alertness and Alarmed), and Aggression (Rutting). Models with Delta Akaike's Information Criterion (ΔAICc) < 7 were chosen for further analysis. Each behavior (Table 3) and subgroups (Table 4) were tested separately for correlations between variables in all three captive sites. The data were standardized with a model script prior to analysis.

The extrinsic parameters included in the GLM analysis were temperature, rain, captive sites, and time of day. These parameters were chosen to test if they affect the behavior of the deer. Some parameters, for example, the presence or absence of visitors, could not be recorded due to limitations. These parameters were then tested against pre-determined social behaviors with the ethogram modified for this study (Table 1). Time of day was divided into two; Morning (0900hrs-1200hrs) and Afternoon (1400hrs-1700hrs).

RESULT

A total of 1826 data points obtained (Table 2) from direct observations were recorded over 122 days (ZN = 258 hours, ZT = 222 hours, SCC = 252 hours, Total = 732 hours of observation) between May to December 2018. Among the three sites, the highest collective frequency was recorded in Zoo Negara (ZN) (1177 data points), followed by a close margin between Sungkai Conservation Centre (SCC) (326 data points) and Zoo Taiping (ZT) (323 data points). On the other hand, grooming was recorded to have the highest frequency in all three sites (ZN = 492, ZT = 94, and SCC = 104). These data points were accumulated for various analyses, including the compositions of behavior based on each site and GLM between all three sites for an in-depth comparison.

A total of 1177 data points were recorded at Zoo Negara. Grooming encompassed 42% (492 data points) overall, followed by anogenital sniffing 21% (249 data points). The lowest at only 1% overall are rutting (9 data points) and neck gripping (10 data points). In Zoo Taiping, grooming was at 29% (94 data points) and anogenital sniff at 26% (83 data points). Again, the lowest recorded behavior was chin resting at 1%. There were no observations of rutting and neck gripping from Zoo Taiping; grooming recorded 32% (104 data points) overall in Sungkai Conservation Centre, followed by anogenital sniffing at 17% (56 data points). Again, the lowest was neck gripping and chinned, resting at < 1%.

Captive sites were shown to have the strongest influence on individual behavior, with 73% of the behavior showing significant correlation (Table 3 & Figure 4) and 66% of the subgroups showing strong affiliation to captive sites (Table 4). No subgroups showed any significant correlation to temperature fluctuation, but three behaviors (27%) showed significance: low stretch, follow, and rutting. Receptive grouping was shown to

Table 2

Mean of each social behavior observed based on individual captive site, average temperature, and the number of days of rain had occurred throughout the study for each captive site. The total frequency of each average site each social behavior to obtain the weighted average of each behavior

CNC	Temp	Rain (days)	LS	AN	FO	FL	DU	CR	NG	GR	LO	AL	RU	Total Data Points
ZN	29.62	4	0.044	0.213	0.094	0.025	0.030	0.021	0.0008	0.364	0.073	0.067	0.0007	1177
ZT	29.28	6	0.053	0.257	0.086	0.099	0.105	0.0003	0.000	0.291	0.031	0.071	0.000	323
SK	28.50	8	0.080	0.172	0.117	0.071	0.043	0.0003	0.0009	0.319	0.012	0.049	0.126	326[1]

1 (LS = Low Stretch, AN = Anogenital Sniff, FO = Follow, FL = Flehmen, UD = Urine Drinking, CR = Chin Resting, NG = Neck Gripping, GR = Grooming, LO = Lookout, AL = Alarmed, RU = Rutting).

be influenced by the presence and absence of rain during the observation period. Time of day (Morning and Afternoon) (Figure 5) resulted in significant influence in less than 40% of the tested individual behavior and only over 30% of the groups.

Table 3

Model-averaged parameters estimate entire sub-models with Delta Akaike's Information Criterion (ΔAICc) < 7 to analyze the relationship between variables and social behaviors. Values in bold are significant.

Explanatory Variables	LS		AN		FO	
	B (CI)	**RI**	**B (CI)**	**RI**	**B (CI)**	**RI**
Intercept	-1.64 (-2.06, -1.23)	-	-0.08 (-0.30, 0.15)	-	-1.28 (-1.70, -0. 87)	-
Temperature	**1.44 (0.58, 2.33)**	**1.00**	0.27 (-0.02, 0.83)	0.68	**-1.28 (-0.43, -2.09)**	**1.00**
Rain	-0.65 (-2.78, 0.46)	0.56	-0.47 (-1.53, 0.10)	0.65	-0.79 (-2.81, 0.30)	0.62
Captive sites	-0.04 (-0.78, 0.49)	0.28	**-1.23 (-1.63, -0.80)**	**1.00**	**-0.56 (-1.36, -0.07)**	**0.78**
Morning/ Afternoon	**1.67 (0.89, 2.45)**	**1.00**	**0.48 (0.10, 0.90)**	**1.00**	**1.28 (0.57-1.97)**	**1.00**

Explanatory Variables	FL		UR		CR	
	B (CI)	**RI**	**B (CI)**	**RI**	**B (CI)**	**RI**
Intercept	-1.40 (-1.77, -1.04)	-	-1.28 (-1.63, -0.94)	-	-3.59 (-4.60, -2.58)	
Temperature	-0.12 (-0.89, 0.28)	0.39	-0.33 (-1.04, 0.03)	0.66	0.43 (-0.37, 1.98)	0.54[1]
Rain	-1.67 (-3.90, 0.15)	0.89	-1.02 (-2.46, 0.43)	0.57	0.32 (-0.73, 2.43)	0.37
Captive sites	-0.04 (-0.66, 0.40)	0.28	**-0.67 (-1.17, -0.16)**	**0.93**	**-2.79 (-4.33, -1.23)**	**1.00**
Morning/ Afternoon	-0.02 (-0.70, 0.55)	0.28	0.26 (-0.37, 0.87)	0.39	0.08 (-0.96, 1.63)	0.32

Full model: model<-glmer (LS ~ (1|Day) + Captive Sites + Temperature + Time of Day (Morning / Afternoon) + Rain, family = "Poisson", data = Mydata)

[2] (LS = Low Stretch, AN = Anogenital Sniff, FO = Follow, FL = Flehmen, UD = Urine Drinking, CR = Chin Resting, NG = Neck Gripping, GR = Grooming, LO = Lookout, AL = Alarmed, RU = Rutting). B (CI) = Estimated mean (95% Confidence Interval) and RI = Relative Importance.

Table 3 *(Continue)*

Explanatory Variables	NG		GR		LO	
	B (CI)	RI	B (CI)	RI	B (CI)	RI
Intercept	-1.23 (-6.11, 6.11)		0.40 (0.20, 0.61)		-2.54 (-3.20, -1.89)	
Temperature	7.40 (-8.90, 3.77)	0.52	0.004 (- 0.33, 0.36)	0.26	0.17 (-0.33, 1.26)	0.40
Rain	-4.33 (-1.76, 1.76)	0.28	0.05 (-0.35, 0.66)	0.30	0.06 (-0.74, 1.20)	0.28
Captive sites	-5.27 (-6.24, 2.91)	0.32	**-1.51 (-1.89, -1.12)**	**1.00**	**-2.60 (-3.62, -1.60)**	**1.00**
Morning/ Afternoon	-4.63 (-3.04, 1.02)	0.48	**0.51 (0.33, 0.70)**	**1.00**	**0.59 (0.10, 1.16)**	**0.93**

[3] (LS = Low Stretch, AN = Anogenital Sniff, FO = Follow, FL = Flehmen, UD = Urine Drinking, CR = Chin Resting, NG = Neck Gripping, GR = Grooming, LO = Lookout, AL = Alarmed, RU = Rutting). B (CI) = Estimated mean (95% Confidence Interval) and RI = Relative Importance.

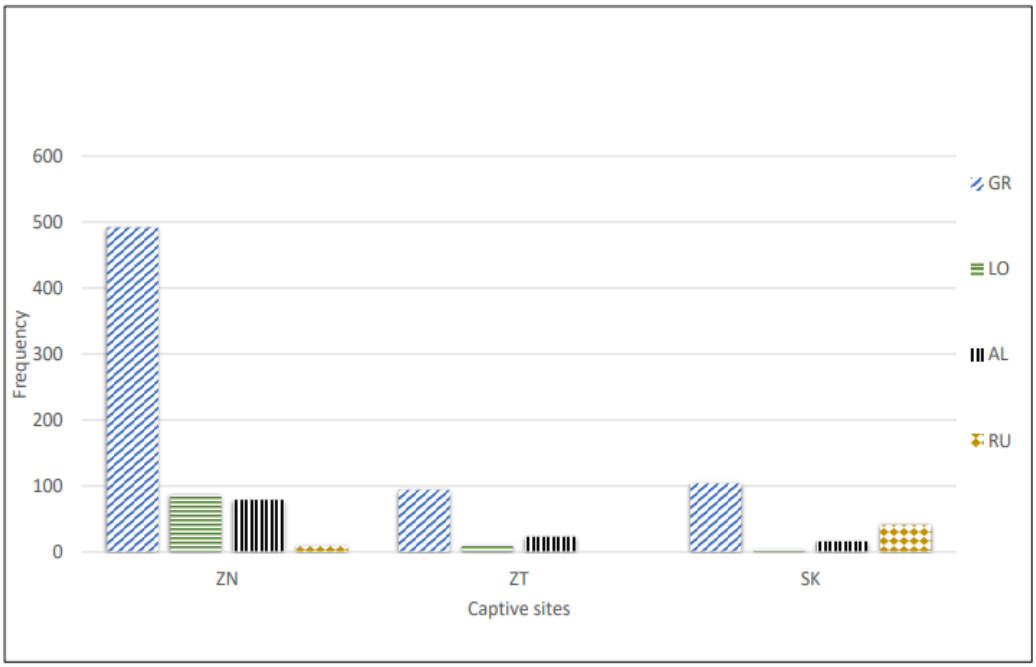

Figure 4. The graphs show the significant behavior recorded in each captive site against the total frequency of observations.

Table 4

Model-averaged parameters estimate entire sub-models with Delta Akaike's Information Criterion (ΔAICc) < 7 to analyze the relationship between variables and grouped social behaviors. Values in bold are significant.

Explanatory Variables	Courtship		Receptive		Pre-mounting	
	B (CI)	RI	B (CI)	RI	B (CI)	RI
Intercept	0.30 (-9.47, 9.47)		-0.90 (-1.22, -0.58)		-3.36 (-4.36, -2.37)	
Temperature	0.73 (-2.73, 1.76)	1.00	-0.24 (-0.79, 0.06)	0.66	0.71 (-0.06, 1.93)	0.75
Rain	-0.89 (-1.47, 1.47)	0.89	**-1.25 (-2.61, -0.12)**	**0.91**	0.13 (-1.22, 2.07)	0.29
Captive sites	-1.07 (7.52, 4.98)	1.00	**-0.40 (-1.06, -0.0005)**	**0.74**	-2.29 (-1.15, 1.29)	0.35
Morning/Afternoon	0.85 (-2.07, 1.38)	1.00	0.02 (-0.48, 0.58)	0.35	0.003 (-1.17, 1.29)	1.00

Explanatory Variables	Grooming		Defensive		Aggression	
	B (CI)	RI	B (CI)	RI	B (CI)	RI
Intercept	0.40 (0.20, 0.61)		0.67 (0.48, 0.86)		-6.21 (-9.47, 9.47)	
Temperature	0.004 (-0.33, 0.36)	0.26	0.04 (-0.20, 0.41)	0.31	-8.00 (-2.73, 1.76)	0.65
Rain	0.05 (-0.35, 0.66)	0.30	0.05 (-0.27, 0.57)	0.31	-2.45 (-1.47, 1.47)	0.70
Captive sites	**-1.51 (-1.89, -1.13)**	**1.00**	**-1.53 (-1.90, -1.16)**	**1.00**	**2.87 (7.52, 4.97)**	**1.00**
Morning/Afternoon	**0.51 (0.33, 0.70)**	**1.00**	**0.49 (0.31, 0.66)**	**1.00**	-5.97 (-2.07, 1.38)	0.65[4]

[4] (Courtship, Receptive, Pre-mounting, Grooming, Defensive and Aggression; refer to Table 1).
B (CI) = Estimated mean (95% Confidence Interval) and RI = Relative Importance.

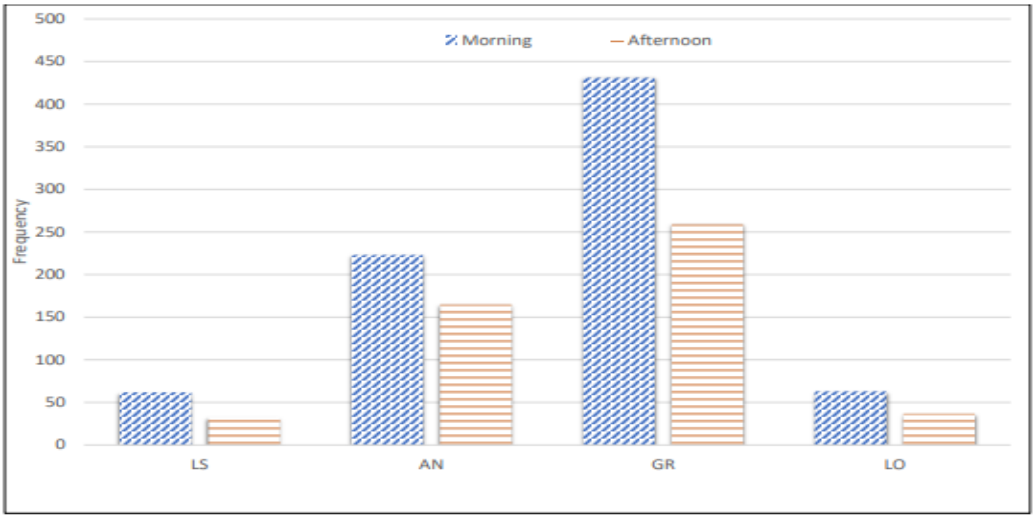

Figure 5. The bar plot is the frequency of each social behavior observed when analyzed according to time of day.

DISCUSSION

Differences in the behavior of sambar deer across different captive sites are influenced by the varying factors from the external environment. Therefore, it could be suggested that the captive animal tends to react to the change in environment as a form of responsive adaptation (Jaman & Huffman, 2008).

Grooming had the highest frequency in Zoo Negara, followed by Zoo Taiping and Sungkai Conservation Centre (Figure 4 & Table 3). It was an unexpected result given that the individuals in Zoo Negara were the lowest among the three captive sites. An assumption can be made here based on the environmental setting or layout of the paddocks in these captivities. Zoo Negara has arguably the smallest captive area of Zoo Taiping and Sungkai Conservation Centre (Figures 1 to 3). In addition, the paddock in Zoo Negara is shared with two other species, hog deer and spotted deer. Sambar deer have been solitary animals in the wild through camera traps (Wong et al., 2019). However, this could have changed or rather be the opposite in a captive setting. It was seen that the herd in Zoo Negara spend most of their time together around the clock. It is worth noting that this would be higher due to the paddock's sharing with other species of deer, causing them to be in a defensive state constantly. Sambar deer being the bigger species of the other two, could create a territorial space within the paddock. The herd would constantly take shelter or rest after feeding in the shack towards the back end of the paddock, rarely occupied by any other species. Given the time this herd spends together, this could link to the high grooming frequency.

Additionally, all three sites had a high frequency of grooming and anogenital sniffing. Therefore, it could be suggested that grooming could additionally be a form of courting

between a stag and doe and not only shows a display of closeness or hygiene. Moreover, grooming can be seen as a social form of communication (Mooring et al., 2004), which could be related to the behavior of anogenital sniffing as part of the courting process. Grooming, in addition, is a way for the stag to assess the emotion/mood of the targeted doe before moving forward. Being solitary in the wild (Wong et al., 2019), a high frequency of grooming could be an adaptive behavior from their counterpart. However, studies have shown that the relative grooming rate is similar to their wild counterparts in ungulates compared to the rates in a captive population (Hart et al., 1992; Mooring et al., 2000).

The situation is different in the other two captive sites as sambar deer, and no other species only occupied each site. Naturally being solitary animals, it is expected for the herd to spend less time grooming or socializing unless necessary as they would in a wild setting. Sambar tends to travel solitarily or in very small groups in the wild (Bhattarai & Kindlmann, 2018), which would reflect low social behavior as it would in our findings. Sungkai Conservation Centre was categorized as a semi-captive setting in this study, and the behavior of the herd was as expected and observed in the wild. Each individual would pan out on their own for grazing or foraging and only gathered if it was raining or during resting periods. The lack of shelter or shade in the paddock when it was raining was the only time the herd was observed to be huddled together or when there was a reason to be alarmed or under threat.

The courtship grouping can be assumed to be not mutually exclusive of each other and are distinct behavior of their own as there was no significant difference in correlation to temperature but showed otherwise when analyzed separately. It could also be due to the difference in frequency of the behavior. Anogenital sniff is a behavior commonly carried out by the male towards a female in the herd. It is part of the pre- courtship behavior whereby the male 'checks' if the female is receptive and is ready for copulation by sniffing the genital area of the female. Sambar deer are nocturnal species (Hart et al., 1992) in the wild. Therefore, it could explain the higher frequency of anogenital sniff in the morning (possibly early morning) compared to the afternoon. Another influencing factor would be the feeding time of these deer, which relates to captive sites themselves. All three captive sites had a morning feeding ranging between 0900hrs to 1100hrs. Feeding time could potentially affect their instincts during those times and, in extension, affect their behavior in the afternoon period. However, further research can have a much definitive answer compared to nocturnal observation.

Urine drinking and Flehmen (Receptive group) were analyzed and found to be possibly influenced by the presence of rain, which had the highest frequency in Zoo Taiping are the town of Taiping is known to be the "Rain Town" of Malaysia, receiving an annual average rainfall 3000mm, which has the highest humidity in Malaysia (Yusof et al., 2017), which is supported by the high average humidity that is recorded for this study (73.93%).

Flehmen is a responsive behavior that occurs in ungulates as a chemical sensory evaluation. It is carried out before ovulation, whereby the urine from the female has several types of chemosensory response (Rajanarayanan & Archunan, 2011). High humidity could result in an unsuitable environment for the pheromones to travel through the air naturally as it would during a hotter day. Therefore, it could result in the increase of Flehmen by the stag in captivity. Unlike in the wild, it is much easier to access doe urine for the stags to be receptive to the herd's oestrus cycle. It has been observed on several occasions where the male has directly lowered its head into the stream of a urinating female and has a Flehmen response, after which results in a higher frequency.

At the observation time, Zoo Negara was upgrading their deer display area, resulting in a high frequency of lookout and alarming behavior. Hence, this reading could be an inaccurate display of their natural behavior as there were strong external influences. The low frequency of lookout and alarmed in Sungkai Conservation Centre was due to the area not being opened to the public, which clearly can be seen as their surrounding environment much easily triggered them, for example, a falling branch or loud noises as their feed is brought into the paddock usually with a small truck or lorry. The herd tends to stay away from the vehicle (especially the females) until the keepers are a distance from the area. The deer in Sungkai Conservation Centre are kept and conditioned, mimicking as closely to their natural setting as possible. Hence, they are not accustomed to external factors, such as visitors or heavy movement, compared to the herds in Zoo Negara and Zoo Taiping. They are also rarely exposed to any external stimulus, further keeping their instincts compared to their counterparts in full captivity.

Rutting was highest based on the number of frequencies in Sungkai Conservation Centre. It could simply be due to the higher number of stags in the area as compared to the other captive sites. In addition, competition for mating as more does could contribute to increased aggression between stags. In the wild, stags are observed to be purely solitary (Matsubayashi et al., 2007), meaning that they would only be together if a doe is receptive for mating reasons. The abnormal amount of stag could create an area of increased aggression, which shows that the sambar deer in Sungkai Conservation Centre is closer in behavioral similarities to their counterparts in the wild. Rutting was shown to be influenced by temperature and captive sites. Rutting often occurs when there are more competing males in an area, resulting in a higher observation frequency in Sungkai Conservation Centre compared to the other captive sites. Moreover, it is only relevant that rutting occurs at a higher temperature, indicating a sunny day where the deer are more active as compared to on a rainy day.

Variation in captive environments thus proves to affect the behavior of captive sambar. Creating an immersive and suitable display compound is lacking in these captive sites. It could be due to a lack of funds in these sites or expertise and understanding of this species.

In the case of Sungkai Conservation Center, where the reintroduction program takes place, to sustain a healthy captive population in terms that are fitting to be released needs to be addressed and practiced by prioritizing improving the surrounding environment and not solely on just breeding and feeding.

Long-term strategies should include changing these captive holdings to reduce their negative impact on the population. A simple but important change would be to add more shaded areas, especially in Sungkai Conservation Center, to encourage better social interaction between individuals rather than creating scarce shaded areas, which disconnects the population often. We were also informed that the debarking behavior of sambar deer in captivity has proven to be an issue as the trees would eventually rot and fall, contributing to the lack of shaded areas. Captive sites, such as Zoo Negara, have taken the approach of securing the bottom of the tree trunks with wire mesh to prevent debarking from taking place. It is a potential solution, but captive management should also provide a scratch post or debarking trunk to encourage debarking behavior naturally rather than depleting it together. More importantly, creating shaded areas mimics the dense Malaysian forest with a dense canopy cover. For example, Zoo Taiping created shaded and non-shaded areas within their captive sites, which gave the population an opportune environment for both conditions.

It is worth noting that Zoo Negara may have had a higher social frequency, but this was contributed to the smaller captive area and having to share this area with other species of deer rather than having a suitable environment, which could potentially deplete other forms of behavior and induce higher stress levels, which can be studied further. Hence, having a higher level of social interactions between individuals may not necessarily be the best scenario as this means, that sambar being a solitary animal in the wild, may not be able to adapt if need be, reintroduced into the wild.

CONCLUSION

With current awareness and movements, the ideology separating captive-held animals and the wild is becoming blurred. Aquariums and zoos are becoming more aware and involved in conservation programs in the field while conserved and natural habitats are being intensively managed and diversified (Minteer & Collins, 2013). Zoo's settings should mimic the natural settings of the captive species as closely as possible. Hence, captive management in Malaysia should be aware and understand that the environmental settings affect animals in captivity. Moreover, there needs to be a rally of voices amongst stakeholders to push for better captive management funding as this is often overlooked in national plans and thus has to rely solely on donations and tourism. More in-depth research can be done to pinpoint better and understand how to improve captive enclosures to accommodate captive animals better.

ACKNOWLEDGMENTS

The authors would like to show their utmost gratitude to the management authorities at these conservation centers for allowing them to conduct this research in their facilities. They would also like to thank the zookeepers in Zoo Negara and Zoo Taiping for aiding them throughout the research and the rangers in Sungkai Conservation Centre for providing a place to stay and aiding the first author in the observations. Unfortunately, there was no funding or grant obtained for the use of this research.

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